Review of bounds on the graviton mass, from the influence of early universe magnetic fields right at start of inflation

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Abstract: - We use the results of A. Montiel et al, as to the contribution of energy density of non linear magnetic components to RW inflationary physics, as well as the standard of ephemeris time to come up with a standard of bound to early universe graviton mass. In doing so, we also ascertain that using the derived evolution equations that the mass of the graviton today could be different from the early universe value with obtain in closed form. Our results also indicate that quintessence, i.e. a time varying cosmological "constant" parameter, will in the case of large initial values of this "cosmological constant" inevitably lead to a singularity. . If one has a magnetic field contributing to a non zero initial scale factor, we will be assuming that the "cosmological constant" remains invariant during space-time expansion. The case of a fast roll physics treatment of inflation is gone over in the end, as a counter point to some of the discussion so offered. I.e. a fast roll, approximation means that the simple cancellation given below in Eq.(3) is no longer assumed. Which would influence the value of initial graviton mass. I.e. heavy gravity in the case of the elimination of slow roll is almost 20 orders of magnitude larger in initial magnitude for gravitons than the observations today portend for massive gravity.

Key-Words: - **Ephemeris time, massive gravitons, non linear electrodynamics , magnetic universe.**

1 Introduction

We begin looking at the concept of emergent time, as given by[1,2,3]

$$\delta t = \sqrt{\frac{\sum_a m_a \cdot \delta x_a \cdot \delta x_a}{2\cdot(E-V)}} \qquad (1)$$

Our interpretation of Eq(1) is that for early universe gravitons, we write[3,4,5,6]

$$\frac{\delta t}{\delta x} = \frac{\sqrt{m_{graviton}}}{\sqrt{2\cdot(E-V)}} \equiv \frac{\sqrt{m_{graviton}}}{\sqrt{2\cdot\hbar\cdot\sqrt{k^2_{graviton} - \frac{a''}{a} + \frac{1}{3}\cdot(4\pi\rho+\Lambda)}}} \qquad (2)$$

Here, near the onset of inflation, we have a simplification as given by, if at the start of inflation[4,5,6]

$$\left.\frac{a''}{a}\right|_{start-\inf} \sim \left.\frac{2}{\eta^2}\right|_{start-\inf} \equiv \left(2a_{initial}H_{\inf}e^{H_{\inf}\cdot t_{initial}}\right) \to 0^+ \qquad (3)$$

Then we have a graviton mass expression we can write as, if we use the thermal approximation[7]

$$\lambda = \lambda_T = \sqrt{2\pi\hbar^2 / m k_B T} \qquad (4)$$

Then,

$$\hbar \cdot k^2 = m_{graviton}\cdot\left(2\pi k_B T\right) \qquad (5)$$

Then, to good approximation

$$\sqrt{m_{graviton}} \sim 2\left(\delta x/\delta t\right)^2 \sqrt{2\pi k_B T} + \frac{1}{3}\cdot\left(4\pi\rho+\Lambda\right)/\left(2\pi k_B T\right) \qquad (6)$$

The rest of the article will be filling in the terms in Eq. (6) above

2.Including in different values for the Λ & Non Linear Electrodynamics for Eq. (6)

We now will be reviewing how to put in the value of density, namely ρ, as due to the magnetic field in NLED, as given in [6] , where we make some predictions. In order to start this process, we initiate setting

$$\rho \equiv \rho_B = -2^\alpha B_0^{2\alpha}\gamma a^{-4\alpha} = 2^\alpha B_0^{2\alpha}\cdot|\gamma|\cdot a^{-4\alpha} = 2^\alpha B^\alpha\cdot|\gamma| \qquad (7)$$

Then, Eq. (7) becomes, if the magnetic field is scaled as

$$B^\alpha = B_0^{2\alpha}\cdot a^{-4\alpha}; B_0 = \text{integration constant} \ (8)$$

$$\sqrt{m_{graviton}} \sim 2\left(\delta x/\delta t\right)^2 \sqrt{2\pi k_B T} + \frac{1}{3}\cdot\left(4\pi 2^\alpha B^\alpha\cdot|\gamma|+\Lambda\right)/\left(2\pi k_B T\right) \equiv 2\left(\delta x/\delta t\right)^2 \sqrt{2\pi k_B T} + \frac{1}{3}\cdot\left(4\pi 2^\alpha B_0^{2\alpha}\cdot a^{-4\alpha}\cdot|\gamma|+\Lambda\right)/\left(2\pi k_B T\right) \qquad (9)$$

If we are asserting, that initially there is a non zero pressure , with density equal to pressure, then the negative pressure will then yield, instead of Eq.(9) conditions which could lead to , instead

$$\sqrt{m_{graviton}} \sim 2\left(\delta x/\delta t\right)^2 \sqrt{2\pi k_B T} + \frac{1}{3}\cdot\left(-4\pi 2^\alpha B^\alpha\cdot|\gamma|+\Lambda\right)/\left(2\pi k_B T\right) \equiv 2\left(\delta x/\delta t\right)^2 \sqrt{2\pi k_B T} + \frac{1}{3}\cdot\left(-4\pi 2^\alpha B_0^{2\alpha}\cdot a^{-4\alpha}\cdot|\gamma|+\Lambda\right)/\left(2\pi k_B T\right) \qquad (9a)$$

Eq.(9a) i.e. initially a fictitious "negative density" due to negative pressure, is highly speculative, and we do not see evidence of it yet. For the rest of this analysis, we will stick with Eq.(9) while in the conclusion mentioning what Eq. (9a) could portend to.

What we are asserting is, that the very process of an existent M field which contributes to a massive graviton in addition to being a Lorentz violation, also, according a non zero initial radii to the universe. i.e. in [8] there exists a scaled parameter λ, and a parameter a_0 which is paired with α_0. For the sake of argument, we will set the $a_0 \propto 10^{-40}$, with t_{Planck} ~ 10^ - 44 seconds. Also set the following constant value, as

$$\alpha_0 = \sqrt{\frac{4\pi G}{3\mu_0 c}}B \qquad (10)$$

$$\lambda = \Lambda c^2/3 \qquad (11)$$

Our supposition is that the minimum length δx may be about a multiple of Planck length, and the time accessible for Eq. (1) and Eq. (2) may be of the form

$$\delta t << 10^{-20}\ \text{seconds} \qquad (12)$$

Whenever one sees the coefficient like the magnetic field, for large values of Λ, the below Eq.(13) will effectively be zero. If the value of Λ is small, throughout space time evolution, then the initial scale factor could be non zero.[8]

$$a_{\min} = a_0\cdot\left[\frac{\alpha_0}{2\lambda}\left(\sqrt{\alpha_0^2+32\lambda\mu_0\omega B^2}-\alpha_0\right)\right]^{1/4} \qquad (13)$$

3. Specific calculations for the initial scale factor

When one has a small cosmological constant, then one would have [8]

$$a_{\min} = a_0\cdot\left[\frac{\alpha_0}{2\lambda}\left(\alpha_0\sqrt{1+\left(32\lambda\mu_0\omega B^2/\alpha_0^2\right)}-\alpha_0\right)\right]^{1/4} \sim \left(a_0\right)\cdot\left[\mu_0\omega B^2\right]^{1/4} + H.O.T. \qquad (14)$$

When one has a larger cosmological constant, then

$$a_{\min} \sim a_0 \cdot \left(\frac{2\pi G}{3\mu_0 c^2}\right)^{2/8} \cdot \left(\frac{96\mu_0\omega}{\Lambda}\right)^{1/8} \cdot B^{3/4} \quad (15)$$

In the situation with a small cosmological constant, the frequency (of emitted radiation) plus the magnetic field strength, are of paramount important. In Eq.(15), should the cosmological constant say have a temperature dependence, then one has , potentially, a much smaller initial minimum .We next will be justifying the relative size of the Λ

4. Showing How to use a temperature varying Λ, as $\Lambda_{Max} \sim c_2 \cdot T_{temperature}^{\tilde{\beta}}$

A temperature varying quintessence version of vacuum energy is given by [9]

$$\Lambda_{Max} \sim c_2 \cdot T_{temperature}^{\tilde{\beta}} \quad \textbf{(16)}$$

This work, uses reference [9] and we also will be considering the following [5,6]

$$\Lambda(t) > 8\pi G\rho / c^4 \quad (17)$$

Looking at Eq.(16) and also what Eq.(17) is saying, i.e. we can look then at what happens if we look at the Hubble "constant" parameter at the start of the inflationary era which in its most extreme form would be

$$\Lambda(t) \sim \left(H_{\text{inflation}}\right)^2 \quad (18)$$

Eq. (16) to Eq.(18) go straight to the heart of determining if one has initially a "cold" versus a hot initial starting point, i.e. if one has a Planck temperature, it would argue that, if Eq. (16) holds, with a Quintessence time varying cosmological constant, that the initial starting point of expansion is almost certainly about a singular configuration with the initial scale factor zero. If, on the other hand, one does not have a temperature varying cosmological constant, regardless of the magnetic field, there are conditions in which one can avoid the initial singularity condition, as can be seen by looking at Eq.(14). Please see **figure 1** as to a treatment as to what may be admissible in inflation

5: Temperature dependence of graviton mass ?

Ultra high initial temperatures, argue in favour of , if there is no initial singularity, (i.e. the quantum bounce, of Loop quantum gravity), a standard treatment of a constant cosmological "constant" i.e. no quintessence. If initial temperatures are not starting off with an ultra high value for initial conditions, then, even if the cosmological constant has a temperature dependence, then one will looking at a non linear temperature dependent mass value as given by

$$\begin{aligned} &m_{graviton} - \sqrt{m_{graviton}} \cdot \left[2 \cdot \left(\delta x / \delta t\right)^2 \cdot \sqrt{2\pi k_B T}\right] \\ &-2 \cdot \left(\delta x / \delta t\right)^2 \cdot \left[\frac{4\pi}{3} \cdot \rho + \frac{\Lambda}{3}\right] = 0 \end{aligned} \quad (19)$$

If having any given singularity would result in $\delta x = 0$, this means that the mass of a graviton is zero. I.e. we will then examine conditions for which the length would be non zero. Furthermore, we wish to avoid the situation for which $\Lambda \to \infty$,or at least where Λ becomes extremely large. i.e. if we have an ultra low initial temperature just before inflation, then to first approximation, we could have

$$m_{graviton} \sim 2 \cdot \left(\delta x / \delta t\right)^2 \cdot \left[\frac{4\pi}{3} \cdot \rho + \frac{\Lambda}{3}\right] (20)$$

If there exists quintessence with Λ as a function of temperature, but where there is a low temperature, to first approximation, if the density is dependent upon a small magnetic field B[6]

$$\sqrt{m_{graviton}} \sim \frac{4\pi}{3} \cdot 2^{\alpha} B^{\alpha} \cdot |\gamma| / \left(2\pi k_B T\right) \quad (21)$$

As to what is a constraint upon Λ, if the distance d from the initial to the end of inflation inflates from 7.7×10^–30 meters which is only about δx = 480,000 Planck lengths initially, then at the end of inflation, if $\Delta t \sim 10$^–30 seconds

Then [10]

$$d(\text{inf}) \sim \delta x \cdot \exp\left[\Lambda \cdot t / 3\right]\Big|_{t=t(\max)\sim10^{\wedge}-30\text{sec}} \sim 1\text{m} \ (22)$$

And[10]

$$\left[\Lambda \cdot t/3\right]^{1/2}\Big|_{t=t(\max)\sim 10^{\wedge}-30\sec} \geq 50-60 \qquad (23)$$

Then,

$$\begin{aligned}&\Lambda(initial-\inf) > \Lambda(today)\\ &\sim 4\times 10^{-10}\, kg\cdot(\sec)^{-2}\, meter^{-1}\end{aligned} \qquad (24)$$

Estimated values of $\Lambda(initial-\inf)$ may give further values : However The equation for the expansion of the Universe says that it has expanded after inflation by almost exactly a factor of 10^{26} , which is a dramatic slow down from an expansion of 10^{50} after the start of inflation to the end of inflation. Thus, the present horizon at the end of inflation was a sphere about 100 cm across (1 meter, or 3 feet). With a present radius of the magnitude of 10^{26} times larger .At the beginning of inflation, the observable Universe was about 10^{50} to 10^{60}times smaller than that, or a maximum radius of the order of 10^{-48} cm. This is much smaller than any known structure, even the tiniest elementary particle

6. Comparison with fast roll inflation (not slow roll)

In arxiv 1411.5021, v1 [11] , the slow roll approximation is replaced with a scale factor expansion we render as

$$a(fast-roll) = \sinh^{1/(1+w)}[(3+w)\cdot H_{\Lambda}t] \qquad (25)$$

Here, we are assuming that , as in Figure 1, that initial starting time, is of the order of about 10^ - 33 seconds, and ends about 10^ - 30 seconds, but what is noticeable is that if $w \sim -.5$ that much of the dynamics of slow roll are recovered, as would be represented by Figure 1, but that the conformal time, as given by Eq.(16) of arxiv 1411.5021, v1 no longer has the simple cancellation out behaviour of Eq.(3) of our document. I.e. before 10^ - 30 seconds, the constituent equation for graviton mass would look very different if the slow roll approximation is removed. This last point is a detail which we will be investigating in future work. The conclusion is, that initial graviton mass will be influenced by if or not we work with either a slow roll approximation , or the fast roll of arxiv 1411.5021, v1 , and that this is a matter the author is investigating.

7. Conclusions

We note that the Eq.(3) above may be modified by a fast roll approximation, which may be worth looking into, i.e. as part of a recalibration as to graviton mass. The initial graviton mass may be, if slow roll is removed, as high as 10^-43 grams as opposed to a slow roll maximum value of initial graviton mass as high as 10^-48 seconds. Both values should be compared to the Goldberg calculation giving a present day upper bound to graviton mass of about 10^ - 62 to 10^ - 65 grams. If our calculations are correct, then it means that heavy gravity (massive gravitons) had a very different set of upper bound limits as to what may be admissible today by astrophysical observations. We assert that final confirmation of some of these results will await comparing the predictions above with [12]

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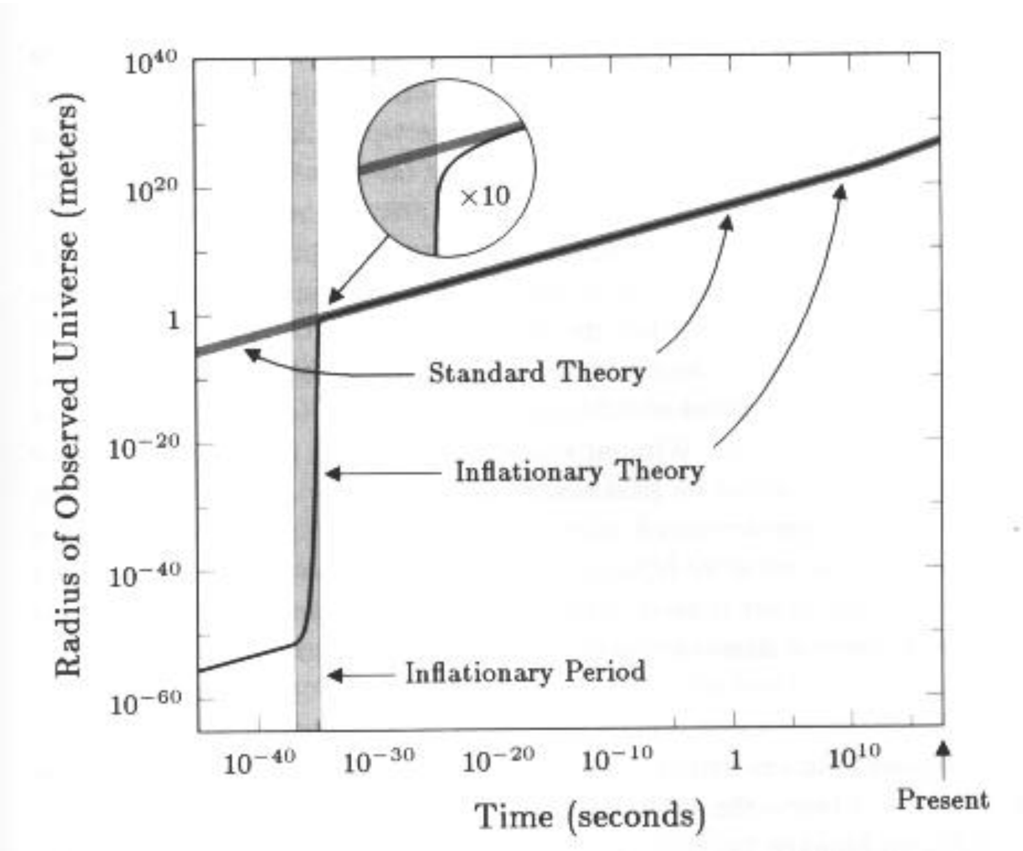

Figure 1 treatment of inflationary physics,