Relic High Frequency Gravitational waves from the Big Bang and How to Detect Them

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Abstract. This paper shows how entropy generation from numerical density calculations of relic gravitons can be measured via a high-frequency gravity wave (HFGW) detector, and suggests the implications this has for the physics of early-universe phase transitions. This paper indicates the role of Ng's revised statistics in gravitational wave physics detection and the application of Baumann *et al*. (2007) formalism of reduction of rank-two tensorial contributions to density wave physics, using the HFGW approximation directly at the beginning as well as Li's treatment of energy density explicitly.

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1. INTRODUCTION

At the June 2008 Dark Side meeting in Cairo, Egypt, Ng (2007) presented cogent arguments that entropy density is proportional to the number of dark matter particles per unit volume, which could also apply to gravitons. Ng's central idea—that entropy and numerical production of "particles" can be applied to density of created gravitons per unit volume—is based on an argument Weinberg (1972) used to calculate the number of gravitons per unit volume in a frequency range between $\omega, \omega + d\omega$. Weinberg's conceptualization of the creation of relic gravitons permits the development of a model entropy growth, starting from a very low level at the beginning of the universe to a much higher level right after the onset of the big bang, where the upper limit for the frequency used in deriving graviton production per unit volume was given by Grishchuk (2007) as $10^{10} Hz$, with some variance. This new model:

1) Assumes a temperature of $T \sim 10^{32} K$, based on Weinberg's (1972) statement that $T \sim 10^{32} K$ is the threshold for when quantum gravity dominates classical gravity,
2) Uses high-frequency gravitational waves (HFGW) explicitly of a scalar field reduction of the rank-two tensor arguments, based on the Baumann *et al*. (2007) use of quantum gravity operators to reduce a rank-two argument to a scalar field and then transform the entire object to a momentum space to get a scalar value for the variation of g_{uv} due to gravity in momentum space, and
3) Uses Fourier analysis to extract relic gravitational wave signatures of the big bang, which is related to CMBR physics.

Ng (2007) established a one-to-one relationship between change in entropy and change in the number of particles. Equating entropy change and graviton particle production suggests that the a sutiably configured GW detector (Li *et al*., 2008) could be used to get an explicit big bang signature from HFGW data sets.

The GW detector (Li *et al.*, 2008) uses a static magnetic field that varies under the impact of HFGWs for background detection of gravitational waves, and a fractal membrane to detect HFGW electromagnetic signatures. Researchers can use these signatures to confirm the existence of HFGWs by assuming that spin entropy density in the Li-Baker detector affects magnetic field spin and magnetism, per Rothman and Boughn (2006). Measurement of gravitons and gravitational waves is a way to establish an association between relic gravitational waves, gravitons, and entropy. This is a follow-up to a suggestion made by Yeo, *et al.* (2006) for how variation of spin entropy in a detector could dramatically enhance the sensitivity of existing HFGW detectors.

The benefit of examining spin entropy density is in showing the existence of gravitons as a physically measurable datum in General Relativity, as well as the interrelationship of gravitons with HFGW from experimental data sets. Rothman and Boughn (2006) have written that the present set of existing detector systems with pre-Li-Baker detector technology (Li *et al.*, 2008) is insufficient to accomplish meaningful detection of gravitons, suggesting that the Li-Baker detector may overcome the limits described by Rothman and Boughn: that with conventional detectors, one would need a detector mass about the size of Jupiter to detect a single graviton.

2. REVIEWING JACK NG'S ARGUMENTS: HOW ENTROPY IS PROPORTIONAL TO A NUMERICAL DENSITY VALUE

The fact that in both the dark matter and in the relic graviton production cases, entropy has similar quantum Boltzmann statistics will be the starting point for a derivation of the production of relic gravitons, linked to falsifiable experimental measurements. Ng **(**2007) used the following approximation for temperature and its variation with respect to a spatial parameter, starting with temperature $T \approx R_H^{-1}$, where R_H can be thought of as a spatial representation of a region of space in which one can acquire statistics for the particles in question. Assume that the volume of space to be analyzed is of the form $V \approx R_H^3$. Then look at a preliminary numerical factor. Here the proportionality argument of $N \sim (R_H/l_P)^2$ is made, where l_P is the Planck's length $\left(\sim 10^{-35} cm\right)$ and a "wavelength" parameter $\lambda \approx T^{-1}$ is also specified. That is, the value of $\lambda \approx T^{-1}$ and of R_H are approximately within an order of magnitude of each other. Ng **(**2007) changes conventional statistics by outlining how to get $S \approx N$, which with additional arguments is defined to be $S \approx < n >$, the numerical density of a species of particles. Ng begins with a partition function

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

which according to Ng, leads to a limiting value of entropy of

$$S \approx N \cdot \left(\log\left[V/N\lambda^3\right] + 5/2\right), \tag{2}$$

but with $V \approx R_H^3 \approx \lambda^3$. If *N* is greater than one, entropy in equation (2) has a negative value. For a quantum Boltzmann statistic calculation to obtain entropy, one does not want entropy with a negative value. The positive valued nature of entropy for physical systems calculated by Boltzmann statistics is a convention of statistical physics. Now this is where Ng introduces the removing of the $N!$ term in equation (1). Inside the log expression, the expression of *N* in equation (2) is removed. This is a way to obtain what Ng refers to as Quantum Boltzmann statistics, where for a sufficiently large *N*,

$$S \approx N . \tag{3}$$

The supposition here is that the value of *N* is proportional to the numerical graviton density $\langle n \rangle$. It is noted that equation (3) gives credence not only to Baker *et al*. (2008) being applied to gravitons, but the same effort as done by Li *et al.* (2007) and as proposed (Beckwith 2008) in a symposium at Chongquing University in October 2008, for astrophysical applications of gravitational waves. Sensitive applications of equation (3) will help confirm the breakthrough physics of how gravitons disturb uniform magnetic fields within a HFGW detector, as remarked by Li *et al*. (2006).]

3. WEINBERG'S 1972 NUMERICAL ESTIMATE: THE NUMBER OF GRAVITONS PER FREQUENCY RANGE

Assuming that $\bar{k} = 1.38 \times 10^{-16} erg / {}^0K$, where ${}^0K$ denotes Kelvin temperatures and where gravitons have two independent polarization states, the number of gravitons per unit volume with frequencies between ω and $\omega + d\omega$ is given by Weinberg (1972) as

$$n(\omega)\, d\omega = \frac{\omega^2 d\omega}{\pi^2} \cdot \left[\exp\left(\frac{2 \cdot \pi \cdot \hbar \cdot \omega}{\bar{k}T} \right) - 1 \right]^{-1} \tag{4}$$

The hypothesis presented here is that input thermal energy (from the prior universe) inputted into an initial cavity/region (dominated by an initially configured low temperature axion domain wall) would be thermally excited to reach the regime of temperature excitation. This would permit an order of magnitude drop of axion density ρ_a from an initial temperature $T_{dS}\big|_{t \le t_P} \sim H_0 \approx 10^{-33} eV$.[Per Beckwith (2008), this calculation assumes that $E_{graviton} \equiv \hbar \omega_{graviton} \propto (volume) \cdot \left[energy\ density \equiv t_0^0 \right]$, where the energy density term is from GR formulas.

4. GIVING FREQUENCY/ ENERGY VALUE INPUTS TO GRAVITONS FROM GR ENERGY DENSITY EQUATIONS

The Li *et al*. (2008) derivation/formula for energy density of gravitational waves is

$$t_0^0 \equiv \frac{c^4 k^2}{4\pi G a^3} \cdot \left[h_\oplus^2 + h_\otimes^2 \right], \tag{5}$$

where $a \approx a_{initial} \cdot \exp(H_{initial} \tau)$, $H_{initial}$ is the initial value of the Hubble expansion parameter, and τ is a conformal time value. This value for an exponentially expanding scale factor will be crucially important in what is calculated later.

4a. The polarization values of relic gravitational waves

Let us now consider how to get appropriate $h_\oplus, h_\otimes$ values by using Baumann *et al*. (2007) very complete treatment of rank-two tensorial contributions to the evolution of the gravitational wave contributions to entropy. This will be helped by having HFGW as a template to simplify a search for appropriate h_{ij} behavior, which will be simplified after the reduction of h_{ij} to a scalar field value. The main centerpiece of the derivation is to take into account a right-hand-side contribution of stress and strain to the conformal time evolution of h_{ij}, which in a scalar Baumann, *et al*. (2007) field contribution reduction of complexity, and leads to the fast Fourier transform (FFT) $\Im h_{ij} \equiv \hat{h}$ with an equation in conformal time τ that can be written as

$$\hat{h} \equiv \frac{A_1(k)}{a(\tau)} \exp\left(i \left[\vec{k} \cdot \vec{x} - k\tau \right] \right) + \frac{A_2(k)}{a(\tau)} \exp\left(i \left[\vec{k} \cdot \vec{x} + k\tau \right] \right) \tag{6}$$

As Li *et al*. (2008) writes, the expression for $\hat{h}$ in equation (6) is in response to a metric is written as

$$g_{\mu\nu} \equiv \begin{pmatrix} -a^2 & 0 & 0 & 0 \\ 0 & a^2(1+h_\oplus) & a^2 h_\otimes & 0 \\ 0 & a^2 h_\otimes & a^2(1-h_\oplus) & 0 \\ 0 & 0 & 0 & a^2 \end{pmatrix} \qquad (7)$$

Changes in the treatment of equation (6) have to be made in order to consider a scalar expansion at the onset of the big bang, which would entail looking at stress and strain contributions to the evolution of the scalar field contribution to gravitational radiation, starting at the onset of the big bang. This treatment of space-time geodesics is modified after stress and strain processes are added to the evolution of the gravitational waves. Addition of stress and strain as presented by Baumann *et al*. (2007) leads to the following evolution equation of space-time deformations and gravitational wave evolution, where pressure p is a constant and T^i_j is a stress term. Furthermore, $k^2 \propto$ energy and $|a''/a| \propto$ potential energy so that

$$\hat{h}'' + 2\frac{a'}{a}\cdot\hat{h}' + k^2\hat{h} = 16\pi\cdot G\cdot a^2\cdot\left[\Pi_k(\tau) = \Im\left(T^{\ i}_{\ j} - p\delta^i_j\right)\right]. \qquad (8)$$

Numerous Bessel and Hankel equations, referenced in Arfken (1985), show how combined solutions of Bessel and/or Hankel equations solve the homogeneous part of equation (8) above, provided that $\Pi_k(\tau) = 0$. If one wishes to take into account stress and strain forces associated with the onset of the big bang, one would have to look at particular and general solutions that use combinations of equations (8) and (9). The solution to equation (8) is based on what Baumann *et al*. (2007) developed in 2007 to deal with relic inflationary contributions to gravitational waves. The particular solution of equation (8) above will involve a Greens function treatment of equation (9), as described below, as an integral solution for h.

Typically, as seen in Arfken (1985), this means putting a delta function on the right-hand side of equation (8), and using the resulting solution of equation (8) as modified, times the right-hand side of equation (8) as the integrand for a particular solution, then integrating over conformal time τ. In this situation, the very convenient $a(\tau)\cdot\hat{h} = \mu(k)$ is taken advantage of to use the Greens function solution to equation (9) with a delta function on the right-hand-side of equation (9) to help construct a particular solution to equation (8). This then will be part of how a particular solution for gravitational wave amplitude evolves in space-time.

5. HFGW in Relic Inflationary Conditions

Now the homogeneous and particular solution for equation (8) above is looked at with comments on HFGW modifications that simplify matters enormously. This will be pertinent to Li, *et al*. (2008) and what will be discussed later in this paper about aHFGW detector system, with its uniform magnetic field impinged upon by incident HFGW. This leads to a experimentally falsifiable claim that before the onset of the CMBR formation 280,000 to 300,000 years after the big bang, data sets are signatures of phase transitions that modeled appropriately with the following formalism.

After making the substitution of $a(\tau)\cdot\hat{h}=\mu(k)$, equation (8) leads to a non-homogeneous perturbed Schrodinger- like equation, which can be written as

$$\mu''+\left(k^2-\frac{a''}{a}\right)\mu=a\cdot\left[16\pi\cdot a^2\cdot\Pi_k\left(\tau\right)\right], \tag{9}$$

where the particular solution to equation (8) becomes

$$\hat{h}_{Particular}=\frac{1}{a(\tau)}\cdot\int d\tilde{\tau}\cdot g_k\left(\tau,\tilde{\tau}\right)\cdot\left(16\pi\cdot G\cdot\Pi_k\left(\tilde{\tau}\right)\right) \tag{10}$$

The kernel in equation (10), $g_k(\tau,\tilde{\tau})$, obeys the following equation if $a''/a<<k^2$, so for

$$g_k''+\left(k^2-\frac{a''}{a}\right)\cdot g_k\equiv\delta\left(\tau-\tilde{\tau}\right), \tag{11}$$

where

$$g_k(\tau,\tilde{\tau})=\frac{1}{k}\left[\sin(k\tau)\cdot\cos(k\tilde{\tau})-\sin(k\tilde{\tau})\cdot\cos(k\tau)\right]. \tag{12}$$

Given the above, a particular solution may be written as

$$\hat{h}_{Particular}=\frac{1}{a(\tau)k}\cdot\int d\tilde{\tau}\cdot[\sin(k\tau)\cos(k\tilde{\tau})-\sin(k\tilde{\tau})\cos(k\tau)]\cdot\left(16\pi\cdot G\cdot\Pi_k\left(\tilde{\tau}\right)\right) \tag{13}$$

Details for the $16\pi\cdot G\cdot\Pi_k(\tilde{\tau})$ part of this particular solution will be presented in the next section; for now, the general solution is presented. The main dynamics of the $16\pi\cdot G\cdot\Pi_k(\tilde{\tau})$ terms are that they are in part linked to quantum fluctuation. That is, the stress and strain are initially nucleated from a vacuum template of space-time itself in the beginning of a new universe, allowing for the following homogeneous part of evolution equation (8), with $\Pi_k\left(\tau\right)=0$, where the homogeneous solution to equation (8) is based on Izquierdo (2006)

$$\hat{h}''+2\frac{a'}{a}\cdot\hat{h}'+k^2\hat{h}=0. \tag{14}$$

In the initial phases of nucleation of a new universe, equation (15) can be simplified as

$$\hat{h}''+2H_{initial}\cdot\hat{h}'+k^2\hat{h}=0. \tag{15}$$

Traditional treatments of both equations (14) and (15) make use of a dynamical, changing value of a'/a, in many cases leading to Bessel/Hankel equation solutions. By setting $a'/a\sim H_{Initial}$, to obtain

$$\hat{h}_{Total}=\hat{h}_{Initial-Value}\cdot\left[\exp\left(-H_{Initial}\tau\right)\right]\cdot\cos\left(k\tau+c_1\right)+\hat{h}_{Particular} \tag{16}$$

implies that in later times the dynamics are largely dominated by the particular, specialized solution.

6. Stress and strain contributions to space time due to early universe production of HFGW

The following analysis will deal with the HFGW contribution to forming the $16\pi \cdot G \cdot \Pi_k(\tilde{\tau})$ stress and strain contribution, using much of what Baumann *et al*. (2007) set for the simplest case of how to evaluate $16\pi \cdot G \cdot \Pi_k(\tilde{\tau})$. This takes into account a simplified treatment of the Bardeen and Wagoner (1971) potential for times $\tau < \tau_{Threshold}$; effectively confining $\tau < \tau_{Threshold}$ to within with two orders of magnitude of the Planck's time interval after big bang nucleation of the present universe.

This means working with the following template for the stress-strain-vacuum nucleation problem

$$\left(16\pi \cdot G \cdot \Pi_k(\tilde{\tau})\right) \equiv S_k(source) = \int d^3\tilde{k} \cdot e\left(k,\tilde{k}\right) \cdot f\left(k,\tilde{k},\tau\right) \cdot \psi_{k-\tilde{k}} \cdot \psi_{\tilde{k}} \tag{17}$$

where $\psi_{\tilde{k}}$ is a quantum fluctuation (offering a simplified model) and the term $e\left(k,\tilde{k}\right)$ is equal to $\tilde{k}^2 \cdot \left(1 - \left(\vec{k} \cdot \vec{\tilde{k}}\right) \big/ k\tilde{k}\right)$. The main result of this section will be to present $f\left(k,\tilde{k},\tau\right)$, where $w \propto 1/3$ is used to obtain

$$f\left(k,\tilde{k},\tau\right) \equiv \frac{4}{3\cdot(1+w)} \left\{ \begin{array}{l} \dfrac{2\cdot(5+3w)}{\left(1+\left|k-\tilde{k}\right|^2 \tau^2\right)} \cdot \dfrac{1}{\left(1+\left|\tilde{k}\right|^2 \tau^2\right)} \\ +4\cdot\left[\dfrac{2\tau}{1+\left|k-\tilde{k}\right|^2 \tau^2} + \tau^2 \cdot \dfrac{\partial}{\partial\tau}\left(\dfrac{1}{1+\left|k-\tilde{k}\right|^2 \tau^2}\right)\right] \cdot \dfrac{\partial}{\partial\tau}\left(\dfrac{1}{1+\left|\tilde{k}\right|^2 \tau^2}\right) \end{array} \right\} \tag{18}$$

Note that this uses the Bardeen and Wagoner (1971) potential in early times, which is

$$\Phi = \frac{1}{1+k^2\tau^2} \tag{19}$$

[Note that the derived quantity of $\hat{h}$, which is a FFT, with quantum raising and lowering operator considerations added, will require an inverse FFT used in the $h_{\oplus}^2 + h_{\otimes}^2$ expression of t_0^0]

7. A Simplified Quantum Fluctuation Model

Here, the ideas of Mukhanov and Wintizki (2007) are used, where they give a quantum fluctuation in k space along the lines of:

$$\psi_k'' + (k^2 + m^2)\psi_k \cong 0 \tag{20}$$

In the limit of low mass, this will lead to

$$\psi_k \sim \exp\left(ik\tau\right) \tag{21}$$

The assumption is made that with additional data acquisition, the nucleation quantum fluctuation formula as outlined in equation (21) will be given considerably more structure.

8. TIES TO THE HFGW DETECTOR

With reference to Beckwith (2008), a power law relationship, first presented by Fontana (2005) using Park's (1955) earlier derivation, is presented as

$$P(power) = 2 \cdot \frac{m_{graviton}{}^{2} \cdot \widehat{L}^{4} \cdot \omega_{net}{}^{6}}{45 \cdot \left(c^{5} \cdot G\right)} \tag{22}$$

With the effective energy $E_{eff} \equiv \langle n(\omega) \rangle \cdot \omega \equiv \omega_{eff}$, where graviton production is connected to equation (22), with $\omega_{eff} \approx \omega_{net}$ **or** $\omega_{net} \to \omega_{eff}$.

This expression in power should be compared with the one presented by Giovannini (2008), averaging the energy-momentum pseudo tensor to get his version of a gravitational power energy density expression

$$\overline{\rho}_{GW}^{(3)}\left(\tau, \tau_{0}\right) \cong \frac{27}{256 \cdot \pi^{2}} H^{2} \cdot \left(\frac{H}{M}\right)^{2} \cdot \left[1 + \vartheta \cdot \left(\frac{H^{4}}{M^{4}}\right)\right] \tag{23}$$

This led Giovannini to state that "should the mass scale be picked such that $M \sim m_{Planck} >> m_{graviton}$, and if the above formula were true, there are doubts that there could be inflation."

It is clear that gravitational wave density is faint, even if one makes the approximation that $H \equiv \dot{a}/a \cong m\phi/\sqrt{6}$ as stated by Linde (2008). So $H \equiv \dot{a}/a \cong m\phi/\sqrt{6}$ and $\dot{\phi} = -m\sqrt{2/3}$ makes it appropriate to use different procedures to come up with relic gravitational wave detection schemes to get quantifiable experimental measurements of relic gravitational waves.

If one makes use of the present day gravitational radiation as $M = V^{1/4}$ (Kofman, 2008), the energy scale with potential *V* and frequency

$$f \cong \frac{(M = V^{1/4})}{10^{7} GeV} Hz \,, \tag{24}$$

implies that $f \sim 10^{10} Hz$. However, using equation (24) assumes that the temperature of thermally induced vacuum energy is rising to a maximum value $5T^{*} \approx 10^{32}\ {}^{0}K$, which is a huge energy flux.

Beckwith (2008) asserted that midway during the thermal/vacuum energy transfer from a prior to the present universe, a relic graviton burst would have occurred. As shown in Table 1, this is consistent with a wormhole introduction of vacuum energy from a prior universe to the present, with a thermal buildup from near-zero vacuum energy values. The threshold burst is then consistent with a buildup of temperature from a prior universe, which introduces a relic graviton energy burst.

TABLE 1. Graviton burst

Numerical values of graviton production	Temp	Scaled Power values
$N1 = 1.794 \times 10^{-6}$	T^{*}	0
$N2 = 1.133 \times 10^{-4}$	$2T^{*}$	0
$N3 = 7.872 \times 10^{21}$	$3T^{*}$	1.058×10^{16}
$N4 = 3.612 \times 10^{16}$	$4T^{*}$	~ 1
$N5 = 4.205 \times 10^{-3}$	$5T^{*}$	0

By way of explanation (Beckwith, 2008), the above table assumes a rapid buildup of temperature resulting from energy-matter transfer from a prior universe. The Wheeler-De Witt wormhole equation, as given by Crowell (2005), contains a pseudo time component. The wormhole model of energy transfer uses Crowell's treatment of the Wheeler-De Witt equation to model a bridge from a prior universe to our present universe. At the time the temperature reaches a maximum value of $5T^{*}$ (10^{32} degrees Kelvin), a graviton burst has already happened within 10^{-35} seconds, and the frequency has gone up to 10^{10} Hz, as given by

$$\Omega_{gw}(\nu) = \frac{\pi^2}{3} h^2(\nu) \left(\frac{\nu}{\nu_H} \right)^2 \tag{25}$$

in Grishchuk (2007) and charted in Figure 1.

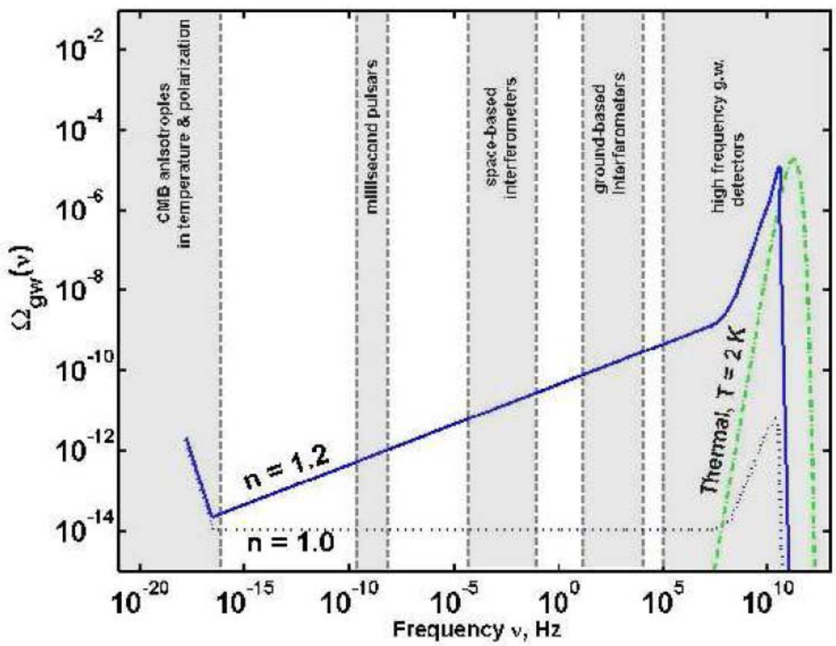

FIGURE 1. Where HFGWs come from: Grishchuk (2007) found the maximum energy density (at a peak frequency) of relic gravitational waves.

9. **Comparing results of numerical production**

Smoot (2007) alluded to the following information theory regarding the number of information bits transferred between a prior and present universe:

1) Holographic principle allowed states in the evolution/development of the Universe - 10^{120}
2) Initially available states given to us to work with at the onset of the inflationary era- 10^{10}
3) Observable bits of information present due to quantum/statistical fluctuations - 10^{8}

The relationship of bits to actual entropy, per Lloyd (2002), is that 10^{120} bits correspond to an entropy reading of 10^{90}. Arguments by Carroll (2005) suggest that black holes in the center of galaxies have entropy readings of 10^{88}, whereas the jump in entropy from about 10^{8} to 10^{90} is due to the jump in $< n >$, where $< n > \sim \Delta S_{graviton-production} \propto 10^{21}$.

In a meeting in Bad Honnef in April 2008, brane theorists suggested that the huge entropy reading of black holes in the center of galaxies is excusable, since most of the purported entropy would be hidden by the event horizon of black holes. From this and discussions with others, it is apparent that the event horizon of a black hole is equivalent to the escape velocity of a black hole, trapping huge amounts of information/entropy, since the escape velocity of a black hole is greater than the speed of light.

However, to measure entropy requires an entropy datum that can be measured. By definition, the black hole trapping of much of entropy in the universe leads to non-measurable data. Furthermore, it is assumed that the increase in entropy due to identification of a change of a relic graviton particle $< n > \sim \Delta S_{graviton-production} \propto 10^{21}$ is within the ability of the Li- Baker HFGW detector (Li *et al.*, 2008) to obtain data sets.

Identifying this relic graviton burst would allow for understanding how entropy increased in the first place and would permit astrophysicists to model different phase transitions in the problem of how the universe traversed through the "graceful exit problem" in inflationary cosmology. Gasperini *et al*. (1996) modeled graceful exit from inflation in terms of the Wheeler-De Witt equation and phase transitions. So far, little new progress has been made in getting the data sets needed to ascertain if their suggestion is true, but the Li-Baker detector should be able to identify falsifiable data collection procedures to confirm or falsify Gaperini's suggestion of graceful exit from inflation.

10. CONTRIBUTION OF NEW GW DETECTOR

According to Li et al. (2008), the GW detector (Li, *et al*., 2008) is designed measure the interaction of HFGWs with a static magnetic field $\hat{B}_y^{(0)}$, allowing researchers to get data on relic HFGWs created from relic big bang conditions. . The electric and magnetic fields are generated by the HFGWs which, when $A_\otimes \approx A_\oplus \approx A(k_g)/a(t)$, and $\omega_g \le 10^{10}\,Hz$ give the following values of electric and magnetic fields:

$$\begin{aligned}
\tilde{E}_x^1 &= \frac{i}{2} A_\oplus \hat{B}_y^{(0)} k_g c \cdot (z + l_1) \exp\left[i(k_g z - \omega_g t) \right] + \frac{1}{4} A_\oplus \hat{B}_y^{(0)} c \exp\left[i\left(k_g z + \omega_g t\right) \right] \\
\tilde{B}_y^{(1)} &= \frac{i}{2} A_\oplus \hat{B}_y^{(0)} k_g \left(z + l_1\right) \exp\left[i\left(k_g z - \omega_g t\right) \right] - \frac{1}{4} A_\oplus \hat{B}_y^{(0)} \exp\left[i\left(k_g z + \omega_g t\right) \right] \\
\tilde{E}_y^{(1)} &= -\frac{1}{2} A_\otimes \hat{B}_y^{(0)} k_g c \cdot \left(z + l_1\right) \exp\left[i\left(k_g z - \omega_g t\right) \right] + \frac{i}{4} A_\otimes \hat{B}_y^{(0)} \exp\left[i\left(k_g z + \omega_g t\right) \right] \\
\tilde{B}_z^{(1)} &= \frac{1}{2} A_\otimes \hat{B}_y^{(0)} k_g \left(z + l_1\right) \exp\left[i\left(k_g z - \omega_g t\right) \right] + \frac{i}{4} A_\otimes \hat{B}_y^{(0)} \exp\left[i\left(k_g z + \omega_g t\right) \right]
\end{aligned} \tag{26}$$

Doing a measurement of the above electric and magnetic fields as stated in equation (26) will lead to detection of relic HFGWs, provided a frequency value of $\omega_g \le 10^{10}\,Hz$ is a base line for measurement in the GW detector in hopefully soon to be available data sets. Li *et al.*, (2008) numerically simulated incident relic graviton flux detected by the GW detector, with a value of $N_g \cong 2.89 \times 10^{14}/\sec$ at a detector site. Beckwith (2008) has also created a model that simulates graviton flux, for all gravitons produced by the big bang, of $< n >_g \sim 7.872 \times 10^{+21}/\sec$

`10a. Quantum Entanglement

Based on the same numerical simulation done by Dr. Li and reported in , Li *et al*., (2008), Dr. Li made a prediction (see equation 27) about the number of HFGW/ gravitons produced by the big bang, as compared to the general number of HFGW/ gravitons which the Li- Baker detector can access at the site of the detector. The difference in the numerator and denominator of equation (27) makes the case for the use of quantum entanglement detectors.There is a gap , i.e. a difference in the number of HFGW gravitons that are detectable by the Li-Baker detector (for all time from the big bang up to the present) and those relic HFGW gravitons from the onset of the big bang. The difference between gravitons producted at the onset of the big bang and those which are generally accessible for all times , from the big bang to the present is given in equation (27) below. The ratio of 10^{-2} appearing in the square root of equation (27) means that one out of an incoming HFGW gravitons detected by a GW detector would be relic in origin—directly due to the big bang—whereas the other 99 gravitons are due to astrophysical processes occurring *after* the big bang. The significance of the 8.76×10^{-2} value in equation (27) below in Li, et al (2008) is that this number refers to the ratio of the strength of the amplitude of the different gravitational wave contributions. I.e. the amplitude of the gravitational waves from the big bang are $\sim 10^{-1}$ weaker at the siter of a GW detector than general HFGW detected at the detector itself. What Li refers to as the strength, overall magnitude, of a PPF is the square root of numerical graviton flux, $\sqrt{N_g}$. So equation (27) refers to the overall magnitude, amplitude difference in value in the process of graviton production in the origins of the universe, to what is seen today.

$$\sqrt{\frac{N_{g-relic-GW}}{N_{g-plane-GW}}} \equiv \sqrt{\frac{2.89\times10^{14}}{3.77\times10^{16}}} \approx 8.76\times10^{-2} \qquad (27)$$

This rarity of relic big bang gravitons means that for a next-generation refinement of sensitivity, the Li-Baker detector would need to use a variant of quantum entanglement to obtain a better data set of relic HFGW originating in the big bang. Yeo *et al.* (2006) presented calculations showing that a passing gravitational wave could influence the spin entropy and spin negativity of a system of *N* massive spin-(1/2) particles, in a way that is characteristic of the radiation. This implies entanglement, as Yeo *et al*. (2006) suggested. This suggests that what is now needed is to develop an actual entanglement entropy-based device that could complement and give additional refinement to the prediction given by equation (27). That would then help to analyze HFGWs to determine relic $\omega_{gravitation}$ values.

11. CONCLUSIONS

This present article brings up a very subtle point about entanglement which the author will allude to. Giovannini (2008) makes reference to a calculation which he performed in 1993 which suggests that all entropy of the universe from the origins of the big bang, to the present day is due to graviton production. The ratio of the amplitude of HFGW as given in equation (27) with a value of $\sim 10^{-1}$ between the amplitudes of HFGW produced from the big bang , to those obtained at all times as collected at the GW detector is really due to entanglement indicating a change in spatial geometry of the universe as it is embedded in a higher dimensional structure. I.e. the geometry changed over time If higher dimensional embedding were obtainable, the amplitude value of equation (27) would go to unity, instead of being. $\sim 10^{-1}$ Seen from the perspective of entropy and graviton production, in higher dimensions, if a physical scientist and/ or engineer had a sufficient dimensional reference point to look at the universe, the ratio of amplitude of gravitational waves at the origin of the big bang, and those as seen up to the present would be the same, not differentiated as indicated in the reference point assumed in setting up equation(27) . Entanglement is really a measurement of dimensional warping of space, a point which the author will clarify in a future article.

Entanglement indicating an almost instantaneous transfer of information in three dimensional space, can be seen as representing in higher dimensional geometry that points which in three space are far apart are in fact neighbors, and actually close together in higher dimensions. If this rule of thumb is applied to with respect to graviton production, it means that physical scientists are studying the very origins of space time nucleation , and not just a measurement of HFGW in a new GW detector.

In this paper, a linkage is established between how to get the FFT of a second-order tensorial contribution of HFGWs and relic HFGWs from the time of the big bang. As noted in the discussion about equation (27), there are significant difficulties in separating out relic HFGW inputs from the big bang from HFGWs that a relic GW detector would get from HFGWs for all times in the universe's evolution from the big bang. This paper also suggests explanations for the relationship between HFGWs, as detected by the HFGW detector, and gravitons as "particles," which is difficult, as noted by Rothman and Boughn (2006).

The key motivations of this paper were to aid in making an experimental linkage between HFGWs and gravitons and to overcome some of the typical problems traditional detectors have, as noted by Rothman and Boughn (2006). A GW detector (Li *et al*., 2008) may suggest a way to formally make the HFGW and graviton linkage explicit in data sets. Furthermore, in refinement of procedures for obtaining better HFGW relic data, this paper points out that Yeo et al. (2006) suggests an entanglement entropy-based detector concept for adding resolution to obtain more differentiation between HFGW contributions from the big bang and those HFGW from all times which are detected at the site of a sutiably configured GW detector. to the already sensitive resolution implied by equation (27). In addition, the analysis leading to Table 1 adds evidence for the existence of gravitons as a measurable physical entity, and suggests detector technology that overcomes the physical limits Rothman and Boughn (2006) postulated for detectors: that they would have to have the diameter of Jupiter in order to detect one graviton a year, a physical measurement absurdity.

In Beckwith (2008), it was suggested how a wormhole construction from a prior universe to our present universe could take place. Support for the wormhole hypothesis of a prior universe contributing a vacuum energy to our present universe is the abrupt rise in temperatures (as given in Table 1), allowing for a relic graviton burst. If a wormhole contributed to early-universe vacuum nucleation, physicists might be able to observe the evolution of early-universe cosmology in the context of the mega-structures larger than the observed universe suggested by Erickcek *et al*. (2008)..

Even if the existence of a structure larger than our universe cannot be inferred, being able to identify an experimentally graceful exit from inflation would be a huge improvement in our current astrophysical understanding of how the universe evolved from the origins of the big bang itself. How could the expansion rate of the big bang slow down, from increasing acceleration to a slowing-down universe expansion? A sutiably configured GW detector could help us investigate whether or not the graceful exit from inflation actually occurred, if it was a relatively sharp change from an increase in expansion to a decrease in the rate of expansion, or if not, if the process constitutes a phase-order transition in the first place.

Then, finally, there is the question of whether or not the total entropy of the universe stabilized after a sharp increase. Currently, Roos (2003) marks the main burst of entropy increase as due to reheating, which is significantly after the big bang, and models it in terms of GUT arguments. He also argues that this sudden increase in entropy at a time significantly after the big bang violates his expectation that after the big bang, the time derivative of entropy is zero. That is, entropy after the big bang stabilizes. The question is then, “Does entropy, abruptly taper off, increase, or change in other ways?” An HFGW detector may be our only way to answer this question.

NOMENCLATURE

$a(t)$ = scale factor $\left[\equiv\left(1+z_{red-shift}\right)^{-1}=\lambda_{rest}/\lambda_{observed}\right]$

c = speed of light (*m/s*)

g_{uv} = metric tensor $\left[\equiv\eta_{uv}+h_{uv}\right]$

G = gravitational constants $\left[6.673\times10^{-11}m^3/kgs^2\right]$

$\hbar$ = reduced Planck constant $\left[\cong1.054\times10^{-34}J\cdot\sec\right]$

J = energy (*J*)

k = $(2\pi/\lambda)$ – part of wave vector

L = length (*m*)

τ = conformal time $\left[\equiv\int dt/a(t)\right]$

t_P = Planck time

T = temperature (*K*)

T^{uv} = GR – energy-stress-tensor

T^{00} = energy-density

dS^2 = arc length, squared of general relativity $\left[\equiv g_{uv}x^u x^v\right]$

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$\hat{h}$ = scalar rendition of Fourier transform of variation of metric Tensor g_{uv} from flat space metric η_{uv}

h_{uv} = gravitational wave contribution to metric distance from the observer

$\lambda_{observed}$ = wavelength of cosmological objects observed on the Earth’s surface

λ_{rest} = wavelength of cosmological objects in their rest frame about themselves, when far from the Earth’s surface

$m_{graviton}$ = $\sim10^{-60}(kg)$

$z_{red-shift}$ = red shift $\left[\equiv\left(\lambda_{observed}-\lambda_{rest}\right)/\lambda_{rest}\right]$

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REFERENCES

Arfken, G, *Mathematical Methods for physicists*, 3rd edition, Academic press, Orlando, Florida, USA, 1985

Baker, R. M. L., Stephenson, G. V. and Li, F., “Proposed Ultra-High Sensitivity HFGW Detector,” in the proceedings of *Space Technology and Applications International Forum*

(STAIF-08), edited by M.S. El-Genk, AIP Conference Proceedings **969**, Melville, NY, (2008), pp. 1045-1054.

Baumann, Daniel, Ichiki, Kiyotomo, Steinhardt, Paul J., and Takahashi, Keitaro, "Gravitational Wave Spectrum Induced by Primordial Scalar Perturbations," http://arxiv.org/PS_cache/hep-th/pdf/0703/0703290v1.pdf , (2007).

Bardeen, J. M. and Wagoner, R.V. "Relativistic discs, I. Uniform rotation," *Astrophys. J.*, 167, (1971), pp. 359-423.

Beckwith, A.W., "Implications for the Cosmological Landscape: Can Thermal Inputs from a Prior Universe Account for Relic Graviton Production?" AIP Conference Proceedings **969**, (2008), pp. 1091-1102.

Carroll, S., *Spacetime and Geometry: An Introduction to General Relativity*, Addison Wesley Co., San Francisco, (2005).

Crowell, L. "Quantum Fluctuations of Space Time," World Scientific Series in Contemporary Chemical Physics, Vol **25**, World Scientific, PTE, LTD, Singapore, (2005).

Erickcek, Adrienne, Kamionkowski, M., Carroll, S.M., "A Hemispherical Power Asymmetry from Inflation," http://arxiv.org/ PS_cache/arxiv/pdf/0806/0806.0377v2.pdf, (2008).

Gasperini, M., Maharana, J. and Veneziano, G.,"Graceful exit in String cosmology," *Nucl. Phys. B*, **472**, (1996), pp. 349-360.

Giovannini, M., *A Primer on the Physics of the Cosmic Microwave Background*, World Press Scientific, Singapore, Republic of Singapore, (2008)

Grishchuk, L.P. "Discovering Relic Gravitational Waves in Cosmic Microwave Background Radiation**,"** http://arxiv.org/ PS_cache/arxiv/pdf/0707/0707.3319v3.pdf, (2007).

Fontana, G., "Gravitational Wave Propulsion," in the proceedings of *Space Technology and Applications International Forum (STAIF-05)*, edited by M. S. El-Genk, AIP Conference Proceedings **746**, Melville, NY, (2005).

Koffman, L., "Pre heating After Inflation," in Lecture notes in Physics **738**, Inflationary cosmology, editors Lemoine, M., Martin, J., Peter, P., , Springer Verlag, Berlin, Federal Republic of Germany, (2008), pp 55-79.

Li, Fangyu, Baker, Robert M. L. and Chen, Zhenya "Perturbative photon flux generated by high frequency relic gravitational waves and utilization of them for their detection," *International Journal of Modern Physics D*, **15**, (2006).

Li, Fang-Yu, Fang, Zhen-Yun and Baker, R. M. L., "Coupling of an open cavity to a microwave beam: A possible new scheme for detecting high-frequency gravitational waves," AIP Conf. Proc. 880, (2007), pp. 1139-1147.

Li, Fangyu, Baker, Robert M L., Fang, Zhenyun, Stephenson, Gary V., and Chen, Zhenya, "Perturbative Photon Fluxes Generated by High-Frequency Gravitational Waves and Their Physical Effects," [Li-Baker Chinese HFGW Detector], *European Physical Journal C.*, accepted June 2, (2008).

Linde , A., "Inflationary Cosmology," in *Lecture notes in Physics* **738**, Inflationary cosmology, editors Lemoine, M., Martin, J., and Peter, P., Springer Verlag, Berlin, Federal Republic of Germany, (2008), pp 1-47.

Lloyd, S., "Computational capacity of the universe," *Phys. Rev. Lett*., **88**, (2002), p. 237901.

Mukhanov, V. P. and Wintizki, S., *Introduction to Quantum Effects in Gravity*, Cambridge University Press, New York, New York, USA, (2007).

Ng, Y. Jack, "Holographic foam, dark energy and infinite statistics," *Phys. Lett. B*, **657**, (2007), pp. 10-14.

Park, D. “Radiations from a Spinning Rod,” *Physical Review*, **99**, No. 4, (1955), pp. 1324-1325.

Izquierdo, German, “Relic gravitational waves in the Expanding Universe,” http://arxiv.org/PS_cache/gr-qc/pdf/0601/ 0601050v1.pdf, (2006).

Roos, Matt, *Introduction to Cosmology*, 3rd edition,” Wiley scientific, San Francisco, California, USA, (2003).

Rothman, T. and Boughn, S., “Can Gravitons be Detected?,” *Foundations of Physics*, **36**, No. 12, December, (2006), pp. 1801-1825.

Smoot, G, “CMB Observations and the Standard Model of the Universe,” 11th Paris Cosmology Colloquium, D. Chalonge School, August 18, (2007).

Tegmark, M. “Parallel Universes,” in *Science and Ultimate Reality: From Quantum to Cosmos*, edited by J. D. Barrow, P. C. W. Davies, and C.L. Harper, Cambridge University Press, (2003).

Weinberg, S., *Gravitation and Cosmology: Principles and Applications of the General theory of Relativity*, John Wiley & Sons, Inc. New York, (1972).

Yeo, Ye, Lim, Zhi Han, Ching, Chee Leong Chong, J., Chua, Wee Kang and Dewanto, A., “Detection of gravitational waves —An application of relativistic quantum information theory,” *EPL*, **78,** (2007), p. 20006.