Thermodynamics and the Energy of GW's as a Consequence of NLED, leading to an initial Temperature and strain h for GW at the start of inflation.

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

Using the approximation of constant pressure , a thermodynamic identity for GR as given by Padmanabhan is applied to Early universe graviton production, We build upon an earlier result in doing this calculation. Previously, we reviewed a relationship between the magnitude of an inflaton, the resultant potential, GW frequencies and also GW wavelengths. The NLED approximation makes full use of the Camara et.al. result about density and magnetic fields to ascertain when the density is positive or negative , meaning that at a given magnetic field strength, if one uses a relationship between density and pressure at the start of inflation one can link the magnetic field to pressure. From there an estimated initial temperature is calculated. This temperature scales down if the initial entropy grows.

Key words: cosmological Index factor, inflaton, GW frequencies, GW wavelengths .
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I. Introduction

We will be working with Padmanbhan's[1] statement as to a thermodynamic entity as to cosmology which is written as[1]

$$\frac{\hbar}{c}\cdot\frac{\kappa}{2\pi}\cdot\frac{c^3}{G\hbar}\cdot d\left(\frac{1}{4}\cdot 4\pi\cdot a^2\right)-\frac{1}{2}\cdot\frac{c^4}{G}\cdot da = Pd\left(\frac{4\pi}{3}\cdot a^3\right) \qquad (1)$$

Then

$$\begin{aligned}
&\frac{\hbar}{c}\cdot\frac{\kappa}{2\pi} = k_B T \\
&\frac{c^3}{G\hbar}\cdot d\left(\frac{1}{4}\cdot 4\pi\cdot a^2\right) = k_B^{-1} dS \\
&\frac{1}{2}\cdot\frac{c^4}{G}\cdot da = dE_g \\
&P\cdot d\left(\frac{4\pi}{3}\cdot a^3\right) = P\cdot dV \\
&a = r = horizon - value \\
&\Rightarrow T\cdot dS - dE_g = P\cdot dV
\end{aligned} \qquad (2)$$

The last equation of Eq.(2) below is what will be reviewed, using the lens of having the pressure, small, and constant. Using the idea that pressure is the negative of density in inflation.

II. Reviewing what to do with pressure, using the ideas of inflation

We use that pressure is the negative of density as to how to power inflation. As well as Eq.(2). In doing so the start of the analysis,is to use Eq.(3) below to parameterize pressure and density due to B fields. By [2

$$\rho = \frac{1}{2\mu_0} \cdot B^2 \cdot \left(1 - 8 \cdot \mu_0 \cdot \omega \cdot B^2\right) \tag{3}$$

This has a positive value only if

$$B < \frac{1}{2 \cdot \sqrt{2\mu_0 \cdot \omega}} \tag{4}$$

For fidelity with inflation, we wish to have the magnetic field bounded as given in Eq.(4), i.e. Eq. (4) is necessary for negative pressure, which is only true, initially, if the density is positive, which puts in a major constraint upon the background B field. i.e. we can argue that there would be likely by the electro weak regime, an increase of the magnetic field, probably due to the synthesis of plasmas leading to E and B field generation, but that there would need to be a critical B field strength.so as to make Eq. (3) and Eq.(4) consistent with inflation. In order to evaluate Eq. (2) so as to extract an initial inflationary temperature, we will be considering a critical B field strength relevant as to initial negative pressure which could affect the strength of GW propagation. Finally in the end which wish to have Eq.(3) and Eq.(4) as consistent with the Davis [3] value of vacuum energy density which we write as

$$\rho_{vacuum} \equiv \frac{\Lambda \cdot c^4}{8\pi \cdot G} \sim 10^{-9} erg / cm^3 \tag{5}$$

Davis rules out quiessence (varying the cosmological constant over time) whereas in our application, we will be asking that our value of Eq.(5) is consistent with the High Z super nova search team graph given below in figure 1 .[4] In essence, that means that our calculations as to density would have to reflect the physics of [3] and [5] as given by .

$$\Lambda \geq \Lambda_{\text{minimum}} \sim 2 \times 10^{-35} s^{-2} \sim 10^{-47} GeV^4 \tag{6}$$

The following bound would have to be adhered to, if the cyclic model of the universe as given by Steinhardt and others held [6] then the frequency as given in Eq. (4) would be related to the vacuum energy [6,7]

$$\Lambda \geq \Lambda_{\text{minimum}} \sim \omega^{-1} \sim \mathbf{1 / radiation\ from\ inflation\ frequency} \tag{7}$$

One could realistically that that then, according to Eq.(4) and Eq. (7) that for a small cosmological constant, that the frequency associated due to an early universe magnetic field would be relatively high. I.e. in doing so, this would set the stage for what comes next, namely setting the frequency of radiation from a first principle fashion which will lead to several goals:

a. Getting temperature dependence, as affected by the frequency, ω (NLED used explicitly here)
b. Making a full analysis of the impact of the last equation of the grouping of Eq.(2), taking into account entropy, and a comparison of energy, as will be explained, in our Eq. (12) as given below figure 1 on the next page..
c. A balance of entropy, versus energy will be entertained and used to explain how to contribute to the strength of a signal. I.e. our outrageous suggestion is that if we understand negative pressure, that we will be in turn able to discuss, up to a point, the strain, h, of relic GW. This last topic will be in the latter part of this document. As part of the conclusion. This, also in part will be seen in a rigorous treatment of [8] which has similarities to what is given in [9]

$$m_g^2 = \frac{\tilde{\kappa} \cdot \Lambda_{\max} \cdot c^4}{48 \cdot h \cdot \pi \cdot G} \tag{8}$$

From here, we use the following to isolate out the term **h,** strain, as can be seen in [8]

$$-3m_g^2 h = \frac{\tilde{\kappa}}{2} T \tag{9}$$

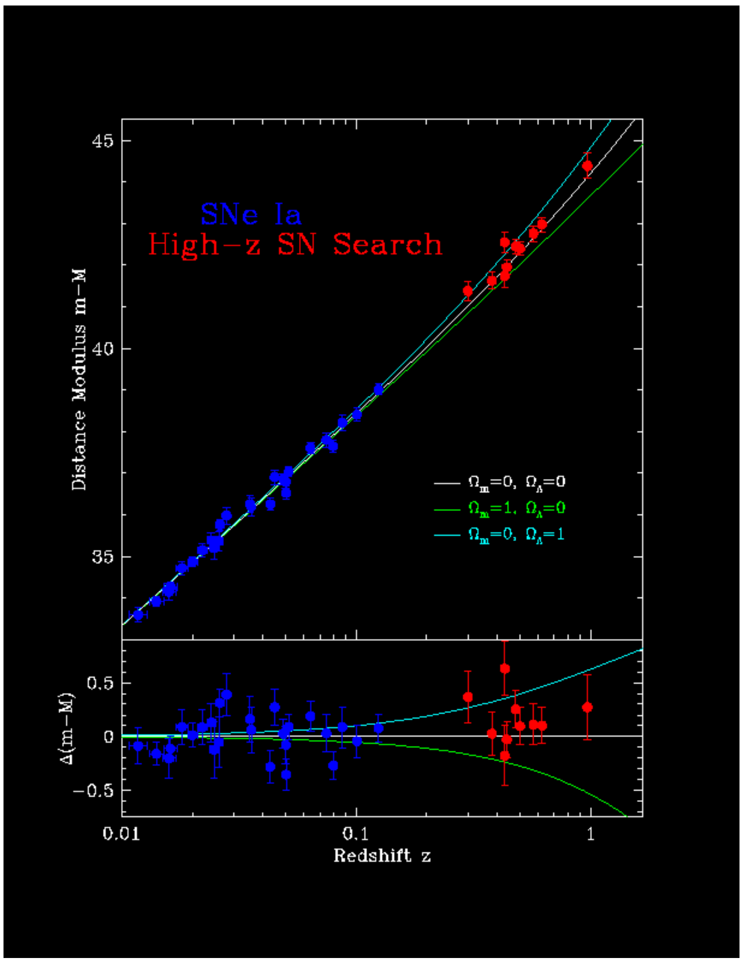
In doing this approximation, we then will read the trace of T (in Eq. (8)) as reading as , in our approximation which has issues and motivation given in [9] but similar to the Davis article [3]

$$T^{ik} = \begin{bmatrix} \hat{\varepsilon} = \rho & 0 & 0 & 0 \\ 0 & p & 0 & 0 \\ 0 & 0 & p & 0 \\ 0 & 0 & 0 & p \end{bmatrix} \Leftrightarrow T = Trace T^{ik} = \left(\hat{\varepsilon} = \rho + 3p \right) = -2\rho_{vacuum} \tag{10}$$

If so, then one has a simple expression for h, as given by

$$h \approx \frac{1}{3} \cdot \frac{\tilde{\kappa}}{m_g^2} \cdot \rho_{vacuum} \tag{11}$$

We will from here, calculate strain **h**, and then set up how to evaluate the initial temperature



- **Figure 1** : (distance/10 pc) so the most distant SN on this plot is at about 7.6 billion pc.) **From [4] . This graph tends to suggest that the cosmological constant is a constant, not variable.**

III. Reviewing what to do with a minimum negative pressure, its importance, and Eq. 2 when examining the strength of relic GW.

To begin with, we make the following approximation as adopted and modified from [1]

$$T \sim \mathrm{S}^{-1} \cdot \left[E_g - \rho \cdot l_p^3 \right] \sim \mathrm{S}^{-1} \cdot \left[\hbar \cdot \omega - \rho \cdot l_p^3 \right] \tag{12}$$

This, above is the temperature, with the S as a measure of initial entropy.If the frequencies in the beginning of this expression are the same as in the density $\rho \cdot$ with the density as given by Eq.(3) then one is observing

$$T \sim S^{-1} \cdot \left[\hbar \cdot \omega - \left(\frac{1}{16\mu_0} \cdot \frac{1}{\mu_0 \cdot \omega} - \frac{8\pi\mu_0}{32\sqrt{2}} \cdot \frac{1}{(\mu_0 \cdot \omega)^{3/2}} \right) \cdot l_p^3 \right] \tag{13}$$

Secondly, we can then look at the strength of the strain as

$$h \approx \frac{1}{3} \cdot \frac{\tilde{\kappa}}{m_g^2} \cdot \left(\frac{1}{16\mu_0} \cdot \frac{1}{\mu_0 \cdot \omega} - \frac{8\pi\mu_0}{32\sqrt{2}} \cdot \frac{1}{(\mu_0 \cdot \omega)^{3/2}} \right) \tag{14}$$

Next, we will consider the input frequencies to be used in t his situation.'

IV. Frequency input into Eq. (13) and Eq. (14)

The basic working tools come from [10] with the following formulations, first of all, the spectral index, defined by, if $\hbar = c = 1$

$$n - 1 = M_{Planck}^2 \cdot \left[3 \cdot \left(\frac{\left[\frac{\partial V}{\partial \phi} \right]}{V} \right)^2 - 2 \left(\frac{\frac{\partial^2 V}{\partial \phi^2}}{V} \right) \right] \tag{15}$$

This should be compared with the e fold equation, as given by

$$N = 70 \cong \frac{1}{M_{Planck}^2} \cdot \int_{\phi_{FINAL}}^{\phi} \frac{V}{\left[\frac{\partial V}{\partial \phi} \right]} \cdot d\phi \tag{16}$$

Eq. (16) is used in tandem with the potential in question to be rendered as

$$V \sim \phi^{\alpha} \tag{17}$$

Furthermore, the potential, reconstructed, is to be compared to a frequency via using the re constructed inflation potential value.

$$E \sim V \sim \omega \tag{18}$$

I.e. after constructing the potential, via Eq.(18), obtaining an initial wave function is given by

$$\lambda_{initial} \sim 1/\omega \tag{19}$$

This initial value of inflation is related to Eq.(16) above via a final value damped by Eq.(16) via

$$\lambda_{initial} \sim \lambda_{final} \cdot \exp(-70) \tag{20}$$

The frequency, initially, is about 2 orders of magnitude larger than the Planck frequency as given below

$$\omega_{Planck} \sim 10^{43}\, Hz \tag{21}$$

The reasons for such statements and their consequences will be the subject of the following article.

V, Showing how to reconstruct the potential (energy)

We write , most likely, that the initial time step is of the order of

$$t_{\min} \approx t_0 \equiv t_{Planck} \sim 10^{-44} s \tag{22}$$

The coefficients of the potential to be worked with in Eq.(17)

$$\frac{n-1}{M_{Planck}^2}\phi_{initial}^2 = -\alpha^2 + 2\alpha \tag{23}$$

We set the initial inflaton via the equation assuming that $\dot{H}$ is a constant, that according to [1]

$$\phi_{initial}^2 = \left[\int \sqrt{-2\dot{H}} \cdot M_{Planck} \cdot dt\right] \approx -2\dot{H} \cdot M_{Planck}^2 \cdot t_{Planck}^2 \tag{24}$$

This assumes that

$$(n-1) \cdot \dot{H} \cdot t_{Planck}^2 \sim \varepsilon^+ \sim small \tag{25}$$

so then that we can use a quadratic value, for a potential which is V given by

$$\begin{aligned}
&\alpha = \alpha_1; \alpha_2 \\
&\alpha_1 \sim \frac{(n-1)}{6} \cdot \dot{H} \cdot t_{Planck}^2 \\
&\alpha_2 = 2 - \alpha_1
\end{aligned} \tag{26}$$

If we pick $A_1 = A; A_2 = 0$, and

$$V \sim A_1\phi^{\alpha_1} + A_2\phi^{\alpha_2} \sim A\phi^{\alpha_1} \tag{27}$$

for initial conditions, then Eq. (16) will yield

$$\begin{aligned}
&V_{\text{inflaton}} \sim A \cdot [1 + \frac{(n-1)}{6} \cdot \dot{H} \cdot t_{Planck}^2] \cdot 280 \cdot M_{Planck}^2 \\
&\sim [1 + \frac{(n-1)}{6} \cdot \dot{H} \cdot t_{Planck}^2] \cdot 280 \cdot M_{Planck} \sim \omega
\end{aligned} \tag{28}$$

To first approximation, the above is giving an initial frequency of

$$280 \cdot M_{Planck} \sim \omega \tag{29}$$

The relevant wavelength is, then approximately 1/ $10^{41} Hz$, or

$$10^{41} Hz \Leftrightarrow \lambda_{initial} \sim 10^{-33} meters \sim 10^2 \times l_{Planck} \tag{30}$$

We will next comment upon the consequences of Eq.(30) and the aftermath.

VI.Conclusion:

Our conclusion is to look at the given frequency, and then the wavelength, taking into account the gigantic expansion from inflation, i.e. the 70 e fold expansion given by inflation. [1] gives us via inflation that Eq.(16) yields , say for Gravity waves, the values

$$\begin{aligned}
&\lambda_{end-of-\text{inflation}} \sim 10^{-8} meters \\
&\omega_{end-of-\text{inflation}} \sim 10^{15} - 10^{16} Hz
\end{aligned} \tag{31}$$

These values, due to an E fold value given through Eq.(16) allow us to state that inflation physics gives us incredibly high initial GW frequencies, which will yield new visas as to how to look at relic GW[1,2] The strain to be considered comes out to $h \sim 10^{-27}$, to be observed, and if the entropy, initially is

$$S \sim S_{initial} \sim 10^5 \neq 0 \tag{32}$$

$$T_{initial} \sim 9 billion \cdot Kelvin \tag{33}$$

Eq.(33) drops if the initial entropy is greater than the value given in Eq.(32), w hich has implications the author will be reviewing.

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