(TITLE Page)

"Review of The Grischuk and Sachin GW Generator Via Tokamak Physics"

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1) Email for correspondence as to future physics article:

Review of The Grischuk and Sachin GW Generator Via Tokamak Physics

(see page 12 for figures)

Abstract

Using the Grischuk and Sachin amplitude for GW generation due to plasma in a toroid we generalize this result for Tokamak physics. We obtain evidence for strain values up to $h \sim 10^{-24}$ in the center of a tokamak which may be detectable in the near Future. Details as to $n_{ions} \cdot \tau_E > 1.5 \times 10^{20}\, m^{-3}\, sec$ may allow for a confinement time τ_E sufficiently long as to permit falsifiable measurement of GW in the coming near future.

1. Introduction:

In 1975 in [1], Russian physicists

Grishchuk and Sachin obtained the following amplitude for GW generated by plasma in a toroid: [1]

$$A\ (\text{amplitude} - GW - Z\ \text{axis}) \simeq h \sim \frac{G}{c^4} \cdot E^2 \cdot \lambda_{GW}^2 \quad (1)$$

Here, E is the E field in the plasma and λ_{GW} is the GW wavelength:

Note: if $\omega_{GW} \sim 10^6$ Hz, then $\lambda_{GW} \sim 300$ meters

In order to fit the λ_{GW} within 3DSR technology [2], we use $\omega_{GW} \sim 10^9$ Hz for $\lambda_{GW} \sim .3$ meters, which puts a premium on E (Electric Field) construction.

The 1st attempt to obtain E results was initiated using a simplified ohms Law, via

$$J = \{\sigma \cdot E\} \quad (2)$$

This lead to unsuitably small A (GW) results, which mean we have looked at a generalization of ohms law, of the form [3]

(wesson page 146)

$$\vec{E} = \sigma \vec{J} - (\vec{v} \times \vec{B}) \quad (3)$$

i.e. both E and B fields,

as well as we will explain

(wesson page 120)

an expression for radial E fields [3]

$$n_j \cdot e_j \cdot (E_r + v_{\perp j} B) = -\frac{dP_j}{dr} \quad (4)$$

where n_j = ion density (j species

e_j = ion charge . j species

E_r = radial E field

$(v_\perp)_j$ = perpendicular velocity (of ions), j species

B = magnetic field

<u>and</u> P_j = **pressure**: j species

The results of using (3) and (4) are that will obtain

$$A \approx \frac{G}{c^4} E^2 \lambda_{GW}^2 \sim \frac{G}{c^4} \cdot \frac{[\text{const}]^2}{R^2} \cdot \lambda_{GW}^2 + \frac{G}{c^4} \cdot B_\theta^2 \cdot \left(\frac{J_t}{ne} + v_R \right)^2 \cdot \lambda_{GW}^2 \quad (5)$$

P. 4:
(5a)

i.e. $A_{GW} \approx (1) + (2)$

↑ (1) term due to $\vec{\nabla} \times \vec{E} = 0$ & $E_\phi = \frac{[\text{const}]}{R}$

↑ (2) term due to $E_m = \frac{dP_j}{\partial x_m} \cdot \frac{1}{n_j e_j} - (v \times B)_m$

1st term will yield:
$h \sim 10^{-38}$ to 10^{-30} for 3DSR 5 meters above Tokamak ring

2nd term will yield:
$h \sim 10^{-23}$ for $T_{temp} \approx 10$ keV (or higher) for 3DSR 5 meters above Tokamak ring

(see page 12 for figures)

2. Agw derived using simplified ohms Law $J = \sigma \cdot \vec{E}$

Start 1st with (TABLE 1)

Current for different Tokamaks:

Experiment	site	Plasma current
JET	Culham (UK)	5 ~ 7 MA
ASDEX	Garching (Ger)	2 MA
D III - D	San Diego (USA)	1.5 - 3 MA
HL - 2A	Chengdu (PRC)	.45 MA
HT - 7U	Hefei (PRC)	.25 MA
ITER (planned)	Saint Paul Les - Durance (France)	15 MA

JF GW $\omega_{GW} \sim 10^9$ Hz

JF GW $\lambda_{GW} \sim .3$ meter

JF σ(Tokamak) $\sim 10\ m^2/sec$

(1) A (GW) center of Ring | HT-7U $\sim 10^{-36}$.

(12) A (GW) 5 meters above ring | HT-7U $\sim 10^{-38}$.

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(2) A (GW) Center of Ring | HL-2A $\sim 10^{-32}$

(2a) A (GW) 5 meters Above ring | HL-2A $\sim 10^{-34}$

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(3) A (GW) center of Ring | DIII-D $\sim 10^{-31}-10^{-30}$

(3a) A (GW) 5 meters Above ring | DIII-D $\sim 10^{-33}-10^{-32}$

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(4) A (GW) center of Ring | ITER $\sim 10^{-29}-10^{-28}$

(4a) A (GW) 5 meters Above Ring | ITER $\sim 10^{-31}-10^{-30}$

3. Enhancing Amplitude; Revisit Ohms Law

Look at surface E field, with [3]

> note: v_R is usually small, can be neglected:

$$E_{\hat{n}} = \left[\frac{d P_j}{d x_n} \cdot \frac{1}{ne} - (v \times B)_n \right] \quad (6)$$

IF

$$(v \times B)_{\hat{n}} \sim v_R B_\theta \quad (7)$$

THEN

> (wesson page 120)

$$E_n = -B_\theta \cdot \left(\frac{j_b}{n_j e_j} + v_R \right) \quad (8)$$

WHERE WE USED [3]

> Page 167, wesson →

$$\frac{d P_j}{d x_n} = -B_\theta \cdot j_b \quad (9)$$

> note: $\xi = \frac{a}{R}$ where a is inner Tokamak ring, R is radial direction

now, 'bounded' current j_b is such that

~~$B_\theta^2 \cdot \left(\frac{j_b}{ne}\right)^2 \sim \frac{B_\theta^2}{e^2} \frac{\xi}{B_\theta^2} n_{drift}^2 \left(\frac{d n_{drift}}{dr}\right)$~~

if

$$j_b \sim -\frac{\xi^{1/2}}{B_\theta} \cdot T \cdot \frac{d n_{drift}}{dr} \quad (10)$$

> (wesson page 167)

Then

$$B_\theta^2 \cdot \left(\frac{j_b}{ne}\right)^2 \sim \frac{B_\theta^2}{e_j^2} \frac{\xi^{1/4}}{B_\theta^2} \left[\frac{1}{n_{drift}} \cdot \left(\frac{d n_{drift}}{dr}\right) \right]^2 \quad (11)$$

(P 7)

If $n_{drift} = n_{drift}|_0 \, e^{\tilde{\alpha} r}$ (12)

Then

$$\frac{1}{n_{drift}} \frac{d n_{drift}}{dr} = \frac{d \ln(n_{drift})}{dr} \quad (13)$$

$$= \tilde{\alpha}$$

Then the 2nd term from Tokamak [redacted] generated GW amplitude, namely from Eq (5), has

$$\frac{G}{c^4} \frac{B_\theta^2 \, \delta b^2}{n_{drift}^2 \, e_{ion}^2} \cdot \lambda_{GW}^2 \sim \frac{G}{c^4} \cdot \left[\frac{\tilde{\alpha}^2 \, \xi^{1/4} \, T_{temp}^2}{e_{ion}^2} \right] \cdot \lambda_{GW}^2 \quad (14)$$

$\sim h$

This assumes using T_{temp}^2 from ignition of Tokamak

$T \sim 10^{\#}$ (fusion) plasma, with strain

$\Rightarrow h \sim 10^{-25}$ for $T_{temp} > 10 KeV$ [3]

Wesson, Page 11

Preliminary calculations

From Wesson [D-T plasma] [3] have a criteria for ignition

$$n_{ion} \, T_{temp} \cdot \tau_E > [3 \times 10^{21} m^{-3} \, KeV] \cdot s \quad (15)$$

where S = seconds, m = meters

If $T_{temp} \sim 10 KeV$,

$n_{ion} \sim 10^{20} m^{-3}$

$\Rightarrow \tau_E \sim 3$ seconds (16)

this for confinement of plasma

Using $T_{temp} \sim 10$ KeV

using $\lambda_{GW} \sim .3$ meters

using $\omega_{GW} \sim 10^9$ ~~HZ~~

Then Eq (14) is approximately 10^{-26}.

Looking at Figure 1.5.1 of Wesson [3], (page 11)

if one increases temp up to $T_{temp} \sim 100$ keV

Then Eq (14) is approximately 10^{-24}

Positioning 3DSR detection device ~5 meters above Tokamak:

$$\frac{G}{c^4} \frac{B_\theta^2 \, \dot{J}_b^2 \, \lambda_{GW}^2}{n_{drift}^2 \cdot e_{ion}^2} \Bigg|_{\substack{5 \text{ meters} \\ \text{above} \\ \text{Tokamak}}} \ll 10^{-26} \qquad (17)$$

P9

4. Can impurities in plasma lengthen τ_E?

TEXTOR Tokamaks

Lengthen τ_E via seeding plasma with impurities ~ say argon, or neon [3]

~ see page 180 [3]

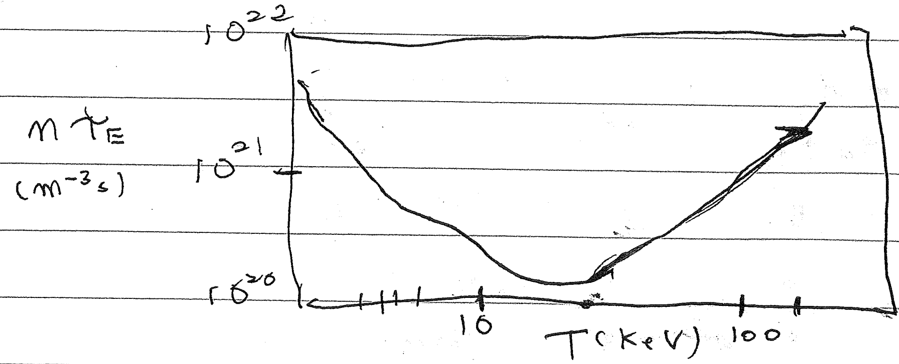
Then

Ref: Wesson, page 180

$\tau_E \propto n_{seeding}$

where $n_{seeding}$ is numerical density of argon/neon in plasma

[See Figure 1.5.1 of Wesson, Page 11



5. conclusion

Limited ohms Law, with $J = \sigma E$ Leads to GW strain amplitude values from 10^{-38} to 10^{-30} for a GW (3DSR) 5 centi-meters above a Tokamak ring.

We add a JB current, & BΘ physics dynamics to GW $A_{GW} \sim \frac{G}{c^4} \cdot E^2 \cdot \lambda_{GW}^2$ with E amplified via an extension of ohms Law,

then $A_{GW} \sim 10^{-24}$ for $T \geq 10$ KeV, and $A_{GW} \sim 10^{-24}$ in center of Tokamak ring. Then $A_{GW} \sim 10^{-26}$ for 3DSR GW detector 5 meters above tokamak ring. note, we used temperature dependence before ion trapping in wesson [3], page 167 for Tokamak for our temperature scaling

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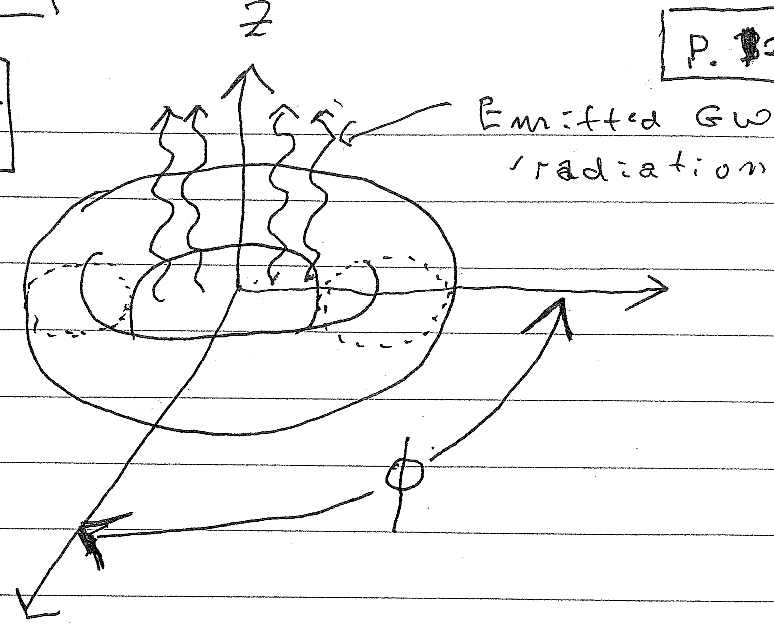
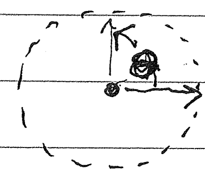
Figures

Fig 1:



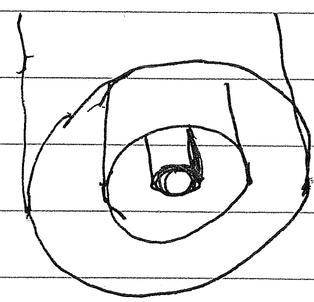
Each 'Face' of the toroid

Fig 2:



← angle of θ, where the co-ordinate system used leads to the following magnetic Flux [illegible] surfaces [3]

Fig 3:



From [3]: magnetic flux surfaces forming a nested set of 'Toroids'