Is Octonionic Quantum Gravity relevant near the Planck Scale? – If Gravity Waves are generated by changes in the geometry of the early universe, how can we measure them?

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Abstract: We ask if Octonionic quantum gravity [1] is a relevant consideration near the Planck scale. Furthermore, we examine whether gravitational waves would be generated during the initial phase, δ_0, of the universe when triggered by changes in spacetime geometry; i.e. what role would an increase in degrees of freedom have in setting the conditions during δ_0, so that the result of these conditions can be observed and analyzed by a gravitational detector. Various initial scenarios are explored. Linking a shrinking prior universe via a wormhole solution for a pseudo time-dependent Wheeler-De Witt equation may permit the formation of a short-term quintessence scalar field. The wormhole solution presented helps to introduce the evolution of the vacuum expectation value (VeV). The wormhole is seen as a high energy, but zero temperature, virtual fluctuation. Among other possibilities, a de facto causal discontinuity in transfer of initial space time 'information' is explored and we calculate what role relic GW data may have in determining δ_0 conditions or allowing us to experimentally detect δ_0. We give conditions for detection of δ_0 if, for example, one can isolate an appropriate first-order perturbative electromagnetic power flux, $\overset{(1)}{T}{}^{uv}$ in scenarios where the graviton has a vanishingly small – but non-zero – rest mass. This paper assumes there is a non-zero 4-dimensional graviton mass since the solutions we are examining apparently contradict the correspondence principle. We contrast the above constructions with questions of when entropy and quantum mechanics fit together or agree, in the very early universe, and when and why such a fit no longer holds [2]. We hope to find traces of the breakdown of the Entropy/QM spacetime regime during δ_0. We suppose that the quantum regime happens when Rindler (flat space) geometry occurs, at the onset of inflation, and that likely the pre-Planckian regime is when highly-curved space time occurs. We also note that increases in the degrees of freedom occur when Rindler geometry is applicable and as space time becomes flat. That change in geometry, in pre to post Planckian time scales, corresponds to a change in the Mutually Unbiased Bases for space time [2] geometry, as the early universe first evolves.

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INTRODUCTION

This paper examines geometric changes that may have occurred in the very earliest phase of the universe, or δ_0, and explores how we might be able to gain insight into this epoch through gravitational wave research. The Planck epoch has remained mysterious, and may be invisible to all other kinds of detectors, but the universe's gravity wave background radiation likely contains the imprint of even the very earliest events. Changes in the geometry of spacetime near the Planck scale could be revealed or studied in this manner. We discuss how to obtain insights into δ_0, initially, while looking at the geometric considerations determining space and time development which would create relevant spacetime geometry phase changes during the early universe. Each such phase change should produce gravitational waves. The geometry to be considered is introduced as given below. We attempt to address thereby some of the questions relating to how pre and post Planckian geometries may evolve.

At the end of this paper, we will bring up an exciting comparison of how entropy, as in flat space geometry fits with quantum mechanics [3], and suggest that the regime of quantum mechanics as connected with space time geometry is in part due to a degree of freedom increase consistent with a topological construction first outlined in the abstract. The readers are also referred to appendix A which summarizes the relevant aspects of J.-W. Lee [3] in connecting space time geometry (initially curved space, of low initial degrees of freedom) to Rindler geometry for the flat space regime occurring when degrees of freedom approach a maxima, initially from t > 0s up to about t <1000s, or so, as outlined in an argument given in Eq. (16). One of the primary results of the paper is reconciling the difference in degrees of freedom versus a discussion of dimensions, per se. How and why the experimental degrees of freedom approach a maxima is something which the primary author, Beckwith, is investigating.

<u>What we will propose is the following, i.e. reference applications of Appendix A.</u>

1. That the degrees of freedom increase, with an increase in temperature, during a transition to a Rindler Geometry flat space regime of space time. As given in Eq (16), with increasing temperature, more degrees of freedom unfold from a topological transition. Degrees of freedom likely approach a maxima as temperature does, but this is a subject needing experimental exploration and verification.

2. That for low but non zero initial temperature, the so called cold universe model, in pre space time in the pre Planckian regime, one has initially a huge degree of generated entropy. At the same time, we have about 2 degrees of freedom, with complex geometry in each geometrical slot, geoinfometric instantiation, or "infometron" of space time, which large quantities of stored entropy enveloped in the 'crevices' between infometrons, or lattice points .

3. Low degrees of freedom for low temperature corresponds to a complex geometry storing large amounts of total entropy in a complex geometric structure, and that later the entropy is released, with a break down of this complex geometric structure, i.e. equivalent to having many lattices, highly ordered, with low degrees of freedom per 'lattice', to many degrees of freedom (DOF) as space time 'lattices' are broken, releasing entropy. The analogy is not perfect, but approximates what would happen as one goes from complex curved space geometry with many 'crevices' for storage of entropy, which are released, "apparently" leading to a lot of entropy, but in reality leading to a release of stored entropy on the way to a flat Rindler geometry spacetime in which flat space time is acting as part of an emergent structure. As suggested by G. Stephenson, there appears to be a trading of DOF for entropy in the early evolution of the universe.

Further elaboration of what is being brought up is tied in with a summary of properties of a mutually unbiased basis (MUB), [2] as seen in **<u>Appendix B.</u>** with one set of mutually unbiased basis at the start of cosmological evolution as will be referenced by Eq. (16) below, which is topologically adjusted to the properties of flat space Rindler geometry. We will call this a change in basis sets, and is another way to quantify and identify a different form of phase transition at the end of this article, and we assert the change involved could be identified by experimental detection of δ_0.

In **Appendix C**, [2] there is a way to quantify two different types of entropy, which in reality are linked to each other by the idea of MUB. The first is a simplified form of Renyi entropy [4] ,explicitly depending upon MUB ideas. The second is one which is discussed in [4] , is based upon a particle count version of entropy, i.e. S ~ <n>, with S an entropy per phase space volume, and <n> an emergent field contribution of particles per phase space volume. This will be built up using formalism appearing in **Appendix C. Appendix** D discusses Seth Lloyds treatment of entropy counting and its connection to information theory, which we view as critical.

The key point of the document will be in determining an inter relationship between a change in MUB, from initial highly complex geometric structure, to flat space time, a new way to quantify a phase transition so resulting , and experimentally verifiable detection of δ_0. In part, this will also bring up another point, that a certain amount of data of a prior universe's space time information will be lost, leading to the question of what information can be retrieved from the early universe as contained in experimental detection of δ_0. Are predictions possible regarding the signal strength of primordial HFGW? Yes. The signal strength of initial HFGW is tied into values of δ_0. The values of δ_0 are set by the difference between Renyi entropy, and a particle count version of entropy, i.e. S ~ <n>. Are predictions also possible regarding signal strength of evolutionary artifacts of early universe HFGW? Again, yes. We can build upon emergent field contributions to <n> based upon analogies explained later in this paper.

What we are talking about is the break down, due to thermal heat flux of an initial mutually unbiased basis set for a very complex initial geometry, and a reconstitution of space time geometry in flat Euclidian space time regime. Eq.(16) is a way to highlight this topological transition, and from there we identify what can be optimally extracted from δ_0 data. The topological transition is due to a change in basis / geometry from the regime of Renyi entropy to entropy in a particle count version of entropy, i.e. S ~ <n>.. The choice of a Gaussian mapping, with two variable inputs, as given by Eq. (16) below is done as a simplest case model. We very well may find that this Gaussian mapping is an over simplification and will add needed elaborations based upon experimental requirements.

Now, let us refer to the tools used to construct the initial space time geometry before we refer to Lee's article [3]. As brought up by Beckwith, and Glinka [5], (assuming a vacuum energy $\rho_{Vacuum} = [\Lambda/8\pi \cdot G]$ initially), with Λ part of a closed FRW Friedman Equation solution.

$$a(t) = \frac{1}{\sqrt{\Lambda/3}} \cosh\left[\sqrt{\Lambda/3} \cdot t\right] \tag{1}$$

to a flat space FRW equation of the form [5]

$$\left[\frac{\dot{a}}{a}\right]^2 + \frac{1}{a^2} = \frac{\Lambda}{3} \tag{2}$$

Which is so one forms a 1-dimensional Schrodinger equation [5],[6], [7]

$$\left[\frac{\partial^2}{\partial \cdot \tilde{a}^2} - \frac{9\pi^2}{4G^2}\left[\tilde{a}^2 - \frac{\Lambda}{3}\tilde{a}^4\right]\right]\psi = 0 \tag{3}$$

with $\tilde{a}_0$ a turning point to potential [5],[6],[7]

$$U(a) = \frac{9\pi^2}{4G^2}\left[\tilde{a}^2 - \frac{\Lambda}{3}\tilde{a}^4\right]. \tag{4}$$

What we are doing afterwards is refinement as to this initial statement of the problem in terms of giving further definition of the term $\rho_{Vacuum} = [\Lambda/8\pi \cdot G]$.

Let us now consider a worm hole as a high energy, but zero temperature, virtual fluctuation conforming to the potential in (4). We will model inputs into the initial value of Λ as high energy fluctuations, and see if they contribute to examination of the formation of non commutative geometry in the beginning/ just before the inflationary era.

This $\rho_{Vacuum} = [\Lambda/8\pi \cdot G]$ if stated correctly may enable tying in initial vacuum expectation value (VeV) behavior with the following diagram. Note that cosmology models have to be consistent with the following diagram.

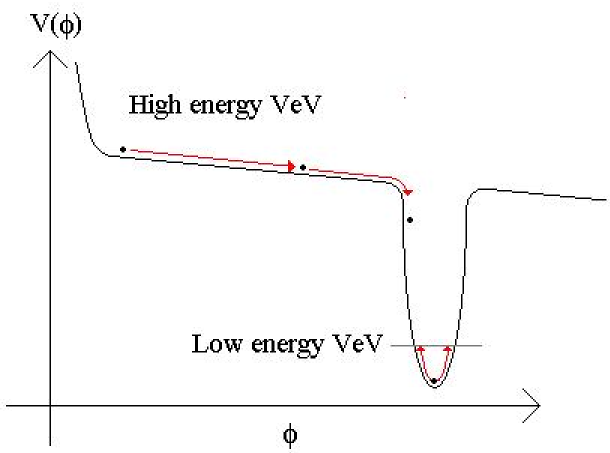

Figure 1, as supplied by L. Crowell, in correspondence to A. W. Beckwith, October 24, 2010 [8]

As stated by L. Crowell [8], in an email sent to A. Beckwith, the way to delineate the evolution of the VeV issue is to consider an initially huge VeV, due to initial inflationary geometry. As stated by L. Crowell [8]:

> *"The standard inflationary cosmology involves a scalar field φ which obeys a standard wave equation. The potential is this function which I diagram 'above'. The scalar field starts at the left and rolls down the slope until it reaches a value of φ where the potential is V(φ) ~ φ^2. The enormous VeV at the start is about 14 orders of magnitude smaller than the Planck energy density ~ (1/L_p)^4 on the long slope. The field then enters the quadratic region, where a lot of that large VeV energy is thermalized, with a tiny bit left that is the VeV and CC of the observable universe. The universe during this roll down the long small slope has a large cosmological constant, actually variable λ = λ(φ,∂φ), which forces the exponential expansion. There are about 60-efolds of the universe through that period. Then at the low energy VeV the much smaller CC gives the universe with the configuration we see today."*

One of the ways to relate an energy density to cosmological parameters and a vacuum energy density may be using a relation as given by (5), as given by Poplawski [9]:

$$\rho_\Lambda = H\lambda_{QCD} \tag{5}$$

Where if λ_{QCD} is at least 200MeV and is similar to the QCD scale parameter of the SU(3) gauge coupling constant, and H a Hubble parameter. Here we consider that if there is a relationship between Eq. (5) above and $\rho_{Vacuum} = [\Lambda/8\pi \cdot G]$ then the formation of inputs into our vacuum expectation values $V \sim 3\langle H \rangle^4 / 16\pi^2$, and also equating $V \sim 3\langle H \rangle^4 / 16\pi^2$ with V(φ) ~ φ^2 [9] would be consistent with an inflaton treatment of initial inflation. We can then equate vacuum potential with vacuum expectation values as follows:

$$\rho_{Vacuum} = [\Lambda/8\pi \cdot G] \approx \rho_\Lambda \approx H\lambda_{QCD} \Leftrightarrow V \sim 3\langle H \rangle^4 / 16\pi^2 \sim V_{\inf} \approx \phi^2 \tag{6}$$

Different models for the Hubble parameter, H exist, and can be directly linked to how one forms the inflaton. The authors presently explore what happens to the relations as given in Eq. (6) before, during, and after inflation.

HOW A WORMHOLE FORMS

The Friedman equation referenced in this paper allows for determining the rate of cosmological expansion. We referenced the Reissner-Nordstrom metric rather than a Kerr-Newman to enforce rotational invariance. Crowell [1] used this solution as a model of a bridge between a prior universe and our own. To show this, one can use results from Crowell [1] on quantum fluctuations in space-time, which provides a model from a pseudo time component version of the Wheeler De Witt equation, using the Reissner-Nordstrom metric to help obtain a solution that passes through a thin shell separating the two space-times. The radius of the shell, $r_0(t)$ separating the two space-times is of length l_P in approximate magnitude, leading to a multiplication of the time component for the Reissner-Nordstrom metric:

$$dS^2 = -F(r)\cdot dt^2 + \frac{dr^2}{F(r)} + d\Omega^2 \quad . \tag{7}$$

This has the distribution and limit of the form:

$$F(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2} - \frac{\Lambda}{3}\cdot r^2 \xrightarrow[T \to 10^{32}\,Kelvin \sim \infty]{} -\frac{\Lambda}{3}\cdot (r = l_P)^2 \quad . \tag{8}$$

Note that Equation (8) referenced above is a way to link this metric to space-times via the following model of energy density equation, linked to a so called "membrane" model of two universes separated by a small "rescaled distance" $r_0(t)$. In practical modeling, $r_0(t)$ is usually of the order of magnitude of the smallest possible unit of space-time, the Planck distance, $l_P \sim 10^{-35}\,cm$, a quantum approximation put into general relativity.. The equation linking Eqn.(7) to energy density ρ is of the form:

$$\rho = \frac{1}{2\pi \cdot r_0}\cdot\sqrt{F(r_0) - r_0^2} \quad . \tag{9}$$

Frequently, this is simplified with the term, $\dot{r}_0(t) \cong 0$. In addition, following temperature dependence of this parameter, as outlined by Park [11] leads to [12]

$$\frac{\partial F}{\partial r} \sim -2\cdot\frac{\Lambda}{3}\cdot(r \approx l_P) \equiv \eta(T)\cdot(r \approx l_P) \quad . \tag{10}$$

This is a wave functional solution to a Wheeler De Witt equation bridging two space-times. The solution bridging two space-times is similar to one made by Crowell between these two space-times with "instantaneous" transfer of thermal heat [1]

$$\Psi(T) \propto -A\cdot\left\{\eta^2 \cdot C_1\right\} + A\cdot\eta\cdot\omega^2\cdot C_2 \quad . \tag{11}$$

This equation has $C_1 = C_1(\omega, t, r)$ as a cyclic and evolving function of frequency, time, and spatial function, also applicable to $C_2 = C_2(\omega, t, r)$ with, $C_1 = C_1(\omega, t, r) \neq C_2(\omega, t, r)$. It is asserted here that a thermal bridge in wormhole form exists as a bridge between a prior and present universe. This assumes that a release of gravitons occurs, which leads to a removal of graviton energy stored contributions to this cosmological parameter, with m_P as the Planck mass, i.e. the mass of a black hole of "radius" on the order of magnitude of Planck length $l_P \sim 10^{-35}$ m. This leads to Planck's mass $m_P \approx 2.17645 \times 10^{-8}$ kilograms, as alluded to by Barvinsky [11], [12].

$$\Lambda_{4-\dim} \propto c_2 \cdot T^{\beta} \xrightarrow[graviton-production]{} 360 \cdot m_P^2 << c_2 \cdot \left[T \approx 10^{32} K\right] \ . \tag{12}$$

Right after the gravitons are released, there is still a drop off of temperature contributions to the cosmological constant. For a small time value, $t \approx \delta^1 \cdot t_P$,where $0 < \delta^1 \leq 1$ and for temperatures sharply lower than = 10 to the 32nd power Kelvin, this difference is the ratio of the value of the four-dimensional version of the cosmological constant divided by the absolute value of the five dimensional cosmological constant, which is equal to 1 plus 1/n, where n is a positive integer. The transition outlined in Eqn. (12) above has a starting point with extremely high temperatures given by a vacuum energy transferal between a prior universe and our present universe. We will next then, look at this model for a possible increase in the degrees of freedom, initially

Increase in degrees of freedom in the sub Planckian regime.

Starting with [5]

$$E_{thermal} \approx \frac{1}{2} k_B T_{temperature} \propto \left[\Omega_0 \breve{T}\right] \sim \tilde{\beta} \tag{13}$$

The assumption is that there would be an initial fixed entropy arising, with $\overline{N}$ as a nucleated structure arising in a short time interval as a temperature $T_{temperature} \varepsilon \left(0^+, 10^{19}\, GeV\right)$ arrives. One then obtains, dimensionally speaking [5],

$$\frac{\Delta \tilde{\beta}}{dist} \cong \left(5 k_B \Delta T_{temp} / 2\right) \cdot \frac{\overline{N}}{dist} \sim q E_{net-electric-field} \sim \left[T \Delta S / dist\right] \tag{14}$$

The parameter, as given by $\Delta \tilde{\beta}$ will be one of the parameters used to define chaotic Gaussian mappings. Candidates as to the inflation potential would be in powers of the inflation, i.e. in terms of ϕ^N, with N=4 effectively ruled out, and perhaps N=2 an admissible candidate (chaotic inflation). For N = 2, one gets [5], [14]

$$[\Delta S] = [\hbar / T] \cdot \left[2k^2 - \frac{1}{\eta^2}\left[M_{Planck}^2 \cdot \left[\left[\frac{6}{4\pi} - \frac{12}{4\pi}\right] \cdot \left[\frac{1}{\phi}\right]^2 - \frac{6}{4\pi} \cdot \left[\frac{1}{\phi^2}\right]\right]\right]\right]^{1/2} \sim n_{Particle-Count} \tag{15}$$

If the inputs into the inflation, as given by ϕ^2 becomes from Eq. (6) a random influx of thermal energy from temperature, we will see the particle count on the right hand side of Eq. (15) above a partly random creation of $n_{Particle-Count}$ which we claim has its counterpart in the following treatment of an increase in degrees of freedom. The way to introduce the expansion of the degrees of freedom from nearly zero, at the maximum point of contraction to having **N(T)~ 10^3** is to first define the classical and quantum regimes of gravity in such a way as to minimize the point of the bifurcation diagram affected by quantum processes.[15] If we suppose smoothness of space time structure down to a grid size of $l_{Planck} \sim 10^{-33}$ centimeters at the start of inflationary expansion we have when doing this construction what would be needed to look at the maximum point of contraction, setting at $l_{Planck} \sim 10^{-33}$ centimeters the quantum 'dot' or infometron, as a de facto measure zero set, as the bounce point, with classical physics behavior before and after the bounce 'through' the quantum dot. Dynamical systems modeling could be directly employed right 'after' evolution through the 'quantum dot' regime, with a transfer of crunched in energy to Helmholtz free energy, as the driver 'force' for a Gauss map type chaotic diagram right after the transition to the quantum 'dot' point of maximum contraction. The diagram, in a bifurcation sense would look like an application of the Gauss mapping of [15].

$$x_{i+1} = \exp\left[-\tilde{\alpha} \cdot x_i^2\right] + \tilde{\beta} \tag{16}$$

In dynamical systems type parlance, one would achieve a diagram, with tree structure looking like what was given by Binous [15], using material written up by Lynch [16] , i.e. by looking at his bifurcation diagram for the Gauss map. Binous's demonstration plots the bifurcation diagram for user-set values of the parameter. Different values of the parameter lead to bifurcation, period doubling, and other types of chaotic dynamical behavior. For the authors' purposes, the parameter x_{i+1} and x_i^2 as put in Eq. (16) would represent the evolution of the number of degrees of freedom (DOF), with ironically, the near zero behavior, plus a Hemoltz degree of freedom parameter set in as fed into $\tilde{\beta}$. The quantum 'dot' (infometron) contribution would be a measure set discontinuity free mapping given by Eq. (15), with the understanding that where the parameter $\tilde{\beta}$ 'turns on' would be right AFTER the 'bounce' through the infinitesimally small quantum 'dot' regime. Far from being trivial, there would be a specific interactive chaotic behavior initiated by the turning on of parameter $\tilde{\beta}$, corresponding – as brought up by Dickau [17] – to a connection between octonionic space and the degrees of freedom available at the beginning of inflation.. Turning on the parameter $\tilde{\beta}$ would be a way to have Lisi's E8 structure [18] nucleated at the beginning of spacetime. $\tilde{\beta}$ would be proportional to the Helmholtz free energy, F, where as Mandl [19, page 272] relates, the usual definition of F=E - TS , becomes instead, here using partition function, Z, with $\overline{N}$ a 'numerical count factor', so that [5], [19]

$$F = -k_B T \cdot \ln Z(T, V, \overline{N}) \tag{17}$$

Note that Y. Jack Ng [20] sets a modification of $Z_N \sim \left(\frac{1}{N!}\right) \cdot \left(\frac{V}{\lambda^3}\right)^N$ as in the use of his infinite quantum statistics, with the outcome that [5] $F = -k_B T \cdot \ln Z(T, V, \overline{N}) \equiv -k_B T N \left[\ln(V/\lambda^3) + 5/2\right]$with V ~ (Planck length)^3 , and the Entropy obeying [5], [20]

$$S \approx N \cdot \left(\log\left[V/N\lambda^3\right] + 5/2\right) \xrightarrow[Ng-\inf inite-Quantum-Statistics]{} N \cdot \left(\log\left[V/\lambda^3\right] + 5/2\right) \approx N \tag{18}$$

Such that the free energy, using Ng infinite quantum statistics reasoning would be [5], [20] a feed into a nucleated structure, a structure which will be examined in the next section via looking at the absolute value of $F = -k_B T \cdot \ln Z(T, V, \overline{N}) \equiv -\frac{5}{2} \cdot k_B T \overline{N}$. Note, here, that the absolute value of F given is a driver to chaotic dynamics, while $x_{i+1} = \exp\left[-\tilde{\alpha} \cdot x_i^2\right] + \tilde{\beta}$, has $\tilde{\beta} \cong |F|$, with coefficient $\tilde{\beta} \cong |F|$ turning on at the start of the inflationary era due to a temperature flux starting as a driving force, and $\tilde{\alpha}$ being a coefficient of damping of the degrees of freedom to near zero, as the contraction phase of the 'universe', while x_i ~ the degrees of freedom, which would grow dramatically, once $\tilde{\beta} \cong |F|$ turns on .

Consequences of having a radical increase in the degrees of freedom initially

We will present results from Mukhanov, et al below which allow for 'sticking energy ' into a simple harmonic oscillation. As done below in Eq. (19) . What V. F. Mukhanov, and S. Winitzki [5], [21] presented can be thought of as utilizing the introduction of thermal energy as discussed in the $\widetilde{\beta} \cong |F|$ The main idea is that $\widetilde{\beta}$ increasing up to a maximum temperature T would enable the evolution and spontaneous construction of the Lisi E8 structure as given by [14]. As Beckwith wrote up [5], including in additional energy due to an increase of $\widetilde{\beta}$ due to increasing temperature T would have striking similarities to the following. We argue that the increase in degrees of freedom is connected to a nucleation space for particles, according to the following argument. Observe the following argument as given by V. F. Mukhanov, and S. Winitzki [5], [21] , as to additional particles being 'created' due to what is an infusion of energy in an oscillator , obeying the following equations of motion [5], [21]

$$\ddot{q}(t) + \omega_0^2 q(t) = 0, \text{ for } t < 0 \text{ and } t > \breve{T};$$

$$\ddot{q}(t) - \Omega_0^2 q(t) = 0, \text{ for } 0 < t < \breve{T} \tag{19}$$

Given $\Omega_0 \breve{T} >> 1$, with a starting solution of $q(t) \equiv q_1 \sin(\omega_0 t)$ if t <0, Mukhanov state that for [5], [21] $t > \breve{T}$;

$$q_2 \approx \frac{1}{2}\sqrt{1 + \frac{\omega_0^2}{\Omega_0^2}} \cdot \exp\left[\Omega_0 \breve{T}\right] \tag{20}$$

The Mukhanov et al argument [4],[20]leads to an exercise which Mukhanov claims is solutions to the exercise yields an increase in number count, as can be given by setting the oscillator in the ground state with $q_1 = \omega_0^{-1/2}$, with the number of particles linked to amplitude by $\breve{n} = [1/2] \cdot \left(q_0^2 \omega_0 - 1\right)$, leading to [5],[21]

$$\breve{n} = [1/2] \cdot \left(1 + \left[\omega_0^2 / \Omega_0^2\right]\right) \cdot \sinh^2\left[\Omega_0 \breve{T}\right] \tag{21}$$

I.e. for non zero $\left[\Omega_0 \breve{T}\right]$, Eq (21) leads to exponential expansion of the numerical state. For sufficiently large $\left[\Omega_0 \breve{T}\right]$, Eq. (25) and Eq. (26) are equivalent to placing of energy into a system, leading to vacuum nucleation. A further step in this direction is given by Mukhanov on page 82 of his book leading to a Bogoluybov particle number density of becoming exponentially large [5],[21]

$$\breve{\breve{n}} \sim \cdot \sinh^2\left[m_0 \eta_1\right] \tag{22}$$

Eq. (21) to Eq. (22) are , for sufficiently large $\left[\Omega_0 \breve{T}\right]$ a way to quantify what happens if initial thermal energy are placed in a harmonic system, leading to vacuum particle 'creation' Eq. (22) is the formal Bogolyubov coefficient limit of particle creation. Note that $\ddot{q}(t) - \Omega_0^2 q(t) = 0, \text{ for } 0 < t < \breve{T}$ corresponds to a thermal flux of energy into a time interval $0 < t < \breve{T}$. Furthermore, consequence of Verlinde's [22] generalization of entropy is also discussed by Beckwith [4], and the number of 'bits' yields the following consideration, which will be put here for startling effect. This is an extension of Appendix D and should be compared with Seth Lloyds number counting algorithm.

Namely, if a net acceleration is such that $a_{accel} = 2\pi k_B cT/\hbar$ as mentioned by Verlinde [5], [22] as an Unruh result, and that the number of 'bits' is

$$n_{Bit} = \frac{\Delta S}{\Delta x} \cdot \frac{c^2}{\pi \cdot k_B^2 T} \approx \frac{3 \cdot (1.66)^2 g^*}{\left[\Delta x \cong l_p\right]} \cdot \frac{c^2 \cdot T^2}{\pi \cdot k_B^2} \tag{23}$$

This Eq. (23) has a T^2 temperature dependence for information bits , as opposed to [5]

$$S \sim 3 \cdot \left[1.66 \cdot \sqrt{\tilde{g}_*}\right]^2 T^3 \sim n_f \tag{24}$$

Should the $\Delta x \cong l_p$ order of magnitude minimum grid size hold, then conceivably when T ~ 10^{19} GeV[5]

$$n_{Bit} \approx \frac{3 \cdot (1.66)^2 g^*}{\left[\Delta x \cong l_p\right]} \cdot \frac{c^2 \cdot T^2}{\pi \cdot k_B^2} \sim 3 \cdot \left[1.66 \cdot \sqrt{\tilde{g}_*}\right]^2 T^3 \tag{25}$$

The situation for which one has [5], [23] $\Delta x \cong l^{1/3} l_{Planck}^{2/3}$ with $l \sim l_{Planck}$ corresponds to $n_{Bit} \propto T^3$ whereas $n_{Bit} \propto T^2$ if $\Delta x \cong l^{1/3} l_{Planck}^{2/3} >> l_{Planck}$.

Connection with the directionality of time issue, for Planckian space – time

We are duplicating part of the argument used, in order to make a point about the origins of the Bunch – Davies representation of the initial vacuum state. We note here a subtle point, i.e. if there is, in a four dimensional representation of Λ, a temperature component, as given by Park[11], that it is then necessary for a semi classical treatment of the wave function of the universe, to assume, initially that the TEMPERATURE of the pre Planckian space time state, would have to be very small . The argument as presented by Beckwith and Glinka is as follows.[5]Beckwith and Glinka [5] noted in a recent publication have argued that the wave function of the universe interpretation of the Wheeler-DeWitt equation depends upon a WKB airy function, which has its argument dependent upon z. When

$$\mathrm{z} \sim \left(\frac{3\pi \cdot \tilde{a}_0^2}{4G}\right)^{2/3} \cdot \left[1 - \left[\frac{\tilde{a}^2}{\tilde{a}_0^2}\right]\right] \xrightarrow[\tilde{a} \to 0]{} \left(\frac{3\pi \cdot \tilde{a}_0^2}{4G}\right)^{2/3} \tag{26}$$

right at the start of the big bang, the wave function of the universe is a small positive value, as given by Kolb and Turner [7]. Having $\tilde{a} \to 0$ corresponds to a classically forbidden region, with a Schrödinger equation of the form (assuming a vacuum energy $\rho_{Vacuum} = \left[\Lambda/8\pi \cdot G\right]$ initially), with Λ part of a closed FRW Friedman equation solution. The vacuum energy is, for $\rho_{Vacuum} = \left[\Lambda/8\pi \cdot G\right]$, for definition of the Λ FRW metric, and is undefined for the regime $0 < \tilde{a} < 1/\sqrt{\Lambda/3}$. I.e. the classically undefined regions for evolution of Eq. (1) to Eq (4) are the same. The problem is this, having $\tilde{a} \to 0$ makes a statement about the existence, quantum mechanically about having a (semi classical) approximation for ψ , when in fact the key part of the solution for ψ , namely $\rho_{Vacuum} = \left[\Lambda/8\pi \cdot G\right]$ is not definable for Eq. (36) if $0 < \tilde{a} < 1/\sqrt{\Lambda/3}$, whereas the classically forbidden region for Eq. (1) depends upon $0 < \tilde{a} < \tilde{a}_0$ where $\tilde{a}_0$ is a turning point for Eq. (3) above. Λ is undefined classically, and is a free parameter, of sorts especially in the regime $0 < \tilde{a} < 1/\sqrt{\Lambda/3}$.

As $\widetilde{a} \to 0$, unless $\Lambda \to 0$, there is no "classical" way to justify the WKB as $\widetilde{a} \to 0$. $\Lambda \to 0$, according to Park in a four dimensional space time if and ONLY if, the temperature in the pre Planckian space time condition were initially equal to ZERO. I.e. if there is such a regime, it means that in an interval of space time just before the Planckian regime that two conditions would happen. For times less than a Planck time interval, the following are equivalent

1. $\Lambda_{4-Dim} \to 0$ if there is time BEFORE Planck time, i.e. 10^{-44} seconds, corresponding to an effective, for OUR universe zero temperature

2. $\rho_{Vacuum}\big|_{4-Dim} = \left[\Lambda_{4-Dim}/8\pi \cdot G\right] \to 0$

The authors argue, that in order to make the above two conditions match up, that there has to be a causal discontinuity in 5 dimensional space time as referenced in **Appendix E** below, i.e. perhaps only information which can be transmitted via evolution of the Hubble parameter would pass from a prior to the present cycle. Temperature presumably would be transferred via a higher, fifth dimension. Eq. (16) assumes that gravitons from a prior universe may transit to the present universe, i.e. be information carriers. But that there is an effective chopping off of most of the prior universe's other than graviton information carried input. We expect that information is thermalized, with gravitons transferred from a prior universe . The graviton is the minimum 'sized ' information carrier, and that all other inputs, other than thermal from a prior universe, are cut out, meaning that effectively over 99% of the prior universe's content would be removed as far as a contributing factor to the present universe's rise. Having said that, it is time to explore the consequences of causal discontinuity for almost all (but graviton) based 'information'. Aside from information carried via gravitons, we view as feasible transition of thermal energy from a prior to the present universe.

Relevance to Octonian Quantum gravity constructions? Where does non commutative geometry come into play ?

. Crowell [1] wrote on page 309 that in his Eq. (8.141), namely

$$\left[x_j, p_i\right] \cong -\beta \cdot \left(l_{Planck}/l\right) \cdot \hbar T_{ijk} x_k \to i\hbar \delta_{i,j} \tag{27}$$

Here, β is a scaling factor, while we have, above, after a certain spatial distance, a Kroniker function so that at a small distance from the confines of Planck time, we recover our quantum mechanical behavior. Our contention is, that since Eq. (26) depends upon Energy- momentum being conserved as an average about quantum fluctuations, that if energy-momentum is violated, in part, that Eq. (27) falls apart. How Crowell forms Eq. (26) at the Planck scale depends heavily upon Energy- Momentum being conserved.[1] Our construction VIOLATES energy – momentum conservation. N. Poplawski[9] also has a very revealing construction for the vacuum energy, and cosmological constant which we reproduce, here

$$\Lambda = \left[\frac{3\kappa^2}{16}\right] \cdot \left(\overline{\psi}\gamma_j \gamma^5 \psi\right) \cdot \left(\overline{\psi}\gamma^j \gamma^5 \psi\right) \tag{28}$$

And

$$\rho_\Lambda = \left[\frac{3\kappa}{16}\right] \cdot \left(\overline{\psi}\gamma_j \gamma^5 \psi\right) \cdot \left(\overline{\psi}\gamma^j \gamma^5 \psi\right) \tag{29}$$

Poplawski writes that formation of the above, is:

> "*Such a torsion-induced cosmological constant depends on spinor fields, so it is not constant in time (it is constant in space at cosmological scales in a homogeneous and isotropic universe). However, if these fields can form a condensate then the vacuum expectation value of* (**Eq. 28**) *will behave like a real cosmological constant"*

Poplawski write his formulation in terms of a quark- gluon QCD based condensate. Our contention is that once a QCD style condensate breaks up due to what is brought up in Appendix E, i.e. that there will afterwards be NO equivalent structure to Eq. (28) and Eq. (29) even at the beginning of inflation right after the break down of space time particle transfer as given by Appendix E. Once that condensate structure is not possible then as quantified by Eq. (8.140) of Crowell [1] , the following will not hold as before:

$$\oint p_i \, dx_k = \hbar \delta_{i,k} \tag{30}$$

no longer holds. Eq. (8.40) of the Crowell manuscript makes the assumption is true, namely

$$\left[x_j, x_k\right] = \beta \cdot l_P \cdot T_{j,k,l} \cdot x_l \tag{31}$$

Does the (QCD) condensate occur post plankian, and not work for pre plankian regime ? Yes.

The problem lies with Eq. (8.140) of Crowell [1]with the final equality not holding. If one were integrating across a causal barrier,

$$\oint [x_j, p_i] dx_k \approx -\oint p_i [x_j, dx_k] = -\beta \cdot l_P \cdot T_{j,k,l} \oint p_i dx_l \neq -\hbar\beta \cdot l_P \cdot T_{i,j,k} \tag{32}$$

Very likely, across a causal boundary, between $\pm l_P$ across the boundary due to the causal barrier, one would have

$$\oint p_i \, dx_k \neq \hbar \delta_{i,k}, \oint p_i \, dx_k \equiv 0 \tag{33}$$

I.e.

$$\left. \oint_{\pm l_P} p_i dx_k \right|_{i=k} \to 0 \tag{34}$$

If so, then [1]

$$\left[x_j, p_i\right] \neq -\beta \cdot \left(l_{Planck} / l\right) \cdot \hbar T_{ijk} x_k \quad and \quad does \quad not \to i\hbar \delta_{i,j} \tag{35}$$

Eq. (39) in itself would mean that in the pre Planckian physics regime, and in between $\pm l_P$, QM no longer applies. What we will do next is to begin the process of determining a regime in which Eq. (34) may no longer hold via experimental data sets.

Understanding how phase shift in Gravitational waves may be affected by the transition to and from a causal discontinuity, and different models of emergent structure cosmology

We will outline how research initiated by both Dr. Beckwith and Dr. Li, and Yang Nang, may give us details of gravitational wave generation by early universe conditions. In [25] as given by Li, and Yang, 2009, Beckwith [26] outlined in Chongquing University, in the Institute of Theoretical physics, the following simplest representation of amplitude, i.e. as given by reading [25] the following simplest case for amplitude, across the different polarized states

$$A_{\otimes} = A_{\oplus} = \breve{A} \tag{36}$$

Furthermore, the first order perturbative (E and M) field may have its components written as

$$\tilde{F}^{(1)}_{0\ 2} = i\tilde{F}^{(1)}_{0\ 1} \tag{37}$$

Secondly, there is a way to represent the" number" of transverse first order perturbative photon flux density as given by (in an earth bound high frequency GW detector).

$$n_r^{(1)} = \frac{c}{2\mu_0 \hbar \omega_{e^-}} \mathrm{Re}\{\ \} \tag{38}$$

$$\{\ \} = i(\exp[-i\theta]) \cdot \tilde{F}^{(1)*}_{0\ 1} \cdot \left[\frac{i}{\omega_{e^-}} \cdot \left(\frac{\partial \Psi_x}{\partial y} - \frac{\partial \Psi_y}{\partial x} \right) \right] \tag{39}$$

The quantity $\frac{i}{\omega_{e^-}} \cdot \left(\frac{\partial \Psi_x}{\partial y} - \frac{\partial \Psi_y}{\partial x} \right)$ is the z component of the magnetic field of a Gaussian beam and one can see that the quantity Q is the quality factor of the detector cavity set up to observe GW , whereas $\breve{A}$ is the experimental GW amplitude in the simplest case, and $\hat{B}_y^{(0)}$ a static magnetic field. Then the $\tilde{F}^{(1)}_{0\ 2} = i\tilde{F}^{(1)}_{0\ 1}$ will lead to

$$\tilde{F}^{(1)}_{0\ 1} = i2\breve{A}\hat{B}_y^{(0)} Q \cdot \left[\sin\left[\frac{n\pi z}{b} \right] \right] \cdot \exp[i(-\omega_g t + \delta_0)] \tag{40}$$

The formula $E_{thermal} \approx \frac{1}{2} k_B T_{temperature} \propto \tilde{\beta}$ is a feed into ω_g provided that we pick time $t \propto$ Planck time, and also set Eq. (39) with $\omega_g \sim \omega_g$ as in part fixed by setting up the $E_{thermal} \approx \frac{1}{2} k_B T_{temperature} \approx \tilde{\beta}$. In other words, for relic GW/ graviton production, a topological transformation and inter relationship between the components $\tilde{\alpha}$ and $E_{thermal} \approx \frac{1}{2} k_B T_{temperature} \propto \tilde{\beta}$ in Eq.(16) for specifying the increase in (topological) degrees of freedom , as a change in geometry,. I.e. before quantum gravity. How do we know that quantum gravity did not pre-exist in prior universe? If this is the case then could GW pass through a wormhole? Well, yes, this is up to a point what is also being discussed. One may have gravitons transit through the worm hole, which may correspond to GW encoded information from a 'prior universe'. Passing gravitons through to a new universe is not the same thing though as a pre Planckian geometry, which we argue is not Octonian gravity, to Octonian gravity conditions arising in early Planckian space time. This is a different perspective than what is normally used in analyzing what may happen in a transition between initial Planck time $\sim 10^{-44}$ seconds, and cosmological evolution up to 10^{-30} seconds We will next specify how to perhaps locate massive gravitons, via an experimental set up which may enable obtaining data for supporting a value for δ_0. The next discussion is an extension of research done by Dr. F. Li, et al, 2003, [27], with commentary made by A. Beckwith [26] as to how to obtain an experimental criteria as to identify traces of massive gravitons, which may play a role in DE models [28].

Re casting the problem of GW/ Graviton signatures in a detector for "massive" Gravitons

We now turn to the problem of detection. The following discussion is based upon with the work of Dr. Li, Andrew Beckwith, and other Institute of theoretical physics researchers in Chongquing University [26],[28].

Assuming that one was measuring stochastic HFGW using the disturbance of electromagnetic energy in a cavity, the minimum gravitational wave 'magnitude' to be measured is limited by the Standard Quantum Limit (SQL), For a cavity containing electromagnetic energy, if Q is the quality factor of a cavity, ξ is the total energy in a cavity, $\hbar\omega_{e^-}$ is the energy of a photon in the cavity, then the minimum sensitivity to a stochastic HFGW would need a metric 'amplitude' of at least [29], [29a], [29b], [30]

$$h_{\min} \approx \frac{1}{\sqrt{Q}} \cdot \sqrt{\frac{\hbar\omega_{e^-}}{\xi}} \tag{41}$$

This can be a significant limitation in practice. For example, as quoted from a document being written up by F. Li et al, for publication [31] if Q $=10^{11}$, E = 10J, and ω_{e^-} is a frequency $=10^{12}$ Hz , then one will obtain $h_{\min} \sim 2{:}5 \times 10^{-17}$ for the stochastic HFGW. Therefore, we can conclude that advanced cavity detectors could be a promising way for the HFGW detection If much higher contained energies are developed. Similarly, if one has, instead, a coherent GW background, [29], [29a], [29b], [30], [31] then

$$h_{\min} \approx \frac{1}{Q} \cdot \sqrt{\frac{\hbar\omega_{e^-}}{\xi}} \tag{42}$$

It this case $h_{\min} \sim 8.1 \times 10^{-23}$ for the non - stochastic HFGW, even at a very low contained energy of 10 J. It is therefore quite plausible that such a detection cavity could be tuned over a range of HFGW frequencies to scan for detectible gravitational waves of either a coherent or stochastic nature. **Appendix F** shows one design for the electromagnetic detection of HFGW, and depicts the cavity configuration.

Given these figures, it is now time to consider what happens if one is looking for traces of gravitons which may have a small rest mass in four dimensions**.** What Li et a.l have shown in 2003 [27] which Beckwith commented upon and made an extension in [28] is to obtain a way to present first order perturbative electromagnetic power flux, i.e. what was called $\overset{(1)}{T}{}^{uv}$ in terms of a non zero four dimensional graviton rest mass, in a detector , in the presence of uniform magnetic field, when examining the following situation, i.e. [27] what if we have curved space time with say an energy momentum tensor of the electro magnetic fields in GW fields as given by

$$T^{uv} = \frac{1}{\mu_0} \cdot \left[-F_{\alpha}^{\mu} F^{\nu\alpha} + \frac{1}{4} \cdot g^{\mu\nu} F_{\alpha\beta} F^{\alpha\beta} \right] \tag{43}$$

Li et al [25] state that $F_{\mu\nu} = F_{\mu\nu}^{(0)} + \widetilde{F}_{\mu\nu}^{(1)}$, with $\left|\widetilde{F}_{\mu\nu}^{(1)}\right| << \left|F_{\mu\nu}^{(0)}\right|$ will lead to

$$T^{uv} = \overset{(0)}{T}{}^{uv} + \overset{(1)}{T}{}^{uv} + \overset{(2)}{T}{}^{uv} \tag{44}$$

The 1st term to the right hand side of Eq. (49) is the energy – momentum tensor of the back ground electro magnetic field, and the 2nd term to the right hand side of Eq. (49) is the first order perturbation of an electro magnetic field due to the presence of gravitational waves.

The above Eq.(48) and Eq. (49) will eventually lead to a curved space version of the Maxwell equations as

$$\frac{1}{\sqrt{-g}} \cdot \frac{\partial}{\partial x^{\nu}} \cdot \left(\sqrt{-g} \cdot g^{\mu\alpha} g^{\nu\beta} F_{\alpha\beta} \right) = \mu_0 J^{\mu} \tag{45}$$

as well as

$$F_{[\mu\nu,\alpha]} = 0 \tag{46}$$

Eventually, with GW affecting the above two equations, we have a way to isolate $\overset{(1)}{T}{}^{uv}$. If one looks at if a four dimensional graviton with a very small rest mass included [28] we can write

$$\frac{1}{\sqrt{-g}} \cdot \frac{\partial}{\partial x^{\nu}} \cdot \left(\sqrt{-g} \cdot g^{\mu\alpha} g^{\nu\beta} F_{\alpha\beta} \right) = \mu_0 J^{\mu} + J_{effective} \tag{47}$$

where for $\varepsilon^{+} \neq 0$ but very small

$$F_{[\mu\nu,\alpha]} \sim \varepsilon^{+} \tag{48}$$

The claim which A. Beckwith made [28] is that

$$J_{effective} \cong n_{count} \cdot m_{4-D-Graviton} \tag{49}$$

As stated by Beckwith, in [24], $m_{4-D-Graviton} \sim 10^{-65}\, grams$, while n_{count} is the number of gravitons which may be in the detector sample. What Beckwith, Li, and Chonquing university researchers intend to do is to try to isolate out an appropriate $\overset{(1)}{T}{}^{uv}$ assuming a non zero graviton rest mass, and using Eq. (47), Eq. (48) and Eq. (49) . From there, the energy density order contributions of $\overset{(1)}{T}{}^{uv}$, i.e. $\overset{(1)}{T}{}^{00}$ can be isolated, and reviewed in order to obtain traces of $\tilde{\beta}$, which can be used to interpret Eq. (16) . I.e. use $\tilde{\beta} \cong |F|$ and make a linkage of sorts with $\overset{(1)}{T}{}^{00}$. The term $\overset{(1)}{T}{}^{00}$ isolated out from $\overset{(1)}{T}{}^{uv}$ present day data. The point here that the detected GW would help constrain and validate Eq. 16.

1st part of Conclusion: Analogue of this sort of break down via string theory language; leading to asking if String theory help restore or break Octonionic gravity?

We hope that there is confirmation of what is brought up in Eq. (48) above. We shall as a future goal mention as to what is a way to confirm or falsify the so called string theory treatment of formation of Octonionic Quantum gravity. A string theory version of how to present a non commutative structure is given in **Appendix G**, and the question we ask is, can string theory's treatment of non commutative geometry be justified ? Are higher dimensions going to help us define regions where Octonionic gravity breaks down ? Our take is that it will not make any difference. For a lot of reasons. One of which is that so far, the string theorists do not know what will happen as to enable the early universe formation of Dp branes. Without Dp branes, then what is brought up by [34] Mayronatos and Szabo will not happen. I.e. string theory without a description of why Dp branes forms initially cannot guarantee the formation of Octonionic gravity. In order to determine if Octonionic gravity breaks down, we need to know how Dp branes form initially in the first place. What is done in the reference [34][by N.E. Mavromatos_and R.J. Szabo are well done but we view them as incomplete for the reasons brought up above. Completing the analogies, and also reconciling them with Fig 1 above are worthy research objectives. We think that the values of cosmological parameters may be heritage values determined in prior universes, encoded in information space and passed on to us via the wormhole of choice. Lee Smolin of Perimeter Institute has made this argument

Now to determine if Dp branes can be mandated to exist at all at the start of inflation will be necessary to determine if they do not exist during pre inflationary cosmology period.

Does string theory help us determine if and when Octonionic gravity may form ? This is the basic question which needs to be asked, and so far until we know if or NOT Dp branes can be mandated to exist at all at the start of inflation, we have no additional gain of information as to the formation of Octonionic gravity.

2nd part of conclusion. Can we justify / Isolate out an appropriate $\overset{(1)}{T}{}^{uv}$ if one has non zero graviton rest mass?

It is difficult. It depends upon understanding what is meant by emergent structure, as a way to generalize what is known in mathematics as the concept of "self-organized criticality" put forward by the Santa Fe school. [35] as well as the concept of negator algebra referring to topos-theoretic results. In (2001) Zimmermann and Voelcker [36] refer to a pure abstract mathematical self organized criticality structure. I.e. the transition alluded to about the following will not hold as before. What is the emergent structure permitting $\oint p_i \, dx_k = \hbar \delta_{i,k}$ to hold ? What is the self organized criticality structure leading to forming an appropriate $\overset{(1)}{T}{}^{uv}$ if one has non zero graviton rest mass? Answering such questions will permit us to understand how to link finding $\overset{(1)}{T}{}^{uv}$ in a GW detector, its full analytical linkage to $\tilde{\beta}$ in Eq (16). The following construction is used to elucidate how a Gaussian beam can perhaps be used to eventually help in isolating $\overset{(1)}{T}{}^{uv}$ in a GW detector. This construction below is to be used to investigate 'massive gravitons'/ and also the initial structure of self organized criticality, in the aftermath of graviton/ gravitational wave generation. Further details can be accessed in Appendix F as to a GW detection system which may be able to help us isolate $\overset{(1)}{T}{}^{uv}$.

One of the main things which we may be able to obtain via investigation of what a suitably configured GW detector can give us is resolution of the following: I.e. Stephen Feeney at University College London and colleagues say they've found tentative evidence of four collisions with other universes in the form of circular patterns in the cosmic microwave background.

In their model of the universe, called "eternal inflation," the universe we see is merely a bubble in a much larger cosmos. This cosmos is filled with other bubbles, all of which are other universes where the laws of physics may be dramatically different from ours. As seen in Figure 3.

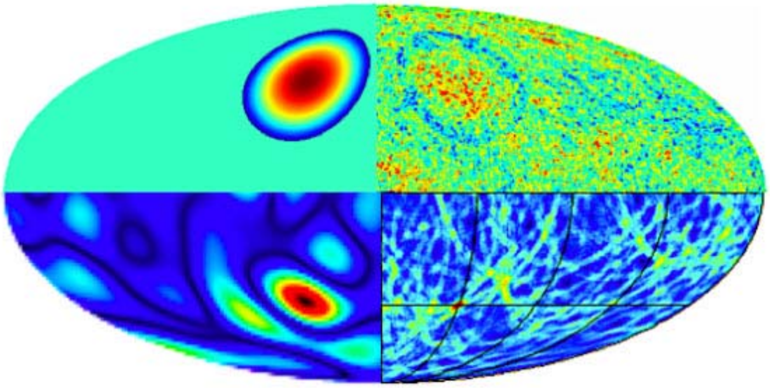

Fig 3, Based upon: First Observational Tests of Eternal Inflation [41]

We are attempting to add more information than Fig (3) above, via suitable analysis of $\overset{(1)}{T}^{uv}$, Note that this Figure 3, plus isolation of $\overset{(1)}{T}^{uv}$ amounts to checking if Penrose's supposition of a universe before the big bang is experimentally falsifiable

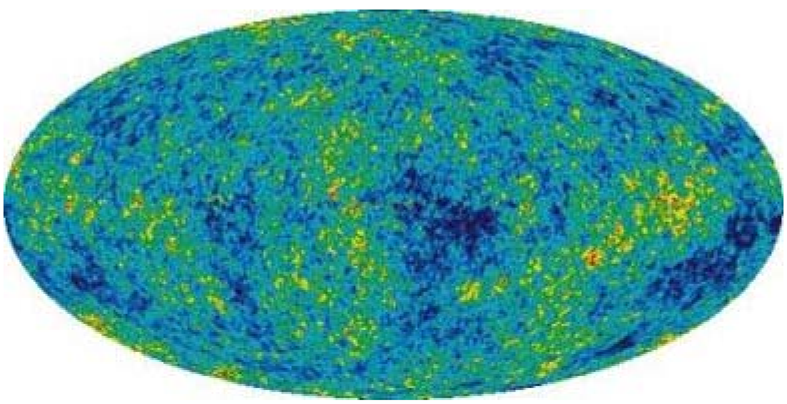

Fig (4) . How to verify the following : Circular patterns within the cosmic microwave background suggest that space and time did not come into being at the Big Bang but that our universe in fact continually cycles through a series of "eons. This claim should be investigated, and is part of Penrose's recent article [42]

Appendix A: Highlights of J.-W. Lee's paper as used by the authors

The following formulation is to high light how entropy generation blends in with quantum mechanics, and how the break down of some of the assumptions used in Lee's paper coincide with the growth of degrees of freedom. What is crucial to Lee's formulation, is Rindler geometry, which is flat space time geometry, not the curved space formulation of initial universe conditions. To enable these ideas, the following formulas are used from [3]. First of all. quoting from [3],

"Considering all these recent developments, it is plausible that quantum mechanics and gravity has information as a common ingredient, and information is the key to explain the strange connection between two. If gravity and Newton mechanics can be derived by considering information at Rindler horizons, it is natural to think quantum mechanics might have a similar origin. In this paper, along this line, it is suggested that quantum field theory (QFT) and quantum mechanics can be obtained from information theory applied to causal (Rindler) horizons, and that quantum randomness arises from information blocking by the horizons

To start this program, we look at the Rindler partition function, as given by

$$Z_R = \sum_{i=1}^{n} \exp[-\beta H(x_i)] = Trace \cdot (\exp[-\beta H]) \tag{A.1}$$

As stated by Lee [3] , *..we expect Z_R to be equal to the quantum mechanical partition function of a particle with mass m in Minkowski space time .* Furthermore, there exists the datum that :Lee made an equivalence between Eq. (A1) and

$$Z_Q = N_1 \int \wp x \cdot \exp\left[\frac{-i}{\hbar} \cdot I(x_i)\right] \tag{A2}$$

Where $I(x_i)$ is the action 'integral' for each path x_i , leading to a wave function for each path x_i

$$\psi \sim \exp\left[\frac{-i}{\hbar} \cdot I(x_i)\right] \tag{A3}$$

If we do a re scale $\hbar = 1$, then the above Wave equation can lead to a Schrodinger equation, as given by [37]

<u>The example given by Lee</u> [3] is that there is a Hamiltonian for which

$$H(\phi) = \int d^3x \cdot \left\{\frac{1}{2} \cdot \left(\frac{\partial \phi}{\partial t}\right)^2 + \frac{1}{2} \cdot (\nabla \phi)^2 + V(\phi)\right\} \tag{A4}$$

Here, V is a potential, and ϕ can have arbitrary values before measurement, and to a degree, Z represent uncertainty in measurement. In Rindler co-ordinates, $H \to H_R$, in co-ordinates (η, r, x_2, x_3) with proper time variance $ard\eta$ then

$$H_R(\phi) = \int drdx_\perp ar \cdot \left\{\frac{1}{2} \cdot \left(\frac{\partial \phi}{\partial r}\right)^2 + \frac{1}{2} \cdot \left(\frac{\partial \phi}{ar\partial \eta}\right)^2 + \frac{1}{2} \cdot (\nabla_\perp \phi)^2 + V(\phi)\right\} \tag{A5}$$

Here, the $\perp$ is a plane orthogonal to the (η, r) plane. If so then

$$Z = tr \exp[-\beta H] \mapsto Z_R = tr \exp[-\beta H_R] \tag{A6}$$

<u>Now, for the above situation, the following are equivalent</u>

1. Z_R thermal partition function is from information loss about field beyond the Rindler Horizon
2. QFT formation is equivalent to purely information based statistical treatment suggested in this paper
3. QM emerges from information theory emerging from Rindler co-ordinate

Lee also forms a Euclidian version for the following partition function, if $I_E(x_i)$ is the Euclidian action for the scalar field in the initial frame. I.e.

$$Z_Q^E = N_1 \int \wp x \cdot \exp\left[\frac{-i}{\hbar} \cdot I_E(x_i)\right] \tag{A7}$$

There exist analytic continuation of $\tilde{t} \mapsto it$ leading to $Z_Q^E \mapsto Z_Q =$ Usual zero temperature QM partition function of Z_Q for ϕ /

Important Claim: The following are equivalent

1. Z_R and Z_Q are obtained by analytic continuation from Z_Q^E
2. Z_R and Z_Q are equivalent .

Question : Can one transcribe Rindler co – ordinates to the ' origin ' of the big bang ?
Provisional Answer: No. Need to have flat space geometry, and ORIGIN of big bang is curved space. I.e. pre Planckian regime is curved space. Also, Rindler co ordinates can be as good a description of present geometry.

Note that Free energy, corresponds to

$$F = -\frac{1}{\beta} \cdot \ln Z_R \cong F_{Classical} \approx (I_E(x_i)) \tag{A8}$$

Here, $F_{Classical} \approx (I_E(x_i))$ **minimized**, means that change in entropy is **maximized**. If we look at Verlinde entropy as associated with lost particle information, it means, if $F = -k_B T \cdot \ln Z(T, V, \overline{N}) \equiv -k_B TN[\ln(V/\lambda^3) + 5/2]$, with $\lambda^3 \geq V$, with V an initial space time volume, and λ the 'wave length, of say a graviton or equivalent space time particle at/about the origin, then one would have up to a point,

$$F = -\frac{1}{\beta} \cdot \ln Z_R \cong F_{Classical} \approx (I_E(x_i)) \sim -k_B TN[\ln(V/\lambda^3) + 5/2] \propto k_B TN \tag{A9}$$

Low temperature mean high entropy, and eventually, when one would get to the Planckian regime of space time, with the squeezing of space time geometry to a flat space Rindler geometry , the particle count algorithm would be along the lines of having all the entropy squeezed to

$$\Delta S \sim n(relic) \sim \text{\# of initial relic particles} \tag{A10}$$

Here, having $\lambda^3 \geq V$, with V the initial Plackian regime sized 'volume' would be equivalent to the causal discontinuity relationship of **a certain amount of 'information' as given above in Eq. (29) and Eq. (30) above**. Also, having $\lambda^3 \geq V$ corresponds to having a filter for the creation of $J_{effective} \cong n_{count} \cdot m_{4-D-Graviton}$, for "massive" gravitons.

Appendix B: Highlights of S. Chaturvedi paper (about MUB) as used by the authors

Based upon [2] we will go through an accounting of what are Mutually Unbiased Bases, so as to lead up to their application in early universe geometry. When going through this, we should keep in mind that what will be done in the application will be making an accounting as to how much information and structure is implied by an initial geometry, as well as what happens when the initial mutually unbiased basis is 'dissolved' by an increase in temperature as outlined via Eq. (16).

To begin with, we go to [2]'s key definition. In a Hilbert space, of dimension N, by a set of mutually unbiased basis, we mean a set of N+1 orthormal basis, , the modus squared if any scalar product of one basis with any member of any other basis = 1/N. Now for his generalization, which has important implications we will elaborate in the text, namely

Let $e^{(\alpha,k)}$ be the k th vector in the α th orthornormal bis. Let $\alpha = 1,......,N-1$. There $\exists$ N(N+1) Nth dimensional vectors satisfying

$$\left|\left\langle e^{(\alpha,k)}, e^{(\alpha',k')}\right\rangle\right|^2 = \delta^{\alpha,\alpha'}\delta^{k,k'} + \frac{1}{N}\cdot\left(1-\delta^{\alpha,\alpha'}\right) \tag{B.1}$$

Here, we have that $\alpha, \alpha' = 0,1,..........,N$ Also, we have that $e_l^{(\alpha,k)}$ is the l th component of k vector of α orthornormal basis, where $\left|\left\langle e^{(\alpha,k)}, e^{(\alpha',k')}\right\rangle\right|^2 = \left|\sum_{l=0}^{N-1}\left\langle e_l^{(\alpha,k)}, e_l^{(\alpha',k')}\right\rangle\right|^2$

For our early universe purposes, the main benefit of MUB would be in 'encryption' of information [39], a point which has direct relevance to highly complex geometry before the transition to quantum mechanics, where the geometry is, in part simplified to 'flat space " , where the rules of quantum Octonian gravity formulation hold.

Appendix C: Renyi Entropy (using MUB) versus Y. Ng particle count entropy

This section is to high light the similarities and differences in entropy, in the pre Planckian regime, Planckian space time, and then in doing so, suggest inputs into experimentally detecting δ_0 .in a gravitational wave detector. [4]

We start off with the description from[4] as to what Renyi Entropy, for a MUB , and from there set up a protocol as to compare the difference in entropy between MUB Renyi Entropy, and Ng entropy [20]. Let us beginas to what is known as Entropic relations

C1. Basics of Entropic relations

Let $|\psi\rangle \varepsilon \mathrm{H}_n$ be a quantum state of $n = LogN$ qubits. Set $B \equiv \{|b_i\rangle\}_{i=1,....n}$ be an orthonormal basis in H_n
So, using the construction of an MUB as given in Appendix 2, we can refer to $\left|\langle b \| b'\rangle\right|^2 = 1/N, for \forall b \varepsilon B, b' \varepsilon B', B \neq B' \varepsilon \beta, \beta$ a set of N+1 MUB for H_n Here we have the

C2 Theorem [Maasen-Uffink88]

For any pair of mutually unbiased basis P and Q for H_n, and $|\psi\rangle \varepsilon \mathrm{H}_n$, then , $\exists$ a probability distribution for

$$B_{\psi(i)} = \left\|\langle b_i |\psi\rangle\right\|^2 \tag{C1}$$

$$H\left(B_{\psi(i)}\right) = -B_{\psi(i)} \log B_{\psi(i)} \tag{C2}$$

So now we go to the definition of Renyi entropy, i.e. for $-1 < \alpha < \infty$ defining the 'Renyi entropy of order α

$$H_\alpha\left(B_{\psi(i)}\right) = -\log\left(\sum_i B_{\psi(i)}{}^{1+\alpha}\right)^{1/\alpha} \tag{C3}$$

$$\begin{aligned} H_0\left(B_{\psi(i)}\right) &= H\left(B_{\psi(i)}\right), \\ H_\infty\left(B_{\psi(i)}\right) &= -\log\left(\max_i B_{\psi(i)}\right) \end{aligned} \tag{C4}$$

And now for the main result, i.e. the [Maasen-Uffink88] theorem

For any pair of mutually unbiased basis, P and Q for H_n, and any state $|\psi\rangle \varepsilon \mathrm{H}_n$ then one has for Log N=n quidbits

$$H(P_n) + H(Q_n) \geq \log N \tag{C5}$$

This inequality involving zeroth order Renyi entropy as given by Eq(C4) should be contrasted with Y. Jack Ng (20) entropy , i.e. S ~ <n>

Appendix D : SETH LLOYD'S UNIVERSE AS A MODIFIED QUANTUM COMPUTER MODEL

Many people would not understand why computational models of the universe would be important to cosmology. What we establish thorough a computational model is a way to explain why the dominant contribution to gravity waves from a wormhole transferal of vacuum energy to our present universe is tilted toward a dominant high-frequency spectrum. This allows us to understand what sort of initial conditions would be favored for graviton production, which it later is claimed could be detected given sufficient signal strength. One can make use of the formula given by Seth Lloyd [23], which relates the number of operations the "Universe" can "compute" during its evolution. Lloyd [23] uses the idea, which he attributed to Landauer, to the effect that the universe is a physical system that has information being processed over its evolutionary history. Lloyd also makes reference to a prior paper where he attributes an upper bound to the permitted speed a physical system can have in performing operations in lieu of the Margolis/Levitin theorem, with a quantum mechanically given upper limit value (assuming E is the average energy of the system above a ground state value), obtaining a *first limit* of a quantum mechanical average energy bound value, if $\# operations/\sec = \tilde{N}$:

$$\tilde{N} \leq 2E/\pi\hbar \quad . \tag{D1}$$

The second limit is the number of operations, linked to entropy, due to limits to memory space, as Lloyd writes:

$$\tilde{N} \cdot \sec \leq S(entropy)/\left(k_B \cdot \ln 2\right) \quad . \tag{D2}$$

What we are suggesting, is that in both Eq. (D1) and Eq. (D2) that we replace the upper bound limits of both of the equations with

$$\tilde{N} \leq 2 \cdot (V(scalar - potential))/\pi\hbar . \approx 2 \cdot \left[V \sim 3\langle H\rangle^4 / 16\pi^2\right] / \pi\hbar \tag{D3}$$

The problem as we will outline just below, though, is that there may be effectively no way to transmit bits of information through a four dimensional continuum.

Appendix E: Causal discontinuity, and Dowker's axiomatic approach to space time physics time in the aftermath of the pre Planckian space time regime 5 dimensional discontinuity

The existence of a nonlinear equation for early universe scale factor evolution introduces a de facto "information" barrier between a prior universe,. To see this, refer to Dowker's [24] paper on causal sets. These require the following ordering with a relation $\prec$, where we assume that initial relic space-time is replaced by an assembly of discrete elements, so as to create, initially, a partially ordered set C:

(1) If $x \prec y$, and $y \prec z$, then $x \prec z$

(2) If $x \prec y$, and $y \prec x$, then $x = y$ for $x, y \quad \varepsilon \quad C$

(3) For any pair of fixed elements x and z of elements in C, the set $\{y \mid x \prec y \prec z\}$ of elements lying in between x and z is always assumed to be a finite valued set.

Items (1) and (2) show that C is a partially ordered set, and the third statement permits local finiteness. Stated as a model for how the universe evolves via a scale factor equation permits us to write, after we substitute $a(t^*) < l_P$ for $t^* < t_P =$Planck time, and $a_0 \equiv l_P$, and $a_0 / a(t^*) \equiv 10^{\alpha}$ for $\alpha >> 0$ into a discrete equation model of a 5 dimensional model of the Friedman equation would lead to the existence of a de facto causal discontinuity in the arrow of time and blockage of information flow, once the scale factor evolution leads to a break in the causal set construction written above .[11]

CLAIM 1 : The Friedmann equation for the evolution of a scale factor $a(t)$, suggests a non partially ordered set evolution of the scale factor with evolving time, thereby implying a causal discontinuity**.** The validity of this formalism is established by rewriting the Friedman equation as follows: in 5 dimensions looking at Λ_{5-Dim} going to infinity as time goes to zero. I.e. if $\delta \cdot t$ is vanishingly small, then[12]

$$\left[\frac{a(t^* + \delta t)}{a(t^*)}\right] - 1 < \frac{\left(\delta\, t \cdot l_P\right)}{\sqrt{\Lambda_{5-Dim}/3}} \cdot \left[1 + \frac{8\pi}{\Lambda_{5-Dim}} \cdot \left[(\rho_{rel})_0 \cdot 10^{4\alpha} + (\rho_m)_0 \cdot 10^{3\alpha}\right]\right]^{1/2} \xrightarrow[\Lambda 5-\dim \to \infty]{} 0 \quad . \text{(E1)}$$

So in the initial phases before the big bang, with a very large 5 dimensional vacuum energy and a vanishing 4 dimensional vacuum energy , the following relation, which violates (signal) causality, is obtained for any given fluctuation of time in the "positive" direction within the confines of time evolution within the pre Planckian regime[12]:

$$\left[\frac{a(t^* + \delta \cdot t)}{a(t^*)}\right] < 1 \quad . \qquad \text{(E2)}$$

The existence of such a violation of a causal set arrangement in the evolution of a scale factor argues for a break in information above a minimal level of complexity being propagated from a prior universe to our present universe. This has just proved non-partially ordered set evolution, by deriving a contradiction from the partially ordered set assumption. Doing this, means that in order to cement having uni directionality of the time flow itself, we would need to define a starting flow for time flow, in one direction starting at the instant of space time created by the Planckian unit of time, and not just before it. We also make a 2nd claim which will be, in five dimensions stated as follows:

CLAIM 2: The following are equivalent . In a space-time evolution sense. Note that a Kerr- Newman metric can obtain much the same information, but the choice of a Reissner-Nordstrom Metric is used here for simplicity, and enforces rotational invariance, which is pertinent to the early universe.

1. There exists a Reisnner-Nordstrom Metric with -F(r) dt^2 dominated by a cosmological vacuum energy term, $\left(-\Lambda/3\right)$times dt^2, for early universe conditions in the time range less than or equal to Planck's time t_P.
2. A solution for a pseudo-time dependent version of the Wheeler De Witt equation exists, with a wave function $\Psi(r,t,T)$ forming a wormhole bridge between two universe domains, with $\Psi(r,t,T)=\Psi(r,-t,T)$ for a region of space-time before signal causality discontinuity for times $|t|<t_P$.
3. The heat flux-dominated vacuum energy value given by $\Psi(r,t,T)$ contributes to a relic graviton burst, in a region of time less than or equal to Planck's time t_P.

The third postulate of Claim 2, is in line with a minimum complexity of a structure which conceivably could transit from one universe to another.

r Appendix F. Brief summary of important facts concerning a proposed HFGW detector system

A Gaussian microwave beam (GB) could be used as the applied EM wave required in the Li effect. It could be produced by a conventional microwave transmitter with its antenna aimed along the +*z*-axis of Figure D1 in conjunction with an orthogonal static magnetic field, and would be configured with microwave absorbent layers on the transmitter compartment walls to absorb side lobes of the GB. In this arrangement it is also known as the Li-Baker detector design [29b], [43] after its two co-inventors.

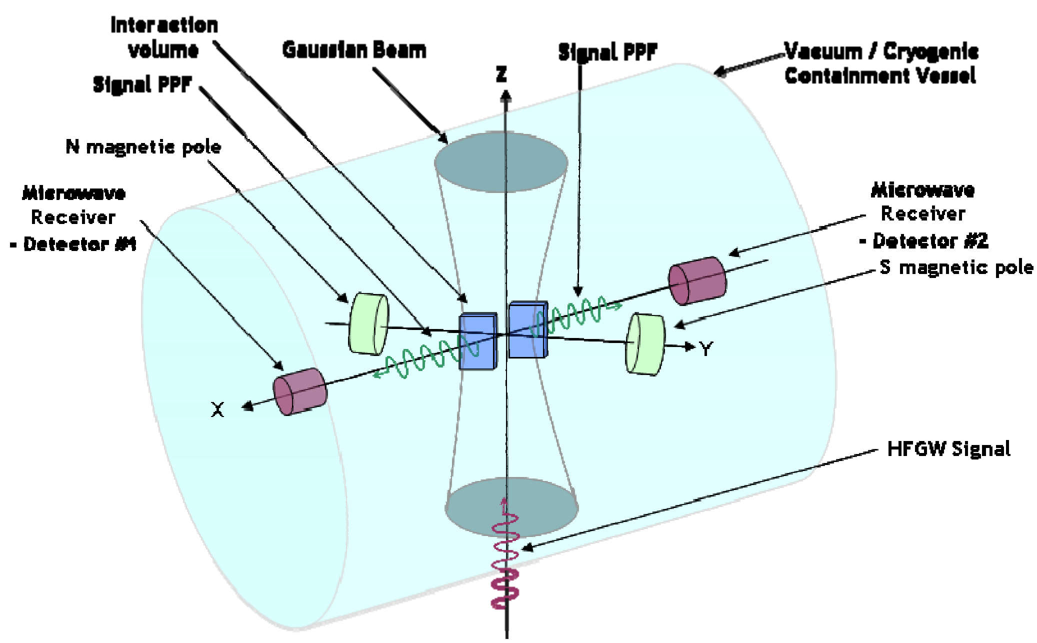

Figure F1. The Li-Baker HFGW Detector Design [38]

The frequency and direction of the GB would be the same as the frequency and direction of the incoming HFGW signal that will be detected to establish a synchro-resonance condition [36], [37] in the interaction volume above the transmitter compartment as shown in Figure D2.

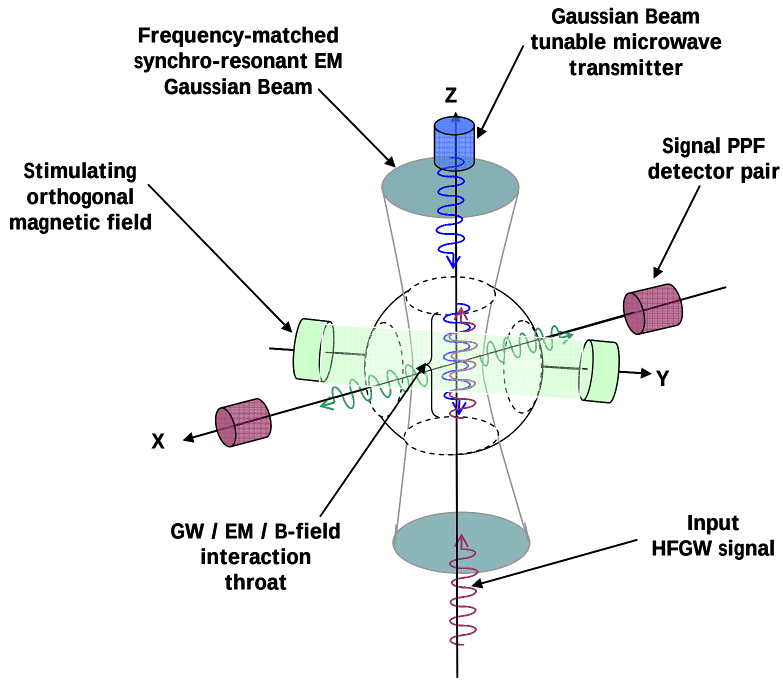

Figure F2. Gaussian-beam transmitter compartment [38]

Figure 2 , with significant modifications could be part of how to determine if causal discontinuity / emergent structure would take place, potentially allowing for the formation of Octonionic non commutative geometry, presaging the existence of quantum gravity in pre space time i.e. before the Planckian regime of space time

Appendix G. Describing in String theory language how to have a non commutative geometry

Dp brane dynamics, a Dp brane action from a reduced field theory, as given by Szabo, on page 103 of his manuscript is a super symmetric Yang Mills theory on a Dp world volume, involving a Yang-Mills potential as given by [33]

$$V(\Phi) = \sum_{m \neq n} Tr\left[\Phi^m, \Phi^n\right]^2 \tag{G1}$$

Here, the $N \times N$ Hermitian matrix fields can be written as, with x_i^m co ordinates giving positions of N distinct Dp branes in the m-th transverse dimension.

$$\Phi^m = U \cdot \; Diag\left[x_1^m, x_2^m, \ldots\ldots, x_N^m\right] \cdot U^{-1} \tag{G2}$$

The Dp branes, we argue, would have no chance of survival in a causal discontinuity regime, i.e. our next paper will discuss the break down of this sort of structure as cited by Szabo [32] . I.e. in the case of p=0, the matrices as given by Eq. (22) are giving a geometrical interpretation in terms of a necessary non commutative geometry, of the sort which breaks down, as implied by Eq. (20) of the main text above.. If Dp branes can be created at the onset of inflation, then there is a region of space time just before the creation of Dp brane where the Octonionic structure no longer holds. This is what should be determined via further research work. Our conclusion is that if Eq. (G1) is true, that even in the case super symmetric matrix mechanics, that a breakdown of the matrix representation of the Yang-Mills potential in terms of Eq. (G2) will be to essentially invalidate the structure of instanton D0 branes (points) so one is looking at a situation where , even with super symmetry that there will be no structure duplicating non commutative geometry

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