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Detection of Gravitational Waves with Semi Classical Features and Resulting Cosmological Implications

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Abstract

The author argues in this document that initial vacuum state values possibly responsible for GW generation in relic conditions in the initial onset of inflation may have a temporary unsqueezed, possibly even coherent initial value, which would permit in certain models classical coherent initial gravitational wave states. Furthermore, several arguments pro and con as to if or not initial relic GW should be high frequency will be presented, with the reason given why earlier string models did NOT favor low frequency relic GW from the big bang. What is observed is that large higher dimensions above our 4 Dimensional space time, if recipients of matter-energy from collapse and re birth of the universe are enough to insure low relic GW. The existence of higher dimensions, in itself if the additional dimensions are small and compact will have no capacity to lower the frequency limit values of relic GW, as predicted by Giovannini, *et al.* in 1995.

Keywords

Graviton, DM, Squeezed States, Coherent States, High Frequency Gravity Waves

1. Introduction

The author finds that the supposition as to the inevitability of low frequency GW from the big bang is supported only by the conclusion that large spatial dimensions above our four dimensions are conduits as to dumping cyclical universe matter-energy into. But notice the assumptions made to back up this claim, *i.e.* very large scale higher dimensions. The Calabi Yau manifold as stated by Becker, *et al.* [1] used as an initial embedding space for dimensions above our space time was for a long time thought of as having compact, almost undetectable small higher dimensions. The initial smallness of the higher dimensions was the reason why Giovennini *et al.* [2] wrote well received string theory articles predicting no favoring of low frequency GW as the primary relic GW signature from the big bang. The author believes that physics fashion has, in this matter, been driving researchers into more and more extreme suppositions. Suppositions such as huge initial dimensions above the typical four dimensions found in traditional space time are fun mathematical exercises, but there is still no conclusive evidence as to their existence. As is stated in the manuscript, enormous higher dimensions above 4 dimensional space time lead to far lower relic gravitational wave frequencies. Use of either QUIET and/or the Li-Baker detector [3] to find the frequency range of relic gravitational waves would do much to determine if our examined 4 dimensional universe is embedded within enormous higher dimensional space time structures. Physics researchers need to get this question of the embedding of 4 dimensional space time in higher dimensions settled so as to form sensible set of suppositions as to measurable physics signals from the big bang which can be measured. Doing so, also, will lead to another item repeatedly not faced by current physics research fashion. Facing up to if or not initial generations of GW/gravity were due to either classical processes, in highly non linear subsequent evolution, or if the processes must be quantum. And how much squeezing of states in initial conditions for inflation (super inflation in the LQG) scenario is listed by no less that Bojowald [4] as an open problem, which will be brought up toward the end of this document, as part of what the author views as important future goals as to cosmology research. The relative role of classical processes in initial vacuum states from emergent fields, versus quantum has implications far beyond the initial spectrum of GW from relic conditions. Once built, the Li-Baker detector as written up in PRD by Li, *et al.* [3] [5], with its focus upon relic gravitational wave frequency would be, if configured correctly, the optimal research tool needed to confirm, if relic gravitational waves from the big bang were either low frequency or high frequency. If relic gravitational waves are high frequency, then the upper limits as to how high the frequencies are would help cosmologists determine if dimensions above four dimensional space time were tiny Calabi Yau compact space entities, as in Beker, *et al.* [1], or did not exist at all, as many people in the loop quantum gravity community are convinced is the case.

2. What about the Inter Relation of String Theory with Counting Algorithms for DM and Graviton Production, in Terms of Entropy?

So, what can be said about the Ng (2008) paradigm of entropy generation [6], which Beckwith [7] [8] [9] has modified and looked at? For a start, consider if the counting algorithm, which is a string theory result, can have any common results with a quantum gas result, which comes from the WDW equation, whose solution is WKB, semi classical in nature? If there is a close interconnection between the classical and quantum formalisms, with the quantum formulation being close to classical values, the author is observing many coherent states, indicating that to a large degree that classical physics will get most of the generation of GW from emergent space time correct. If there is squeezing of initial GW states, from the birth of the present cosmos, then a far more complex picture emerges, which either indicates a quantum gravity view of emergent GW is necessary, or as Coda [10], and others believe highly non linear processes are occurring which have the character of quantum nucleation of space time physics.

The question of relative over lap of classical and quantum processes in terms of wave functions for the evolution of the universe will be crucially important in determining coherency issues as far as relic GW, and gravitons from relic conditions, which the author will return to repeatedly during this presentation.

3. Review of Simple Models as to Gravitons as Produced Either by (Quantum Gravity) Strings, LQG, (or by Processes Which May Not Be Quantum Gravity Based?)

The author wishes now to review what may be some of the counting algorithms appropriate for entropy generation, and which may contribute to answering if or not GW are mandated to be, from the beginning either a classical versus a quantum processes. In part this next page is due to concepts the author presented in Rencontres De Blois [11], and is a starting point for our inquiry as to the necessity, or lack of, of modeling Gravity as either classical/quantum based in relic conditions.

4. Introduction with Regards to the NG Particle Count and Entropy Paradigm

Two alternative routes to generation of entropy are presented. The first, is a counting algorithm, is an adaptation of Ng's [6] infinite quantum (modified Boltzmann's) statistics; the second references A. Glinka's research presentation on "graviton gas" as a way to provide a perspective? As to how to get a partition function for gravitons that is congruent with the Wheeler De Witt equation. Here are a few questions which are posed for the reader.

1) Is each "particle count unit" as suggested by Ng equivalent to a brane-antibrane unit in brane treatments of entropy?

2) Is the change of entropy $\Delta S \approx \Delta N_{\text{gravitons}}$?

3) Is this graviton production scheme comparable to Glinka's quantum gas [12], from the Wheeler De Witt equation?

5. Entropy Generation via Ng's Infinite Quantum Statistics

This discussion is motivated to present a purely string theory approach and to see if its predictions may overlap with semi classical WDM (semi classical) treatments of cosmology. The contention being advanced is that if there is an overlap between these two methods that it may aid in obtaining experimentally falsifiable data sets for GW from relic conditions.

The author wishes to understand the linkage between dark matter and gravitons. If DM is composed of, as an example, KK gravitons, higher dimensional versions of the KK tower of graviton masses in dimensions above 4 dimensions contribute to a dark matter candidate. If how relic gravitational waves relate to relic gravitons"? To consider just that, the author will look at the "size" of the nucleation space, V (volume). When considering dark matter, DM. V (volume) for nucleation is HUGE. Graviton space V(volume) for nucleation is tiny, well inside inflation if initial gravitational waves are extremely high frequency, as would be the case with the model Giovannini, *et al.* [13] proposed. Therefore, the log factor drops OUT of entropy S if V chosen properly for both eqn. 1 and eqn. 2. Ng's result [6] begins with a modification of the entropy/partition function Ng used the following approximation of temperature and its variation with respect to a spatial parameter, starting with temperature $T \approx R_H^{-1}$ (R_H can be thought of as a representation of the region of space where the author takes statistics of the particles in question). Furthermore, assume that the volume of space to be analyzed is of the form $V \approx R_H^3$ and look at a preliminary numerical factor the author shall call $N \sim \left(R_H / l_P\right)^2$, where the denominator is Planck's length (on the order of 10^{-35} centimeters). The author also specifies a "wavelength" parameter $\lambda \approx T^{-1}$. So the value of $\lambda \approx T^{-1}$ and of R_H are approximately the same order of magnitude. Now this is how Jack Ng [6] changes conventional statistics: he outlines how to get $S \approx N$, which with additional arguments the author refines to be $S \approx \langle n \rangle$ (where $\langle n \rangle$ is graviton density). Begin with a partition function [6]

$$Z_N \sim \left(\frac{1}{N!}\right) \cdot \left(\frac{V}{\lambda^3}\right)^N \tag{1}$$

This, according to Ng, leads to entropy of the limiting value of, if $S = \log\left[Z_N\right]$

$$\begin{aligned} & S \approx N \cdot \left(\log\left[V / N\lambda^3\right] + 5/2\right) \\ & \xrightarrow[\text{Ng infinite Quantum Statistics}]{} N \cdot \left(\log\left[V / \lambda^3\right] + 5/2\right) \approx N \end{aligned} \tag{2}$$

But $V \approx R_H^3 \approx \lambda^3$, so unless N in Equation (2) above is about 1, S (entropy) would be <0, which is a contradiction. Now this is where Jack Ng introduces removing the $N!$ term in Equation (1) above, *i.e.*, inside the Log expression the author, following Ng [6] remove the expression of N in Equation (2) above. The modification of Ng's entropy expression [6] is in the region of space time for which the general temperature dependent entropy Kolb and Turner expression breaks down. In particular, the evaluation of entropy the author does via the modified Ng argument above is in regions of space time where g before re heat is an unknown, and probably not measurable number of degrees of freedom The Kolb and Turner entropy expression [14] has a temperature T related entropy density which leads to that the author is able to state total entropy as the entropy density time's space time volume V_4 with $g_{\text{re heat}} \approx 1000$, according to De Vega [15], while dropping to $g_{\text{electro weakt}} \approx 100$ in the electro weak era. This value of the space time degrees of freedom, according to de Vega has reached a low of $g_{\text{today}} \approx 2\text{-}3$ today. The author asserts that Equation (2) above occurs in a region of space time before $g_{\text{re heat}} \approx 1000$, so after reheating Equation (2) no longer holds, and the author instead can look at [2] [14]

$$S_{\text{total}} \equiv s_{\text{Density}} \cdot V_4 = \frac{2\pi^2}{45} \cdot g_{\bullet} \cdot T^3 \cdot V_4 \tag{3}$$

where $T < 10^{32}\ \text{K}$. The author compares Equation (1) and Equation (2), as how they stack up with Glinka's [12] quantum gas, if the author identifies $\Omega = \frac{1}{2|u|^2 - 1}$ as a partition function (with u part of a Bogoliubov transformation) due to a graviton-quintessence gas, to get information theory based entropy

$$S \equiv \ln \Omega \tag{4}$$

Such a linkage would open up the possibility that the density of primordial gravitational waves could be examined, and linked to modeling gravity as an effective theory. John F. Donoghue [16] has the right slant on it as an adjunct to quantum field theory. Which brings up, again to what degree gravity is either a classical or quantum result. The details of linking what is done with (2) and bridging it to (3) await additional theoretical development, and are probably conceptually understandable if the following is used to link the two regimes. *I.e.* using the number of space time operations used to create (2), via Seth Lloyds [17]

$$I = S_{\text{total}} / k_B \ln 2 = [\#\,\text{operations}]^{3/4} = \left[\rho \cdot c^5 \cdot t^4 / \hbar\right]^{3/4} \tag{5}$$

Essentially, what will be done is to use 5 to show linkage between a largely thermally based production of entropy, as implied by (3) and a particle counting algorithm, as given by (2). This due to the problems inherent in making connections between a particle count generation of entropy, and thermal contributions. *I.e.* two different processes are involved. The big news is though that the WKB is semi classical, whereas anything from string theory is, well, QFT, plus. If one understands if Equation (5) is a semi classical process, or is an effective quantum theory as alleged by Donghue [16], one can ask if entropy production, and information generation is semi classical or quantum in nature.

Where there is an overlap between a classical wave function, and its quantum mechanical analog, that means there is a minimization of spreading of a wave functional. *I.e.* see Roy Glauber [18].

One can say the following. That if there is an overlap between the Wheeler De Witt equation derived quantum gas which was brought up by Glinka [6], where the WDW can have WKB semi classical solutions, and the string theory counting algorithm, Then, if the end results are similar, the fact is that the quantum procedure, *i.e.*. Brane theory is over lapping with WKB, means that there is a minimization of uncertainty. Note that the supposition of how classical and quantum processes can give similar answers is presented in rich detail by Glauber [18] and the example talked about here is its GW analog.

Gravitons are stated conceptually to be akin to photons in light waves. If there is a large deviation/perturbation of the initially Gaussian states of space time wave functions, there is likely a break from classical physics due to the complexity of evolving wave function states influenced increasingly by non Gaussian perturbations. This non Gaussian process is reflected by marked deviation from planar wave state approximations used in the evolution of wave functions.

In the case of gravitons, as coherent states, once squeezing of coherent states occurs, the, mere act of squeezing of the initial states destroys the initial classical super position of graviton states which would contribute to a GW. How and what particular mix of squeezed versus un squeezed relic states one can expect is important for determining frequencies to look for which are from relic conditions. Relic GW is possibly an end result of complex non linear evolutionary processes. Proper detection of their frequencies via the Li-Baker detector [19] and how they emerge from the beginning of space time may allow answering fundamental questions as to how gravitons/gravity waves arose. How does one actually know about first or second order phase transitions, due to GW. Since it has been brought up, let us now review, briefly the issue of coherence, versus de coherence of initial vacuum states, and its relevance as to classical versus quantum factors as to generation of GWs.

6. Issues about Coherent State of Gravitons (Linking Gravitons with GW)

In the quantum theory of light (quantum electrodynamics) and other bosonic quantum field theories, coherent states were introduced by the work of Glauber [18]. Now, it is well appreciated that Gravitons are NOT similar to light. So what is appropriate for presenting gravitons as coherent states? Coherent states, to first approximation are retrievable as minimum uncertainty states. If one takes string theory as a reference, the minimum value of uncertainty becomes part of a minimum uncertainty which can be written as given by Venziano [20], where $l_S \cong 10^{\alpha} \cdot l_{\text{Planck}}$, with $\alpha > 0$, and $l_{\text{Planck}} \approx 10^{-33}$ centimeters

$$\Delta x > \frac{\hbar}{\Delta p} + \frac{l_S^2}{\hbar} \cdot [\Delta p] \tag{6}$$

To put it mildly, if the author is looking at a solution to minimize graviton position uncertainty, the author, will likely be out of luck if string theory is the only tool the author has for early universe conditions. Mainly, the momentum will not be small, and uncertainty in momentum will not be small either. Either way, most likely, $\Delta x > l_S \cong 10^{\alpha} \cdot l_{\text{Planck}}$ In addition, it is likely, as Klaus Kieffer [21] in his book "Quantum Gravity" (on page 290 of that book) that if gravitons are excitations of closed strings, then one will have to look for conditions for which a coherent state of gravitons, as stated by Mohaupt [22] occurs. What Mohaupt is referring to is a string theory way to re produce what Ford gave in 1995, *i.e.* conditions for how Gravitons in a squeezed vacuum state, the natural result of quantum creation in the early universe will introduce metric fluctuations. Ford's [23] treatment is to have a metric averaged retarded Green's function for a mass less field becoming a Gaussian. The condition of Gaussianity is how to obtain semi classical, minimal uncertainty wave states, in this case de rigor for coherent wave function states to form. Ford uses gravitons in a so called "squeezed vacuum state" as a natural template for relic gravitons. *I.e.* the squeezed vacuum state (a **squeezed coherent state**) is any state such that the uncertainty principle is saturated. In QM coherence would be when $\Delta x \Delta p = \hbar/2$. In the case of string theory it would have to be

$$\Delta x \Delta p = \frac{\hbar}{2} + \frac{l_S^2}{2 \cdot \hbar} \cdot [\Delta p]^2 \tag{7}$$

Begin with noting t hat if one is not using string theory, the author, Beckwith, merely set the term $l_S \xrightarrow[\text{non string}]{} 0$, but that the author is still considering a variant of the example given by Glauber [18] with string theory replacing Glauber's stated example.

However, in string theory, the author, Beckwith observes a situation where a vacuum state as a template for graviton nucleation is built out of an initial vacuum state, $|0\rangle$. To do this though, as Venkatartnam, and Suresh did [24], involved using a squeezing operator $Z[r,\vartheta]$ defining via use of a squeezing parameter r as a strength of squeezing interaction term, with $0 \le r \le \infty$, and also an angle of squeezing, $-\pi \le \vartheta \le \pi$ as used in

$$Z[r,\vartheta] = \exp\left[\frac{r}{2} \cdot \left(\left[\exp(-i\vartheta)\right] \cdot a^2 - \left[\exp(i\vartheta)\right] \cdot a^{+2}\right)\right],$$

where combining the $Z[r,\vartheta]$ with

$$|\alpha\rangle = D(\alpha) \cdot |0\rangle \tag{8}$$

Equation (8) leads to a single mode squeezed coherent state, as they define it via

$$|\varsigma\rangle = Z[r,\vartheta]|\alpha\rangle = Z[r,\vartheta] D(\alpha) \cdot |0\rangle \xrightarrow[\alpha \to 0]{} Z[r,\vartheta] \cdot |0\rangle \tag{9}$$

The right hand side of Equation (9) given above becomes a highly non classical operator, *i.e.* in the limit that the super position of states $|\varsigma\rangle \xrightarrow[\alpha \to 0]{} Z[r,\vartheta] \cdot |0\rangle$ occurs, there is a many particle version of a "vacuum state" which has highly non classical properties. Squeezed states, for what it is worth, are thought to occur at the onset of vacuum nucleation, but what is noted for $|\varsigma\rangle \xrightarrow[\alpha \to 0]{} Z[r,\vartheta] \cdot |0\rangle$ being a super position of vacuum states, means that classical analog is extremely difficult to recover in the case of squeezing, and general non classical behavior of squeezed states. Can one, in any case, faced with $|\alpha\rangle = D(\alpha) \cdot |0\rangle \neq Z[r,\vartheta] \cdot |0\rangle$ do a better job of constructing coherent graviton states, in relic conditions, which may not involve squeezing?. Note L. Grishchuk wrote in (1989) [25] in "On the quantum state of relic gravitons", where he claimed in his abstract that "It is shown that relic gravitons created from zero-point quantum fluctuations in the course of cosmological expansion should now exist in the squeezed quantum state". The authors have determined the parameters of the squeezed state generated in a simple cosmological model which includes a stage of inflationary expansion. It is pointed out that, in principle, these parameters can be measured experimentally'. Grishchuk, *et al.*, [25] [26] [27] [28] reference their version of a cosmological perturbation h_{nlm} via the following argument. How the author works with the argument will affect what is said about the necessity, or lack of, of squeezed states in early universe cosmology [25] [26] [27] [28]. From Class. Quantum Gravity: 6 (1989), L 161-L165, where h_{nlm} has a component $\mu_{nlm}(\eta)$ obeying a parametric oscillator equation, where K is a measure of curvature which is $=\pm 1, 0$, $a(\eta)$ is a scale factor of a FRW metric, and $n = 2\pi \cdot [a(\eta)/\lambda]$ is a way to scale a wavelength, λ, with n, and with $a(\eta)$

$$h_{nlm} \equiv \frac{l_{\text{Planck}}}{a(\eta)} \cdot \mu_{nlm}(\eta) \cdot G_{nlm}(x) \tag{10}$$

$$\mu''_{nlm}(\eta) + \left(n^2 - K - \frac{a''}{a} \right) \cdot \mu_{nlm}(\eta) \equiv 0 \tag{11}$$

If $y(\eta) = \dfrac{\mu(\eta)}{a(\eta)}$ is picked, and a Schrodinger equation is made out of the Lagrangian used to formulate the above Equation (11) above, with $\hat{P}_y = \dfrac{-i}{\partial y}$, and $M = a^3(\eta)$, $\Omega = \dfrac{\sqrt{n^2 - K^2}}{a(\eta)}$, $\breve{a} = [a(\eta)/l_{\text{Planck}}] \cdot \sigma$, and $F(\eta)$ an arbitrary function. $y' = \partial y / \partial \eta$. Also, the author is working with an example which has a finite volume $V_{\text{finite}} = \int \sqrt{{}^{(3)}g} \, \mathrm{d}^3 x$.

Then the Lagrangian for deriving Equation (11) is (and leads to a Hamiltonian which can be **also** derived from the Wheeler De Witt equation), with $\varsigma = 1$ for zero point subtraction of energy [25] [26] [27] [28]

$$L = \frac{M \cdot y'^2}{2a(\eta)} - \frac{M^2 \cdot \Omega^2 a \cdot y^2}{2} + a \cdot F(\eta) \tag{12}$$

$$\frac{-1}{i} \cdot \frac{\partial \psi}{a \cdot \partial \eta} \equiv \hat{H} \psi \equiv \left[\frac{\hat{P}_y^2}{2M} + \frac{1}{2} \cdot M \Omega^2 \hat{y}^2 - \frac{1}{2} \cdot \varsigma \cdot \Omega \right] \cdot \psi \tag{13}$$

Then there are two possible solutions to the S. E. Grushchuk created in 1989 [25] [26] [27] [28], one a non squeezed state, and another squeezed state. So in general the author works with

$$y(\eta) = \frac{\mu(\eta)}{a(\eta)} \equiv C(\eta) \cdot \exp(-B \cdot y) \tag{14}$$

The **non squeezed state** has a parameter $B\big|_{\eta} \xrightarrow[\eta \to \eta_b]{} B(\eta_b) \equiv \omega_b / 2$ where η_b is an initial time, for which the Hamiltonian given in (14) in terms of raising/lowering operators is "diagonal", and then the rest of the time for $\eta \neq \eta_b$, the **squeezed state** for $y(\eta)$ is given via a parameter B for squeezing which when looking at a squeeze parameter r, for which $0 \le r \le \infty$, then (14) has, instead of $B(\eta_b) \equiv \omega_b/2$

$$B\big|_{\eta} \xrightarrow[\eta \neq \eta_b]{} B(\omega, \eta \neq \eta_b) \equiv \frac{i}{2} \cdot \frac{(\mu/a(\eta))'}{(\mu/a(\eta))} \equiv \frac{\omega}{2} \cdot \frac{\cosh r + [\exp(2i\vartheta)] \cdot \sinh r}{\cosh r - [\exp(2i\vartheta)] \cdot \sinh r} \quad (15)$$

Taking Grishchuck's formalism literally, a state for a graviton/GW is not affected by squeezing when the author is looking at an initial frequency, so that $\omega \equiv \omega_b$ initially corresponds to a non squeezed state which may have coherence, but then right afterwards, if $\omega \neq \omega_b$ which appears to occur whenever the time evolution, $\eta \neq \eta_b \Rightarrow \omega \neq \omega_b \Rightarrow B(\omega, \eta \neq \eta_b) \equiv \frac{i}{2} \cdot \frac{(\mu/a(\eta))'}{(\mu/a(\eta))} \neq \frac{\omega_b}{2}$ A reasonable research task would be to determine, whether or not $B(\omega, \eta \neq \eta_b) \neq \frac{\omega_b}{2}$ would correspond to a vacuum state being initially formed right after the point of nucleation, with $\omega \equiv \omega_b$ at time $\eta \equiv \eta_b$ with an initial cosmological time some order of magnitude of a Planck interval of time $t \approx t_{\text{Planck}} \propto 10^{-44}$ seconds.

7. Open Questions. Turbulence in Initial GW Production and How to Model It? Either Classically or Quantum Mechanically

What happens if there is a switch over from an initially uncompressed state, to one which has compression? Several things could happen. First of all, one may be able to see colliding plane wave representations of GW, *i.e.* the geometry of the colliding wave space time becomes amendable to analysis, as was presented by Vladimir Belinski, and Enric Venrauger [29] in their book on Gravitational solitons, starting on page 202. In particular, their Equation (7.60) has parameters which represent gravitational shock waves in collision, followed by trailing gravitational radiation. If one believes that relic GW processes can be largely preserved in the onset of the big bang in a "frozen" profile then the interactive region for generation of GW signals from GW shock waves in collision could account for the datum represented by Fangyu Li *et al.* [3] as far as the alleged random back ground as far as GW processes. Secondly is the issue which Bojowald [30] talked to the author about in the 12 Marcel Grossman conference, mainly what is known, and what is not know about the geometry of space time, presumably in the aftermath of the big bounce (LQG). Bojowald's [30] paper leaves the relative degree of squeezing mandated by the big bounce as a "to be solved" datum.

For the sake of comparison, furthermore, Abhay Ashtekar [31] [32] wrote a simple treatment of the Bounce causing Wheeler De Witt equation along the lines of, for $\rho_* \approx const \cdot (1/8\pi G\Delta)$ as a critical density, and Δ the eignvalue of a minimum area operator. Small values of Δ imply that gravity is a repulsive force, leading to a bounce effect.

$$\left(\frac{\dot{a}}{a}\right)^2 \equiv \frac{8\pi G}{3} \cdot \rho \cdot \left(1 - (\rho/\rho_*)\right) + H.O.T. \quad (16)$$

Furthermore, Bojowald [30] specified criteria as to how to use an updated version of Δ and $\rho_{*} \approx const \cdot (1/8\pi G\Delta)$ in his GRG manuscript on what could constitute grounds for the existence of generalized squeezed initial (graviton?) states. Bojowald [30] was referring to the existence of squeezed states, as either being necessarily, or NOT necessarily a consequence of the quantum bounce. As Bojowald wrote it up, in both his Equation (26) which has a quantum Hamiltonian $\langle \hat{V} \rangle \approx H$, with

$$\left.\frac{\mathrm{d}\langle \hat{V} \rangle}{\mathrm{d}\phi}\right|_{\phi \approx 0} \xrightarrow[\text{existence of un squeezed states} \Leftrightarrow \phi \approx 0]{} 0 \tag{17}$$

and $\hat{V}$ is a "volume" operator where the "volume" is set as V, Note also, that Bojowald has, in his initial Friedman equation, density values $\rho \equiv \frac{H_{\text{matter}}(a)}{a^{3}}$, so that when the Friedman equation is quantized, with an initial internal time given by ϕ, with ϕ becoming a more general evolution of state variable than "internal time". If so, Bojowald [30] writes, when there are squeezed states

$$\left.\frac{\mathrm{d}\langle \hat{V} \rangle}{\mathrm{d}\phi}\right|_{\phi \neq 0} \xrightarrow[\text{existence of squeezed states}]{} N(\text{value}) \neq 0 \tag{18}$$

For his Equation (26), which is incidentally when links to classical behavior break down, and when the bounce from a universe contracting goes to an expanding present universe, Bojowald also writes that if one is looking at an isotropic universe, that as the large matter "*H*" increases, that in certain cases, one observes more classical behavior, and a reduction in the strength of a quantum bounce. Bojowalds states that "Especially the role of squeezed states is highlighted. The presence of a bounce is proven for uncorrelated states, but as squeezing is a dynamical property and may change in time".

I claim that what Bojowald [30] is leading up to, is specifying a parameter space in initial conditions which one may be able to do a semi classical analysis of the sort referenced by Vladimir Belinski, and Enric Venrauger [29] in their book on Gravitational solitons, starting on page 202 of their text. As stated earlier, their Equation (7.60) has parameters which represent gravitational shock waves in collision, followed by trailing gravitational radiation. Not only that, but initial un squeezed states may be, in part represented/presentable as due to the worm hole analysis of initially introduced from a prior universe, to today's universe by the Wheeler de Witt pseudo time representation of an initial vacuum state, as has been brought up by Beckwith [8] [9].

Last, but not least, would be to also examine, from first principles, what Corda [10] raised as a distinct possibility Namely using "investigation of the transverse effect of gravitational waves (GW's) could constitute a further tool to discriminate among several relativistic theories of gravity on the ground. "*I.e.* using transverse effects as another further tool to distinguish on the foundations of what Li *et al.* [19] listed as random background for the processes in which relic

GW are generate in early space time conditions.

8. Conclusions

The author is fully aware of how unpopular his conclusions will be with respect to current string theory proponents, who have managed to move string theory from its initial Calibi Yau compact higher dimensions focus, as Giovannini [13], and others used successfully to argue for almost unlimited higher frequencies as to relic GW, to the unlimited higher dimensions specified by Randal [33], and Arkani-Hamed, *et al.* [34]… The author, also views as potentially revolutionary the implications as argued by t'Hooft, Corda, and others that Gravity is essentially classical in its origins. A datum which can be investigated by determining if Belunski and Vergaguer [29] are right about their interaction region for shock waves, as could be modeled for initial conditions, *i.e.* this modeling of Vladimir Belunski [29], and Enric Vergaguer's modeling of the collision of GW is under way right now by the author, and the results will be mapped onto possible relic GW spectra, once numerical protocol for doing so is fully developed by the author. The final pay off, of moving beyond post modern physics, and re-setting the discussion back to laboratory science, will be in investigating a supposition t'Hooft [35] [36] [37] advanced as to Quantum mechanics, which has never been satisfactorily investigated. The reconstruction of generation of GW in initial conditions may be allowing us to illustrate '*t Hooft's proposal to reconstruct quantum mechanics* as an emergent theory. It does not get any better than this, in terms of learning reality as are known. The author will in a subsequent publication, elaborate upon why early generation of GW could be the perfect template as to investigating T'Hoofs supposition in proper detail, and what that could mean with respect to physics.

Finally, there is the paper by Roy Kerr [38], as to non singularities in black hole physics, which needs to be explored as to how this fits within the scheme we are building.

Note he wrote

Quote

There is no proof that black holes contain singularities when they are generated by real physical bodies. Roger Penrose claimed sixty years ago that trapped surfaces inevitably lead to light rays of finite affine length (FALL's). Penrose and Stephen Hawking then asserted that these must end in actual singularities. When they could not prove this they decreed it to be self evident. It is shown that there are counterexamples through every point in the Kerr metric. These are asymptotic to at least one event horizon and do not end in singularities.

End of quote

The significance we claim is that we have a very similar situation as to the early universe, and that black holes, primordially, in their lack of a singularity, are similar to the situation which emerged as to Pre Planckian space-time physics. This has to be developed within the context of the GW and other parameters of the early universe model we are building on.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Becker, K., Becker, M. and Schwarz, J. (2007) String Theory and M-Theory, a Modern Introduction. Cambridge University press, New York. https://doi.org/10.1017/CBO9780511816086

[2] Giovannini, M. (2008) A Primer on the Physics of the Cosmic Microwave Background. World Press Scientific, Singapore. https://doi.org/10.1142/6730

[3] Li, F.Y., Baker Jr., R.M.L., Fang, Z.Y., Stephenson, G.V. and Chen, Z.Y. (2008) Perturbative Photon Fluxes Generated by High-Frequency Gravitational Waves and Their Physical Effects. *Regular Article—Theoretical Physics*, **56**, 407-423. https://doi.org/10.1140/epjc/s10052-008-0656-9

[4] Bojowald, M. (2008) Quantum Nature of Cosmological Bounces. *General Relativity and Gravitation*, **40**, 2659-2683. http://arxiv.org/abs/0801.4001 https://doi.org/10.1007/s10714-008-0645-1

[5] Li, F.Y., Baker, R.M.L. and Chen, Z.Y. (2006) Perturbative Photon Flux Generated by High Frequency Relic Gravitational Waves and Utilization of Them for Their Detection. http://arxiv.org/abs/gr-qc/0604109

[6] Ng, Y.J. (2008) Spacetime Foam: From Entropy and Holography to Infinite Statistics and Nonlocality. *Entropy*, **10**, 441-461. https://doi.org/10.3390/e10040441

[7] Beckwith, A.W. (2009) Entropy Growth in the Early Universe and Confirmation of Initial Big Bang Conditions (Wheeler De Witt eqn. results vs. String theory?). http://vixra.org/abs/0908.0109

[8] Beckwith, A.W. (2008) Implications for the Cosmological Landscape: Can Thermal Inputs from a Prior Universe Account for Relic Graviton Production? *AIP Conference Proceedings*, **969**, 1091-1102. https://doi.org/10.1063/1.2844947

[9] Beckwith, A.W. (2009) Relic High Frequency Gravitational waves from the Big Bang, and How to Detect Them. *AIP Conference Proceedings*, **1103**, 571-581. http://arxiv.org/abs/0809.1454 https://doi.org/10.1063/1.3115567

[10] Corda, C. (2008) Primordial Production of Massive Relic Gravitational Waves from a Weak Modification of General Relativity. *Astroparticle Physics*, **30**, 209-215. http://arxiv.org/abs/0812.0483 https://doi.org/10.1016/j.astropartphys.2008.09.003

[11] Beckwith, A.W. (2007) Instanton Formation of Vacuum Energy via the Reissner-Nordstrom Geometry of a Wormhole Bridge between a Prior to Our Present Universe. arXiv: 0710.3788.

[12] Glinka, L. (2007) Quantum Information from Graviton-Matter Gas. *Sigma*, **3**, Article 087. https://doi.org/10.3842/SIGMA.2007.087

[13] Giovannini, M., Gasperini, M. and Veneziano, G. (1995) Primordial Magnetic Fields from String Cosmology. *Physical Review Letters*, **75**, 3796-3799. https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.75.3796 https://doi.org/10.1103/PhysRevLett.75.3796

[14] Kolb, E. and Turner, S. (1994) The Early Universe. Westview Press, Chicago.

[15] de Vega, H. (2009) Inflation in the Standard Model of the Universe. http://isapp2009.mib.infn.it/media/lectures/devega.pdf

[16] Donoghue, J.F. (1995) Introduction to the Effective Field Theory Description of Gravity. http://arxiv.org/abs/gr-qc/9512024

[17] Lloyd, S. (2002) Computational Capacity of the Universe. *Physical Review Letter*, **88**, Article ID: 237901. https://doi.org/10.1103/PhysRevLett.88.237901

[18] Glauber, R. (1963) Coherent and Incoherent States of the Radiation Field. *Physical Review Journals Archive*, **131**, 2766-2788. https://doi.org/10.1103/PhysRev.131.2766

[19] Woods, L. (2012) Diffraction from Embedded Reflectors in LiBaker HFGW Detector. *Physics Procedia*, **38**, 66-76. https://doi.org/10.1016/j.phpro.2012.08.012

[20] Veneziano, G. (1993) Classical and Quantum Gravity from String Theory. In: Bento, M.C., Bertolami, O., Mourao, J.M. and Picken, R.F., Eds., *Classical and Quantum Gravity*, World Press Scientific, Singapore, 134-180.

[21] Kieffer, K. (2008) Quantum Gravity. 3rd Edition, Oxford University Press, Oxford.

[22] Mohaupt, T. (2003) Introduction to String Theory. *Lecture Notes in Physics*, **631**, 173-251. https://arxiv.org/abs/hep-th/0207249 https://doi.org/10.1007/978-3-540-45230-0_5

[23] Ford, L.H. (1994) Gravitons and Lightcone Fluctuations. http://arxiv.org/abs/gr-qc/9410047

[24] Venkataratnam, K. and Suresh, P. (2008) Density Fluctuations in the Oscillatory Phase of Nonclassical Inflaton in FRW Universe. *International Journal of Modern Physics D*, **17**, 1991-2005. http://arxiv.org/abs/0712.3129 https://doi.org/10.1142/S0218271808013662

[25] Grishchuk, L. and Sidorov, Y. (1989) On the Quantum State of Relic Gravitons. *Classical and Quantum Gravity*, **6**, L161. https://doi.org/10.1088/0264-9381/6/9/002

[26] Grishchuk, L.P. (1993) Quantum Effects in Cosmology. *Classical and Quantum Gravity*, **10**, 2449-2478. http://arxiv.org/abs/gr-qc/9302036 https://doi.org/10.1088/0264-9381/10/12/006

[27] Grishchuk, L. (1998) The Detectability of Relic (Squeezed) Gravitational Waves by Laser Interferometers. http://arxiv.org/abs/gr-qc/9810055

[28] Grishchuk, L. (2008) Discovering Relic Gravitational Waves in Cosmic Microwave Background Radiation. http://arxiv.org/abs/0707.3319

[29] Belunski, V. and Verdaguer, E. (2001) Gravitational Solitons. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9780511535253

[30] Bojowald, M. (2008) Loop Quantum Cosmology. *Living Rev. Relativity*, **11**, 4. http://www.livingreviews.org/lrr-2008-4 https://doi.org/10.12942/lrr-2008-4

[31] Ashtekar, A. and Bojowald, M. (2006) Quantum Geometry and the Schwarzschild Singularity. *Classical and Quantum Gravity*, **23**, 391-411. https://arxiv.org/abs/gr-qc/0509075 https://doi.org/10.1088/0264-9381/23/2/008

[32] Ashtekar, A. and Bojowald, M. (2006) Quantum Geometry and the Schwarzschild Singularity. *Classical and Quantum Gravity*, **23**, 391-411. https://arxiv.org/abs/gr-qc/0509075 https://doi.org/10.1088/0264-9381/23/2/008

[33] Randall, L. (2002) Extra Dimensions and Warped Geometries. *Science*, **296**, 1422-1427. https://doi.org/10.1126/science.1072567

[34] Arkani-Hamed, N., Kaplan, D., Murayama, H. and Nomura, Y. (2001) Viable Ultraviolet-Insensitive Supersymmetry Breaking. *Journal of High Energy Physics*, **102**, 41. http://arxiv.org/abs/hep-ph/0012103 https://doi.org/10.1088/1126-6708/2001/02/041

[35] T'Hooft, G. (1993) Dimensional Reduction in Quantum Gravity. http://arxiv.org/abs/gr-qc/9310026

[36] T'Hooft, G. (2008) A Locally Finite Model for Gravity. *Foundations of Physics*, **38**, 733-757. http://arxiv.org/abs/0804.0328 https://doi.org/10.1007/s10701-008-9231-3

[37] T'Hooft, G. (2006) The Mathematical Basis for Deterministic Quantum Mechanics. http://arxiv.org/abs/quant-ph/0604008

[38] Kerr, R.P. (2023) Do Black Holes Have Singularities? https://arxiv.org/abs/2312.00841

Nomenclature

$M_P \approx 2.176 \times 10^{-8}\,[\mathrm{kg}]$

$t_P = \sqrt{\hbar \cdot G / c^5}$

$G = 6.67300 \times 10^{-11}\ \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$

$g = \det(g_{ab})$

$r_s = 2Gm/c^2$

$\tilde{\bar{R}}$ – Ricci scalar

$\lambda_C = 2 \cdot \pi \cdot \hbar / m \cdot c$