Part 2 : Review of Tokamak Physics as a way to construct a device optimal for Graviton detection and generation within a confined small spatial volume, as opposed to Dyson's "infinite astrophysical Volume" calculations

ANDREW WALCOTT BECKWITH

Physics department

Chongqing University

College of Physics, Chongqing University Huxi Campus

No. 55 Daxuechen Nanlu, Shapingba District, Chongqing 401331

which is in Chinese:重庆市沙坪坝区大学城南路55号重庆大学虎溪校区

People's Republic of China

Rwill9955b@gmail.com

Abstract: *- Review of arguments in refutation of Dyson's alleged prohibition against use of device physics as to determining if Gravitons can be determined to exist is followed up by use of a hot Plasma within a Tokamak in a re do of the amplitude of alleged Gravitational waves. This overlaps with gravitons, and we follow up with an analysis of the pertinent form of Gravitons, i.e. do we have massless or massive gravitons. In addition we also obtain GW of amplitude as low as*
$$\left[h_{2nd-term} \big|_{T_{Temp} \geq 100 KeV} \right]_{5-meters-above-Tokamak} \sim 10^{-26} - 10^{-27}$$ *five meters above the Tokamak center* such low strain values are extremely close to brane world GW, and strain values in early universe cosmology. This is after our device analysis. *Using Grischuk and Sachin (1975) amplitude for the GW generation due to plasma in a toroid, we generalize this result for Tokamak physics. We obtain evidence for strain values up to* $h_{2nd-term} \sim 10^{-25} - 10^{-26}$ *in a Tokamak center. These values are an order of magnitude sufficient to allow for possible detection of gravitational waves. The critical breakthrough is in utilizing a burning plasma drift current, which relies upon a thermal contribution to an electric field.* Such low strain values are extremely close to brane world GW, and strain values in early universe cosmology. We conclude with statements as to comparing our basic results with those of Yan-Gang Miao, Ying-Jie Zhao *as to their generalized HUP which gives support to the suppositions given in our comparison of the character of gravitons which are initially at the start of inflation versus those of our present era, as measured by the Tokamak*

Key-Words: - **Tokamak physics, confinement time (of Plasma), GW amplitude, Drift current**

1. Review of the Dyson argument which we cite for use in Tokamaks.

Our first goal is to show that Dyson's arguments as given in [1] as to the impossibility of Graviton detection no longer apply to Tokamaks. Note, Dyson in [1] derived criteria as to the probability one could obtain physical phenomenon theoretically modelled by the Gertsenshtein effect [2]. The Gertsenshtein effect [2] is the coupling of magnetic fields, gravitons, and photons. In the Dyson treatment [1] of the Gertsenshtein effect [2] , Dyson hypothesized distances up to many light years for an interaction of magnetic fields, gravitons and photons, for experimental signals which could be detected on the Earth's surface. This assumed geometry of many light years distance lead to the predicted Gertshenshtein effect [2] unable to allow for graviton detection. In contrast to this assumed vast distances for the Gertshenshtein effect in reference [1], the author has devised via tokamak generation of gravity waves which is discussed in this article which lead to an interaction length of meters for the magnetic field, gravitons, and photons. The reduced length is due to the magnetic field

which the gravitons interact with, being inside the detector itself, thereby insuring a 100 % probability for the Gertsenshtein effect occurring. This is commensurate with predictions given in reference [3].The Tokamak example brings up an important point, that even if one wants to measure gravitational waves, the Gertshenshtein effect for gravitons, magnetic field, and photons is within the small 3 dimensional geometry of the detector, with an enormous magnetic field. To do this note that we are talking about a Tokamak of the type described in [4].Having the Gerteshenshtein effect in such a small volume dramatically raises the likelihood of detection of gravitons, via resultant photons being picked up by the 3DSR device which in this care would be put above the Tokamak given in [5]

2. Probability for the Gertsentshtein effect, as described by Dyson for the Tokamak GW experiment.

We will briefly report upon Dyson's well written summary results, passing by necessity to the part on the likelihood of the Gertsenshtein effect occurring in a laboratory environment [1]. In doing so we put in specific limits as to frequency and the magnetic field, since in our work the objective will be to have at least theoretically a 100% chance of photon-graviton interaction [1] which is the heart of what Dyson reported in his research findings. What we find, is that with a frequency of about 10 to the 9th Hertz and a magnetic field of 10 to the 9th Gauss that there is nearly 100% chance of the Gertsentshtein effect being observed, within the confines of the Tokamak experiment as outlined in accommodating the geometrical considerations as related to in references [4,5].

The Gertentshtein effect is linked to how there is a linkage, signal wise, between gravitons and photons, and we are concerned as to what is a threshold as to insure that GW may be matched to the photons used by Dr. Li and others [5] to signify GW in a detector . To do so let us look at the Dyson criteria as a minimum threshold for the Gertentshtein effect happening   [1], namely

$$D \cdot B^2 \cdot \omega \leq 10^{43} \qquad (1)$$

The propagation distance is given by D, the magnetic field by B, and the frequency of gravitational radiation is given by ω. We assume that the gravitational frequency is commensurate with the gravitational frequency of gravitons, i.e. that they are, averaged out one and the same thing. In doing so, making use of [1] we suppose on the basis of analysis that D is of the order of 10 to the 2nd power, since D is usually measured in centimetre, and by [1] we are thinking of about a 1 meter **If B is of the order of 10 to the 9th Gauss Hertz**, as deemed likely by the geometry as suited for [4], then we have that if the **GW frequency , ω is likewise about 10 to the 9th Hertz** , that Eq.(1) is easy to satisfy.

The problem though is that we need to go to the Li Dectector for 3DSR, and step beyond the first document's

Gertenshehtein effect becomes then having the probability below become exactly zero, in the case of the first equation in the bunch of Eq. Given in Eq.(2) below, due to the tininess of D (distance)

$$P = \sin^2(B/L) \sim (GB^2D^2/4c^2)$$
$$\&$$
$$L = (10^{25}/B)$$
$$\& \qquad (2)$$
$$P \sim \sin^2 \sqrt{(10^{36}/B^2 \cdot \omega^2)} \propto 10^{36}/B^2 \cdot \omega^2 \ll 1$$
$$\&$$
$$P = 10^{-24} B^2$$

We will have a different measurement protocol in place than the Gertenshehtein effect.

. Keep in mind that the GW detector is, as given in the 2nd part of this article that if it is situated about five meters above the Tokamak, i.e. presumably the one in Hefei, PRC [4] .Note, that, ironically, Dyson gets much larger values of Eq. (2) than the above setting the frequency to be a huge value , by postulating GW frequency inputs as to the value of ω about 10 to the 20th Hertz, i.e. our value of ω is likewise about 10 to the 9th Hertz, much lower. If one has such a high frequency, as given by Dyson, the of course, Eq. (2) would then be close to zero for the probability of the Gertentshtein effect happening. I.e. our analysis indicates that a medium high GW frequency, presumably close to 10 to the 9th Hertz, and **D** 10 to the 2nd power, presenting satisfaction of both Eq.(1) and Eq.(2). Note the main point though, for large values of **D,** Eq. (1) will not hold, making Eq.(2) not relevant, and that means in terms of the Dyson analysis, that far away objects generating gravitons will not be detectable. Via the Gertentshtein effect. **However, in our case we use the 3DSR effect** since the Gertsenshtein effect is ruled out. Having said that, we have our modus operandi, which is to attempt to look at the way Plasma physics could lead to graviton and GW generation. This means looking at [5], and also considering the phenomenology as given in [6] which of course is to be kept relevant to the restrictions as given in [5,7]

3. Introduction to the Plasma physics.

Russian physicists Grishchuk and Sachin [8] obtained the amplitude of a Gravitational wave (GW) in a plasma as

$$A(amplitude-GW) = h \sim \frac{G}{c^4} \cdot E^2 \cdot \lambda_{GW}^2 \quad (3)$$

This should be compared with [9] , and we can diagram the situation out as follows [10]
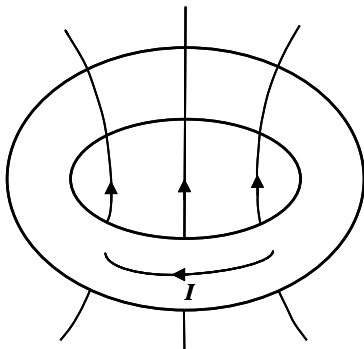
Fig. 1 *We outline the direction of Gravitational wave "flux". If the arrow in the middle of the Tokamak ring perpendicular to the direction of the current represents the z axis, we represent where to put the GW detection device as 5 meters above the Tokamak ring along the z axis. This diagram was initially from Wesson* [3]

Note that a simple model of how to provide a current in the Toroid is provided by a transformer core. This diagram is an example of how to induce the current I, used in the simple Ohms law derivation referred to in the first part of the text
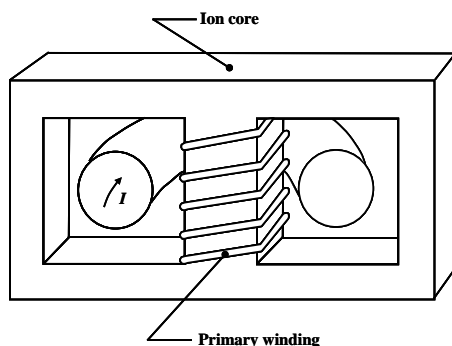
Fig. 2 *Flux change provided by a transformer core, in the simple current model first referred to in this paper. This figure is from Wesson* [10]

Here, E is the electric field whereas λ_{Gw} is the gravitational wavelength for GW generated by the Tokamak in our model. In the original Griskchuk model, we would have very small strain values, which will comment upon but which require the following relationship between GW wavelength and resultant frequency.

Note, if $\omega_{GW} \sim 10^6 \, Hz \Rightarrow \lambda_{Gw} \sim 300 \; meters$, so we will be assuming a baseline of the order of setting $\omega_{GW} \sim 10^9 \, Hz \Rightarrow \lambda_{Gw} \sim .3 \; meters$, as a baseline measurement for GW detection above the Tokamak. Furthermore, we will write the strain, introduced by (massive) Gravitons, as given by [11]. The precise values of the strain due solely to an Ohms law treatment of current, and the electric field will lead to, by first principles comparison of magnitude of terms using [9]

$$A(GW.amplitude) \sim h \sim \frac{G \cdot W_E \cdot V_{volume}}{c^4 \cdot \tilde{a}} \quad (4)$$

Where

$$W_E = Average - energy - density$$
$$V_{volume} = Volume - Toroid \qquad (4a)$$
$$\tilde{a} = inner - radii(Toroid)$$

This Eq. (2) above is due to the 1st term of a two part composition of the strain, with the 2nd term of the strain value significantly larger than the first term and due to ignition of the Plasma in the Tokamak. The first term of strain is largely due to what was calculated by Grishkuk [8] et. al. The second term is due to Plasma fusion burning. This plasma fusion burning contribution is due to non-equilibrium contributions to Plasma ignition, which will be elaborated on in this document. Note that the first term in the strain derivation is due to the electric field within a Toroid, not Plasma fusion burning, and we will first of all discuss how to obtain the requisite strain, for the electric field contribution to the current, inside a Tokamak. Making use of Ohms law.

2. Comment as to the derivation of strain generated by an electric field, and small strain values in the Tokamak.

We will examine the would-be electric field, contributing to a small strain values similar in part to Ohms law .A generalized Ohm's law ties in well with Figures 1 and 2 above

$$J = \sigma \cdot E \qquad\qquad (5)$$

In order to obtain a suitable electric field, to be detected via 3DSR technology [5, 11] [4, 5], we will use a generalized Ohm's law as given by Wesson [10] [3] (page 146), where E and B are electric and magnetic fields, and v is velocity. We should understand that this undercuts the use of Figure 2 above.

$$E = \sigma^{-1} J - v \times B \qquad\qquad (6)$$

As discussed with Dr. Wen Hao in November, 2014, in Chongqing University, the term in Eq. (6) given as $v \times B$ deserves special commentary. If v is perpendicular to B as occurs in a simple

equilibrium case, then of course, Eq. (6) would be, simply put, Ohms law, and spatial equilibrium averaging would then lead to

$$E = \sigma^{-1}J - v \times B \xrightarrow[v-perpendicular-to-B]{} E = \sigma^{-1}J \ (7)$$

What saves the contribution of Plasma burning as a contributing factor to the Tokamak generation of GW, with far larger strain values commencing is that one does not have the velocity of ions in Plasma perpendicular to B fields in the beginning of Tokamak generation. It is, fortunately for us, a non equilibrium initial process, with thermal irregularities leading to both terms in Eq. (7) contributing to the electric field values.

We will be looking for an application for radial free electric fields being applied e.g., Wesson [10] [3] (page 120)

$$n_j e_j \cdot \left(E_r + v_{\perp j} B \right) = -\frac{dP_j}{dr} \qquad (8)$$

Here, n_j = ion density, jth species, e_j = ion charge, jth species, E_r = radial electric field, $v_{\perp j}$ = perpendicular velocity, of jth species, B = magnetic field, and P_j = pressure, jth species. The results of Eq. (5) and Eq. (6) are

$$\frac{G}{c^4} \cdot E^2 \cdot \lambda_{GW}^2 \sim \frac{G}{c^4} \cdot \left[\frac{Const}{R}\right]^2 \cdot \lambda_{GW}^2 + \frac{G}{c^4} \cdot \left[\frac{J_b}{n \cdot e} + v_R\right]^2 \cdot \lambda_{GW}^2 = (1^{st}) + (2^{nd}) \qquad (9)$$

Here, the 1st term is due to $\nabla \times E = 0$, and the 2nd term is due to $E_n = \frac{dP_j}{dx_n} \cdot \frac{1}{n_j \cdot e_j} - (v \times B)_n$ with the 1st term

generating $h \sim 10^{-38} - 10^{-30}$ in terms of GW amplitude strain 5 meters above the Tokamak , whereas the 2nd term has an $h \sim 10^{-26}$ in terms of GW amplitude above the Tokamak. The article has contributions from amplitude from the 1st and 2nd terms separately. The second part will be tabulated separately from the first contribution assuming a minimum temperature of $T = Temp \sim 10 KeV$ as from Wesson [10]

4. GW h strain values when the first term of Eq.(9) is used for different Tokamaks

We now look at what we can expect with the simple Ohm's law calculation for strain values. As it is, the effort lead to non-usable GW amplitude values of up to $h \sim 10^{-38} - 10^{-30}$ for GW wave amplitudes 5 meters above a Tokamak, and $h \sim 10^{-36} - 10^{-28}$ in the centre of a Tokamak. I.e. this would be using Ohm's law and these are sample values of the Tokamak generated GW amplitude, using the first term of Eq. (9) and obtaining the following value [8] with a change as

$$h_{First-term} \sim \frac{G}{c^4} \cdot E^2 \cdot \lambda_{GW}^2 \sim \frac{G}{c^4} \cdot \left[\frac{J}{\sigma}\right]^2 \cdot \lambda_{GW}^2 \ (9a)$$

We summarize the results of such in our first table as given for when $\omega_{GW} \sim 10^9 Hz \Rightarrow \lambda_{Gw} \sim .3 \ meters$ and with conductivity $\sigma(tokamak - plasma) \sim 10 \cdot m^2/\sec$ and with the following provisions as to initial values. What we observe are a range of Tokamak values which are, even in the case of ITER (not yet built) beyond the reach of any technological detection devices which are conceivable in the coming decade. This table and its results, assuming fixed conductivity values $\sigma(tokamak - plasma) \sim 10 \cdot m^2/\sec$ as well as $\lambda_{Gw} \sim .3 \ meters$ is why the author, after due consideration completed his derivation of results as to the 2nd term of Eq. (9) which lead to even for when considering the results for the Chinese Tokamak in Hefei to have[6]

$$h_{Second-term} \sim \frac{G}{c^4} \cdot E^2 \cdot \lambda_{GW}^2 \sim \frac{G}{c^4} \cdot \left[\frac{J_b}{n \cdot e} + v_R \right]^2 \cdot \lambda_{GW}^2 \quad (10)$$

Or values 10,000 larger than the results in ITER due to Eq. (10).'

We summarize the results of such in our first table as given for when $\omega_{GW} \sim 10^9 Hz \Rightarrow \lambda_{Gw} \sim .3 \ meters$ and with information from Table 1 of Appendix A, so

View **appendix A** below which has useful data

Table 1*:* Values of strain at centre of Tokamak, and 5 meters above Tokamak:

Note that we are setting $\lambda_{Gw} \sim .3 \ meters$, $\sigma(tokamak - plasma) \sim 10 \cdot m^2/\sec$, using Eq.(11) above for Amplitude of GW.

What makes it mandatory to go the 2nd term of Eq. (11) is that even in the case of ITER, 5 meters above the Tokamak ring, the GW amplitude is 1/10,000 the size of any reasonable GW detection device, and this including the new 3DSR technology (Li et al, 2009) [5, 11] . Hence, we need to come up with a better estimate, which is what the 2nd term of Eq. (7) is about which is derived in the next section

4 Enhancing GW strain Amplitude via utilizing a burning Plasma drift current: Eq. (6)

The way forward is to go to Wesson, [10] (2011, page 120) and to look at the normal to surface induced electric field contribution

$$E_n = \frac{dP_j}{dx_n} \cdot \frac{1}{n_j \cdot e_j} - (v \times B)_n \quad (11)$$

If one has for v_R as the radial velocity of ions in the Tokamak from Tokamak centre to its radial distance, R, from centre, and B_θ as the direction of a magnetic field in the 'face' of a Toroid containing the Plasma, in the angular θ direction from a minimal toroid radius of $R = a$, with $\theta = 0$, to $R = a + r$ with $\theta = \pi$, one has v_R for radial drift velocity of ions in the Tokamak, and B_θ having a net approximate value of: with B_θ not perpendicular to the ion velocity, so then [10]

$$(v \times B)_n \sim v_R \cdot B_\theta \quad (12)$$

This should be considered within the constraints given by [11] as well as the geometry given in [12] for the Hefei Tokamak.
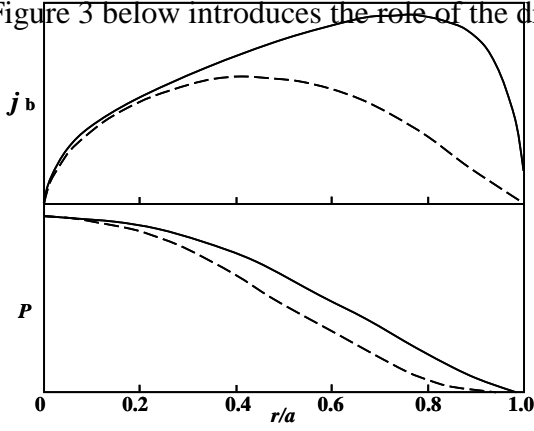
Also, as a first order approximation: From Wesson [10] (page 167) the spatial change in pressure denoted

$$\frac{dP_j}{dx_n} = -B_\theta \cdot j_b \quad (13)$$

Here (ibid), the drift current, using $\xi = a/R$, and drift current j_b for Plasma charges, i.e.

$$j_b \sim -\frac{\xi^{1/2}}{B_\theta} \cdot T_{Temp} \cdot \frac{dn_{drift}}{dr} \qquad (14)$$

Figure 3 below introduces the role of the drift current, in terms of Tokamaks [10]

Fig. 3 *Typical bootstrap currents with a shift due to r/a where r is the radial direction of the Tokamak, and a is the inner radius of the Toroid This figure is reproduced from Wesson* [10]

Then one has

$$B_\theta^2 \cdot \left(j_b/n_j \cdot e_j\right)^2 \sim$$

$$\frac{B_\theta^2}{e_j^2} \cdot \frac{\xi^{1/4}}{B_\theta^2} \cdot \left[\frac{1}{n_{drift}} \cdot \frac{dn_{drift}}{dr}\right]^2 \qquad (15)$$

$$\sim \frac{\xi^{1/4}}{e_j^2} \cdot \left[\frac{1}{n_{drift}} \cdot \frac{dn_{drift}}{dr}\right]^2$$

Now, the behaviour of the numerical density of ions, can be given as follows, namely growing in the radial direction, then [10]

$$n_{drift} = n_{drift}\big|_{initial} \cdot \exp[\tilde{\alpha} \cdot r] \qquad (16)$$

This exponential behaviour then will lead to the 2nd term in Eq. (9) having in the centre of the Tokamak, for an ignition temperature of $T_{Temp} \geq 10 KeV$ a value of

$$h_{2nd-term} \sim$$

$$\frac{G}{c^4} \cdot B_\theta^2 \cdot \left(j_b/n_j \cdot e_j\right)^2 \cdot \lambda_{GW}^2 \qquad (17)$$

$$\sim \frac{G}{c^4} \cdot \frac{\xi^{1/4} \tilde{\alpha}^2 T_{Temp}^2}{e_j^2} \cdot \lambda_{GW}^2 \sim 10^{-25}$$

As shown in **Fig. 4** (copied from Wesson 2011), [10] there is a critical ignition temperature at its lowest point of the curve in the having $T_{Temp} \geq 30 KeV$ as an optimum value of the Tokamak ignition temperature for

$n_{ion} \sim 10^{20} m^{-3}$, with a still permissible temperature value of $T_{Temp}\big|_{safe-upper-bound} \approx 100 KeV$ with a value of $n_{ion} \sim 10^{20} m^{-3}$, due to from page 11, [10] the relationship of Eq.(18), where τ_E is a Tokamak confinement of plasma time of about 1-3 seconds, at least due to [10]

$$n_{ion} \cdot \tau_E \geq 1.5 \times 10^{20} \cdot m^{-3} \cdot \sec \qquad (18)$$
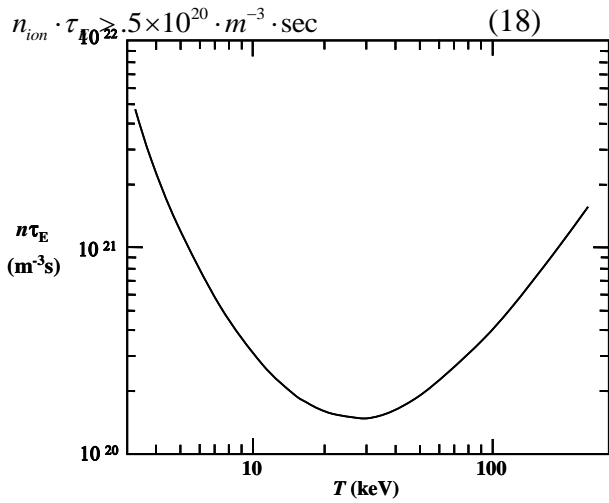
Fig. 4 *The value of* $n\tau_E$ *required to obtain ignition, as a function of temperature. Figure reproduced from Wesson* [10]

Also, as shown in Fig. 4, $T_{Temp}\big|_{safe-upper-bound} \approx 100 KeV$ then one could have at the Tokamak centre, i.e. even the Hefei based Tokamak [10,12]

$$h_{2nd-term}\big|_{T_{Temp} \geq 100 KeV} \sim$$
$$\frac{G}{c^4} \cdot \frac{\xi^{1/4} \tilde{\alpha}^2 T_{Temp}^2}{e_j^2} \cdot \lambda_{GW}^2 \sim 10^{-25} - 10^{-26} \qquad (19)$$

This would lead to, for a GW reading 5 meters above the Tokamak, then lead to for then the Hefei PRC Tokamak [10, 12]

$$\left[h_{2nd-term}\big|_{T_{Temp} \geq 100 KeV} \right]_{5-meters-above-Tokamak}$$
$$\sim \frac{G}{c^4} \cdot \frac{\xi^{1/4} \tilde{\alpha}^2 T_{Temp}^2}{e_j^2} \cdot \lambda_{GW}^2 \sim 10^{-27} \qquad (20)$$

Note that the support for up to 100 KeV for temperature can yield more stability in terms of thermal Plasma confinement as give in **Fig. 5** below, namely from [10] we have
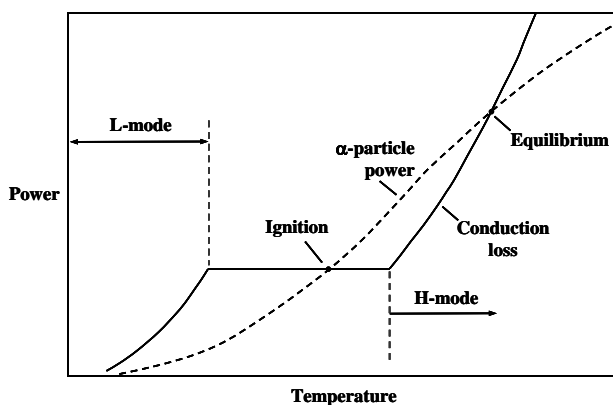
Fig 5 *Illustrating how increase in temperature can lead to the H mode region, in Tokamak physics where the designated equilibrium point, in Fig. 5 is a known way to balance conduction loss with alpha particle power, which is a known way to increase τ_E i.e. Tokamak confinement of plasma time* [9]

5. Details of the model in terms of terms of adding impurities to the Plasma to get a longer confinement time (possibly to improve the chances of GW detection).

We add this detail in, due to a question raised by Dr. Li who wished for longer confinement times for the Plasma in order to allegedly improve the chances of GW detection for a detector 5 meters above the Tokamak in Hefei. Wesson [10] (2011) stated that the confinement time may be made proportional to the numerical density of argon/ neon seeded to the plasma [10] (page 180). This depends upon the nature of the Tokamak, but it is a known technique, and is suitable for analysis, depending upon the specifics of the Tokamak. I.e. this is a detail Dr. Li raised with his co-workers in Hefei, PRC in 2014 [12].

6. Restating the energy density and power which would be in the Hefei Tokamak, using the formalism of Eq. (4) directly

$$W_E \sim \frac{\tilde{\alpha} \cdot \lambda_{GW}^2}{V_{volume}} \cdot \frac{\xi^{1/4} \tilde{\alpha}^2 T_{Temp}^2}{e_j^2} \qquad (21)$$

$$W_E \cdot V_{volume} \sim \tilde{\alpha} \cdot \lambda_{GW}^2 \cdot \frac{\xi^{1/4} \tilde{\alpha}^2 T_{Temp-plasma-fusion-burning}^2}{e_j^2}$$

The temperature for Plasma fusion burning, is then about between 30 to 100 KeV, as given by Wesson [10]

The corresponding power as given by Wesson is then for the Tokamak [10]

$$P_\Omega = E \cdot J \le \frac{E}{\mu_0} \cdot \frac{B_\phi}{R} \qquad (22)$$

The tie in with Eq. (20) by Eq. (22) can be seen by first of all setting the E field as related to the B field, via E (electrostatic) $\sim 10^{12} Vm^{-1}$ as equivalent to a magnetic field B $\sim 10^4 T(Torr)$ as given by [9]. In a one second interval, if we use the input power as an experimentally supplied quantity, then the effective E field is

$$E_{applied} \sim \frac{\xi^{1/8} \cdot \tilde{\alpha}}{e_j} \times T_{Tokamak-temperature} \qquad (23)$$

What is found is, that if Eq. (22) and Eq. (23) hold. Then by Wesson [10], pp. 242-243, if $Z_{eff} \sim 1.5, q_a q_0 \sim 1.5, (R/\tilde{a}) \approx 3$ Then the temperature of a Tokamak, to good approximation would be between 30 to 100 KeV, and then one has [10]

$$B_\phi^{4/5} \sim .87 \cdot \left(\tilde{T} = T_{Tokamak-temperature} \right) \qquad (24)$$

Then the power for the Tokamak is

$$P_\Omega \big|_{Tokamak-toroid} \leq \frac{\xi^{1/8} \cdot \tilde{\alpha}}{\mu_0 \cdot e_j \cdot R} \times \frac{\left(T_{Tokamak-temperature} \right)^{9/4}}{(.87)^{5/4}} \quad (25)$$

Then, per second, the author derived the following rate of production per second of a $10^{-34} eV$ graviton, as given by, if $\tilde{a} = R/3$

$$n \big|_{massive-gravitons/\sec ond} Tokamak$$

$$\propto \frac{3 \cdot \hbar \cdot e_j}{\mu_0 \cdot R^2 \cdot \xi^{1/8} \cdot \tilde{\alpha}} \times \frac{\left(T_{Tokamak-temperature} \right)^{1/4}}{\lambda_{Graviton}^2 \bullet m_{graviton} \cdot c^2 \cdot (.87)^{5/4}} \quad (26)$$

$$\sim 1/\lambda_{Graviton}^2 scaling$$

If there is a fixed mass for a massive graviton, the above means that as the wavelength decreases, that the number of gravitons produced between plasma burning temperatures of 30 to 100 KeV changes dramatically. The change in graviton number is not nearly so sensitive as to Plasma fusion burning as for 30 to 100 KeV temperature variation.

Numerical inputs into Eq. (26) have indicated that there are roughly 1000 gravitons per second generated by Plasma fusion burning, with a strain value of $h \sim 10^{27} 5$ meters above the centre of the Hefei Tokamak[12]. If so, then the long confinement time of the Hefei Tokamak, for plasmas, would indicate a chance that a detector may be able to obtain a graviton signal. That depends upon if $h \sim 10^{27}$ is, with the equipment available actually detectable. If so, then the next task is the extremely time consuming process of experimental verification of the measurements, and answering questions as to the reliability of the obtained data sets.

7 Looking at the role of Gravitons, in massless and massive gravity configurations

We do note that there will be a complimentary relationship between presumed brane world generated GW [13], which has the similar order of magnitude to the Tokamak generated GW and gravitons. Hence, due to [13] we will bring up some material which is related to the nature of gravitons, from first principles.

Note that in the early universe, the following may be considered as complimentary, i.e. that we are looking at material from [14, 15]. To start of with consider how to obtain massive gravitons, and to do that we start with material from [16].

$$\Lambda_{Einstein-Const.} = 1/l_{Radius-Universe}^2 \qquad (27)$$

Which in turn may help us understand when the formation of this value occurred, i.e. [17]

$$m_{graviton} = \frac{\hbar}{c} \cdot \sqrt{\frac{(2\Lambda)}{3}} \approx \sqrt{\frac{(2\Lambda)}{3}} \qquad (28)$$

We are supposing that Eq. (27) and Eq. (28) holds at the formation of a Schwartzshield mass of the Universe radius. Also, here is our candidate as to the formation of an initial time step. As given.

$$t_{initial} \sim \frac{2}{g_*^{2/3}} \cdot \frac{10^\alpha}{N} \cdot L_{Planck} \qquad (29)$$

Then, up to a point, if the above is in terms of seconds, and N sufficiently large, we could be talking about an initial non zero entropy, along the lines of the number of nucleated particles, at the start of the cosmological era. As given by making use of quantum infinite statistics as well as our adaptation of it [18]

$$S(initial) \sim \left(N \doteq n\right) \sim \frac{2}{g_*^{2/3}} \cdot \frac{10^\alpha}{t_{initial}} \cdot L_{Planck} \qquad (30)$$

Initial entropy would be small, but non zero, and would be affected by g_* strongly, i.e. the initial degrees of freedom assume would play a major role as far as how initial entropy and initial time steps would be initiated. i.e. in this configuration, there is room then for in the early universe, a rest mass of a graviton, of approximately 10^ -62 grams, which would tie an initial non zero entropy, as in Eq. 30, with an initial time step, as given in Eq. 29, with the number, n ~ N of gravitons as given with mass m, of Eq. (28), as possibly conferring information transfer, i.e. looking at what shows up as a proportionality factor as far as how to obtain entropy is in having the following set up, i.e. if we look eventually at the Schwartzhield radius of the universe as occurring at redshift z = 1000, about 300,000 years after the big bang, then

$$\frac{4\pi}{3}\left(R_{Schwartzshield-radii-Universe}\right)^3$$
$$\approx \left(S_{Universe}\right) \times \left(\lambda_{QM-effects}\right)_{BH}^3 \qquad (31)$$

Furthermore, there is a linkage which can be made to Seth Lloyds number of operations, i.e. [16]

$$\#(operations) \sim \left(S_{Universe}\right)^{4/3} \sim 10^{126}$$
$$\Leftrightarrow \frac{4\pi}{3}\left(R_{Z\sim1100(first\ light-radii-Universe)}\right)^3 \qquad (32)$$
$$\simeq \frac{4\pi}{3}\left(\left[\#(operations)\right] \sim 10^{126} \times \left(\lambda_{QM-effects}\right)_{BH}^3\right)$$

Whereas if t(initial) ~ t (H) as given below

$$\lambda_{QM-effects-BH} \sim \sqrt[3]{\frac{t_H}{t_{Planck}}} \cdot L_{Planck} \sim 10^{-15}\,meters \qquad (33)$$

The entropy of the universe, as given by S ~N , with the linkage as given by Ng. [19] would tie into an initial frequency range, which would be extremely high, and that due to the smallness of the wavelength, as given by Eq. (33) above.

If initial wavelength, as given by Eq.(33) is inversely proportional to an INITIAL version of energy, then there could be a version of this affecting the mass of a graviton as given by $\lambda \sim c/\omega$, being re written, as through use of Eq. (29) as of the rest mass of a graviton about Planck time leading to

$$\lambda \sim c/\omega \sim \left(c \cdot t_{min} \sim \frac{c \cdot g_*^{2/3} N}{2 L_{Planck} 10^{\alpha}} \sim \frac{V(volume) \cdot \hbar^3}{3 m_g^2 \cdot c} \right) \propto N \tag{31}$$

$$\sim Entropy$$

$$\Leftrightarrow m_g^2 \sim \frac{2 V(volume) \cdot L_{Planck} 10^{\alpha} \cdot \hbar^3}{3 c^2 \cdot g_*^{2/3} N} \propto \frac{1}{N}$$

$$\sim S_{initial-entropy}^{-1} (Before \quad z = 1000)$$

I.e. before Planck time, we would have the graviton mass as effectively zero, and it would about the time of Planck time, scale as given in Eq. (31) with graviton rest mass eventually being in tandem with Eq. (28)

Then, if the following hold before and after Planck time [18]

$$\Theta(t - t_{Planck}) = 0, t < t_{Planck}$$

$$\Theta(t - t_{Planck}) = 1, t > t_{Planck} \tag{32}$$

$$m_g = 0; t < t_{Planck}$$

$$m_{graviton} = \frac{\hbar}{c} \cdot \sqrt{\frac{(2\Lambda_{today})}{3}} \approx \sqrt{\frac{(2\Lambda)}{3}}; t > t_{Planck}$$

$$m_{graviton} = \frac{\hbar}{c} \cdot \sqrt{\frac{(2 \cdot \Theta(t - t_{Planck}) \cdot \Lambda_{today})}{3}}$$

Eq. (31) and Eq. (32) define the range of values of the Planck mass, as given, and also, the Pre Octonionic (Pre Planckian time) regime to Planckian time regime as given by

What we are considering is the following transformation, simply put. And this will be hopefully detected by a change in phase, given by use of reference [6] style **phase** δ_0

In addition we use [19]

$$\delta t \Delta E \geq \left. \frac{\hbar}{\delta g_{tt}} \right|_{Pre-Octonionic}$$

$$\xrightarrow[\text{change in phase, given byp phase } \delta_0]{} \delta t \Delta E \geq \hbar \Big|_{Octonionic} \tag{33}$$

$$with \quad \delta t \geq \frac{\hbar}{\delta g_{tt} \Delta E} FIXED$$

8. Now about conditions to obtain the relevant data for phase δ_0

This paper examines geometric changes that occurred in the earliest phase of the universe, leading to values for data collection of information for phase δ_0, and explores how those geometric changes may be measured through gravitational wave data. The change in geometry is occurring when we have first a pre quantum space time state, in which, in commutation relations [20] (Crowell, 2005) in the pre Octionic space time regime no approach to QM commutations is possible as seen by Eq.(34), i.e in Pre Octonionic, Pre Planckian space time [20]

$$\left[x_j, p_j \right] \neq i \cdot \hbar \tag{34}$$

In the situation when we approach quantum "octonionic gravity applicable" geometry, Eq. (34) becomes [20]

$$\left[x_{j,}p_{j}\right]=i\cdot\hbar$$

(35)

Having said that, if Gravitons are from the early electro weak era, in terms of production, in early universe conditions, the situation is definable via [15]

We will elaborate upon this, but we have to state that purely massless gravitons are commensurate with the Pre Planckian era, and that conditions given in [14] hold.

I.e. for the Tokamak, we are working with the present day era of Eq. (32) given above.

8. Examination of our write up about gravitons and the tie in with the HUP, and cosmological constant with the work of Yan- Gang Miao, and Ying-Jie Zhao

In [21] there is a use of a relationship between the size of a spatial interval of space-time and the cosmological constant. What is of interest, is that due to what the authors call a suppression index, which they call '**n**', that the authors up to a point partially confirm the results we have been talking of. I.e., the difference is that they use their results to confirm the existence of a cosmological constant in its present value, but do not discuss the pre Planckian space-time considerations we have brought up. It is of note though that their suppression index, 'n' is of the magnitude of present day estimations of entropy (if we take Entropy as a counting of 'particles' in space-time). In doing so, we take note that the 'suppression' index so obtained was of the order of 10^121, which is according to [22] tied into estimations of early to late space-time dynamics, which is given credence in [23]. The noteworthy matter to bring to the attention of the readers is that there is in **formula 10 of reference [21]** an explicit "vacuum energy" expression, which has the minimum length, delta x, of the order of Planck's length as part of a formula leading to "vacuum energy" in formula 10 of reference [21] which is presumed to be of the magnitude of the Cosmological 'constant'. Left unsaid though is then the derivation of the factor 'n' as part of a 'suppression' meme of reducing an initially huge energy value, by 10^-121 as given in Eq. (11) of reference [21]. However in dong so, the factor 'n' has the value of 10^123 which the authors then say was corrected to be of the value of 10^121.

Here is the take away. If one is making the identification of S~ 'n', as in a counting algorithm, for entropy along the lines of Ng's infinite quantum statistics, as given in [18], then the suppression factor 'n' is of the magnitude of the present entropy of the universe which could be predicted via following [22, 23]. Hence, we make the following identification, namely following [18, 21]

S (entropy, today) ~ N(counting factor)   ~ 'n' (suppression factor) ~ 10^121   (37)

If we literally took this as gospel, we would be assuming the existence of an enormous suppression factor index 'n' would be enough if in tandem with entropy, to state, if 'n' were fixed, that we would have the existence of a cosmological constant of today's value, if formula 10 of reference [21] held. Needless to say though if 'n' ~ N ~ entropy (early universe) were considerably smaller than 10^121, then the cosmological 'constant' of the early universe would be considerably larger than what it is today. By many orders of magnitude.

The equations in question from [21] reads as follows, namely

$$\left(\Delta X\right)_{min} \sim \hbar\sqrt{\beta} \sim l_{:Planck}$$

$$\Lambda \sim vacuum-energy \sim \left(\frac{\hbar c}{8\pi^2\left(\hbar\sqrt{\beta}\right)^4}\right) \cdot \left(\frac{\Gamma\left(\frac{2}{'n'},\frac{3}{2^{'n'}}\right)}{3^{2/'n'}}\right)$$

$$\& \Lambda \sim \Lambda\left(today\right) \tag{38}$$

$$iff \left(\frac{\Gamma\left(\frac{2}{'n'},\frac{3}{2^{'n'}}\right)}{3^{2/'n'}}\right) \sim 10^{-121}-10^{-123}$$

$$\Leftrightarrow 'n' \sim 10^{121}-10^{123} \simeq S(entropy-today)$$

The vacuum energy in question is the same as the cosmological constant, if and only if the factor 'n' is so enormous. Aside from the numerology , which is suggestive, there is a basic inconsistency which we wish to find an answer to because the 'vacuum energy' starts off with a Planck's length, but the presumed $'n' \sim 10^{121}-10^{123} \simeq S(entropy-today)$ suggests Planckian physics.

We wish to find a resolution between this apparent inconsistency in future work, but we applaud the insight of [21] as linking 'vacuum energy', 'n' and the minimum length, which is in their estimation Planck length.

Needless to say, up to a point they may be arguing for 'quintessence' if much smaller 'n' as N which is proportional to early universe entropy existed. We do know though by the supernova candle, that by the time of the formation of the first stars, that the cosmological 'constant' was stable and of the same value as of the present era. This is a topic which the research group is well aware of and which deserves specific study and review.

9.   Conclusion. GW generation due to the Thermal output of Plasma burning

Further elaboration of this matter in the experimental detection of experimental data sets for massive gravity lies in the viability of the expression derived, namely Eq. (21)

. $h \sim 10^{27}$ for a GW detected 5 meters above a Tokamak represents the extreme limits of what could be detected, but it is within the design specifications of what Dr. Li et al. (2009)[4,5] presented for PRD readership. The challenge, as frankly brought up in discussions in Chongqing University is to push development of 3DSR hardware to its limits, and use the Hefei Tokamak configuration as a test bed for the new technology embodied in the Plasma fusion burning generation of Gravitation waves.

The importance of the formulation is in the explicit importance of temperature. I.e. a temperature range of at least $10KeV \leq T_{Temp} \leq 100KeV$. In making this range for Eq. (25), care must also be taken to obtain a sufficiently long confinement time for the fusion plasma in the Tokamak of at least 1 second or longer, and this is a matter of applied engineering dependent upon the instrumentation of the Tokamak in Hefei, PRC.

Furthermore, .Wen, Li, and Fang, proved in [13] the likelihood of brane world generation of HFGW which are close to the values of strain and frequency which could be generated by the Tokamak described above. '

We also should be aware, of taking consideration of the extreme non linearity of the conductivity of plasmas as discussed in [24] as the kinks and irregularities in the magnetic field, are a serious contributor to the irregularities in the MHD simulations which will be part of a future study, of the effects of gravity wave and graviton generation later on.

This marks the conclusion of this submitted document for Advances in High Energy Physics, By Dr. Andrew Walcott Beckwith

References:

[1] FREEMAN DYSON, *Int. J. Mod. Phys. A*, **28**, 1330041 (2013) [14 pages] DOI: 10.1142/S0217751X1330041X

[2] M. E. Gertsenshtein, 1961. \Wave Resonance of Light and Gravitational Waves", JETP,41, 113-114, English translation in Soviet Physics JETP, 14, 84-85 (1962).

[3] F. **Li, F., M. Tang, M., D. Shi. "Electromagnetic response of a Gaussian beam to high frequency relic gravitational waves in quintessential inflationary models", PRD 67,104008 (2003), pp1-17**

[4] J. Li, H. Y. Guo, et.al." A long-pulse high-confinement plasma regime in the Experimental Advanced Superconducting Tokamak", *Nature Physics* (2013) doi:10.1038/nphys2795; Received 17 April 2013 Accepted 24 September 2013 Published online 17 November 2013

[5] F.Y. Li et al., Phys. Rev. D 80, 064013 (2009), arxiv re-qc/0909.4118 (2009)

[6] F. **Li F., and N. Yang, "Phase and Polarization State of High Frequency Gravitational waves", *Chin Phys. Lett. Vol 236, No 5(2009), 050402, pp 1-4***

[7] M. Maggiore, *Gravitational Waves: Volume 1. Theory and Practice* Oxford University press, 2008, Oxford UK

[8] L.P. Grishchuk, M.V. Sazchin "Excitation and Detection of Standing Gravitational Waves", Zh. Eksp. Theor. Fiz 68, pp 1569-1582 (1975) Moscow

[9] F. Li, l M. Tang, J. Luo, and Y-C. Li, "Electrodynamical response of a high energy photon flux to a gravitational wave", Phys. Rev. D. 62, 44018, (2000)

[10] J. Wesson; "Tokamaks", 4th edition, 2011 Oxford Science Publications, International Series of Monographs on Physics, Volume 149

[11] [R.C. Woods et al, Journal of Modern physics 2, number 6, starting at page 498, (2011)

[12] J. Li,et al, " A Long Pulse high Confinement Plasma regime in the experimental Advanced Super conducting Tokamak", Nature Physics (2013), doi 10.1038/ nphys 2795, Published November 17, 2013

[13] H. Wen, F. Li, and Z. Fang "Electromagnetic response produced by interaction of high-frequency gravitational waves from brane world with galactic-extragalactic magnetic fields" PR *D 89*, 104025, Published May 14, 2014

[14] Beckwith, A. (2016) Gedanken Experiment Examining How Kinetic Energy Would Dominate Potential Energy, in Pre-Planckian Space-Time Physics, and Allow Us to Avoid the BICEP 2 Mistake. *Journal of High Energy Physics, Gravitation and Cosmology*, **2**, 75-82. doi: 10.4236/jhepgc.2016.21008.

[15] A. Beckwith, Open Journal of Microphysics, 2011, 1, 13-18 doi:10.4236/ojm.2011.11002 Published Online May 2011 (http://www.SciRP.org/journal/ojm)

[16] Ali, A.F. and Das, S. (2015) Cosmology from Quantum Potential. Physics Letters B, 741, 276-279.

[17] Haranas, I. and Gkigkitzis, I. (2014) "The Mass of Graviton and Its Relation to the Number of Information According to the Holographic Principle". International Scholarly Research Notices, 2014, Article ID: 718251. http://www.hindawi.com/journals/isrn/2014/718251/

[18] Jack Ng, Y. (2008) Space-Time Foam: From Entropy and Holography to Infinite Statistics and Nonlocality. Entropy, 10, 441-461. http://dx.doi.org/10.3390/e10040441

[19] Beckwith, A. (2016) Gedanken Experiment for Refining the Unruh Metric Tensor Uncertainty Principle via Schwarzschild Geometry and Planckian Space-Time with Initial Nonzero Entropy and Applying the Riemannian-Penrose Inequality and Initial Kinetic Energy for a Lower Bound to Graviton Mass (Massive Gravity). *Journal of High Energy Physics, Gravitation and Cosmology*, **2**, 106-124. doi: 10.4236/jhepgc.2016.21012.

[20] Crowell, L., "Quantum Fluctuations of Space Time ", World Scientific Series in Contemporary Chemical Physics, Vol 25, World Scientific, PTE, LTD, 2005, Singapore

[21] *Yan-Gang Miao, Ying-Jie Zhao, "***Interpretation of the Cosmological Constant Problem within the Framework of Generalized Uncertainty Principle",** Int. J. Mod. Phys. D 23 (2014) 1450062, http://arxiv.org/abs/1312.4118

[22] Damien A. Easson, Paul H. Frampton, George F. Smoot, "Entropic Accelerating Universe", Phys.Lett.B696:273-277, 2011, http://arxiv.org/abs/1002.4278

[23] Alexander Shalyt-Margolin, "Entropy in the Present and Early Universe: New Small Parameters and Dark Energy Problem", Entropy 2010, 12, 932-952; doi: 10.3390/e12040932

[24] Hirshman, S.:P, Hawruluk, R. J. and Birge, B. "Neoclassical conductivity of a Tokamak Plasma" Nuclear Fusion 17, 611 (1977)

Appendix A

Table 1: ***Values of strain at center of Tokamak, and 5 meters above Tokamak if only using square of E field contribution to strain equation. This table neglects using Eq. (21), which allows for*** $h \sim 10^{27}$: ***In Appendix A, only Eq. (10) is utilized for the strain value which is woefully inadequate***

$\lambda_{Gw} \sim .3\ meters$, $\sigma(tokamak - plasma) \sim 10 \cdot m^2/\sec$, **using Eq.6 above for Amplitude of GW.**

Experiment	Site/ location	Plasma current, in (Mega-Amps) MA	Strain, h, in center of the Tokamak	Strain, h, 5 meters above the center of the Tokamak
JET	Culham, Oxfordshire **(UK)**	**8** = 3.2 MA (circular plasma) + 4.8 MA (D-shape plasma)	$h \sim 10^{-31}$	$h \sim 10^{-33}$
ASDEX	**Garching (GER)**	**5**	$h \sim 10^{-32}$	$h \sim 10^{-34}$
DIII-D	**San Diego (USA)**	**3-3.5**	$h \sim 10^{-32}$	$h \sim 10^{-34}$
HL-2A	**Chengdu (PRC)**	**.48**	$h \sim 10^{-34}$	$h \sim 10^{-36}$
HT-7U	**Hefei (PRC)**	**1.0**	$h \sim 10^{-33}$	$h \sim 10^{-34}$
ITER(planned)	**Saint Paul Les-Durance (FR)**	**15**	$h \sim 10^{-28} - 10^{-29}$	$h \sim 10^{-30} - 10^{-31}$