“Order of estimate of graviton mass and its relationship to primordial graviton wavelength”

A. Beckwith[1]
Chongqing University *Department of Physics: Chongqing University*, Chongqing , PRC , 400044

E-mail: abeckwith@uh.edu

Abstract. The following question is asked, how does one get a scaled dimensional value to a non zero graviton mass in the present era, from primordial initial conditions of the universe? Using Valev generated mass of the universe values, as well as a Valev valued radius of the universe in the present era, we derive a massive graviton mass of about 10 to the – 62 grams or $m_g < 2\times 10^{-29} eV \sim 2\times 10^{-38} m_{nucleon}$ which puts severe constraints upon the relic graviton wavelength. In doing so, we affirm that the initial gravitons are massively redshift expanded, while also putting severe constraints upon the Hubble parameter. Doing so means using the Visser stress energy tensor for massive gravitons**. The results so obtained are consistent with massive redshift stretching of primordial EW (or earlier) GW production. If relic GW and gravitons are not forced to be ultra low frequency, then Lavenda’s questions as to the soundness of inflation have to be revisited**

1.**Introduction**

We examine Visser’s [1] treatment of a stress energy tensor for gravitons. This paper specifically forces relic gravitons, should they exist to be ultra low frequency. If this is wrong, this may be a gate way to analyze the arguments given in [2] and [3]. I.e. is massive red shifting of gravitons and gravitational waves from before the electroweak regime necessary? Keep in mind also the oft cited rule of a graviton mass obeying [4], namely $h \equiv \eta^{uv} h_{uv} = Trace\cdot(h_{uv})$ and $T = Trace\cdot\left(T^{uv}\right)$ that

$$-3m_{graviton}^2 h = \frac{\kappa}{2}\cdot T \tag{1}$$

This rule is incorrectly cited as a way of forcing the RHS of Eq. (1) to be zero, and we will use instead the results of Novello and Neves [5] to obtain a graviton mass related to an anti De Sitter cosmological constant as given by

$$-m_g^2 = \frac{2}{3}\Lambda = \frac{2}{3}\Lambda_{AdS/CFT} \tag{2}$$

[1] To whom any correspondence should be addressed.

We then use the analysis of what is given as to the massive graviton equation of Eq. (3) below to really obtain a way to get an exact limit as to non zero graviton mass in the present era. Next we will review Visser's treatment of the stress energy tensor of GR, and its applications. Visser [1] in 1998, stated a stress energy treatment of gravitons along the lines of

$$T_{uv}\big|_{m\neq 0} = \left[\left(\frac{\hbar}{l_P^2\lambda_g^2}\right)\cdot\left(\frac{GM}{r}\right)\cdot\exp\left(\frac{r}{\lambda_g}\right)+\left(\frac{GM}{r}\right)^2\right]\times\begin{bmatrix}4&0&0&0\\0&0&0&0\\0&0&0&0\\0&0&0&0\end{bmatrix} \tag{3}$$

Furthermore, his version of $g_{uv} = \eta_{uv} + h_{uv}$ can be written as setting

$$h_{uv} \equiv 2\frac{GM}{r}\cdot\left[\exp\left(\frac{-m_g r}{\hbar}\right)\right]\cdot\left(2\cdot V_\mu V_\nu + \eta_{uv}\right) \tag{4}$$

If one adds in velocity 'reduction' put in with regards to speed propagation of gravitons[1]

$$v_g = c\cdot\sqrt{1-\frac{m_g^2\cdot c^4}{\hbar^2\omega_g^2}} \tag{5}$$

We will use the above results, combined with a description of a quantum averaged value of a stress energy tensor in the expression given by Birrell and Davies [6] , if $\Lambda = \Lambda_{AdS/CFT} \propto \Lambda_B$,

$$R_{uv} - R\cdot g_{uv} = \left[-\Lambda_B g_{uv} + 8\pi G_B\cdot\langle T_{uv}\rangle\right] \tag{6}$$

The right hand side of Eq. (6) vanishes and we do set $\langle T_{uv}\rangle$ = **The stress energy tensor, Eq.(3).**

In lieu of the wavelength in Eq. (3) is, we can bring up that according to Kim [7] , if the square of the frequency of a graviton, with mass, is >0, and real valued, it is likely that the graviton is stable, at least with regards to perturbations. Kim's article [7] is with regards to Gravitons in brane / string theory, but it is likely that this is the same dynamic for semi classical representations of a graviton with mass. And furthermore the Kim result pertinent to stability plus the right hand side of Eq. (6) will be a way to fix the value of a wave function, and other parameters, especially after we derive an asymptotic value of mass of the graviton, in the present era, from conditions specified by Valev [8] , as to the mass and radius of the Universe we will cite to make some crucial concluding remarks.

2. Conditions permitting not only graviton mass stability but also the limit of graviton mass in the present era.

Looking at Eq. (6) is the same as looking at the following, analyzing how [9] implies stability of the graviton if

$$0 < \frac{1}{6m_g c^2}\left(\frac{\hbar^2}{l_P^2\lambda_g^2}\cdot\exp\left[-\frac{r}{\lambda_g}+\frac{m_g\cdot r}{\hbar}\right]+\left(\frac{MG}{r}\right)\cdot\exp\left(\frac{m_g r}{\hbar}\right)\right) < 1 \tag{7}$$

Note that Visser [1] writes $m_g < 2\times10^{-29}eV \sim 2\times10^{-38}m_{nucleon}$, and a wave length $\lambda_g \sim 6\times10^{22}$ meters. We reference these limits in ascertaining material for what comes next, which is an asymptotic limit for the graviton mass in the present era, assuming that we are measuring gravitons produced at/ before the electro weak era, probably via the mechanism discussed in [10]. To do so we can examine

$$\Lambda = -\left(g_{uv}\right)^{-1} \cdot \left[\frac{8\pi}{3} \cdot G_B \cdot \left\langle T_{uv}\right\rangle\right] = -\frac{3}{2} \cdot m_g^2 \qquad (8)$$

This leads, after some manipulation

$$m_g^2 \sim \frac{64\pi G_B}{9} \cdot \left(g_{uv}\right)^{-1} \cdot \left[\frac{\hbar^2}{l_P^2 \lambda_g^2} \cdot \frac{GM}{r} \cdot \exp\left(\frac{r}{\lambda_g}\right) + \left(\frac{GM}{r}\right)^2\right] \qquad (9)$$

as well as ascertaining the value of Eq. (9) with r the usual distance from a graviton generating source, and M the mass' of an object which would be a graviton emitter put severe restrictions as to the volume of space time values for which r could be ascertained. We use the Valev values [8] for when H is the present Hubble parameter value, so that

$$r(radius-of-universe) \sim cH^{-1} \qquad (10)$$

Also, the mass of the Universe, as given by Valev [8] is

$$M = (\text{Mass}-of-universe) \sim c^3 \cdot 2^{-1} \cdot \left(G \cdot H\right)^{-1} \qquad (11)$$

The author believes that such a configuration would be leading to $\frac{GM}{r} \sim \frac{c^4}{2H^2}$, as of Today

$$m_g^2 \sim \frac{64\pi G_B}{9} \cdot \left[\frac{\hbar^2}{l_P^2 \lambda_g^2} \cdot \frac{c^4}{2H^2} \cdot \exp\left(\frac{c}{H\lambda_g}\right) + \left(\frac{c^4}{2H^2}\right)^2\right] \qquad (12)$$

This mass of a graviton would be stable for spacetime regime well after the Electro Weak transition point in early cosmology evolution.

This criteria for Eq. (12) will lead to the following criteria, i.e. we will write this as a general solution to Eq. (8) for massive gravitons

$$\left[\left(\frac{\hbar}{l_P^2 \lambda_g^2}\right) \cdot \left(\frac{GM}{r}\right) \cdot \exp\left(\frac{r}{\lambda_g}\right) + \left(\frac{GM}{r}\right)^2\right] = Const = c_1 \qquad (13)$$

i.e. using the Valev scaling [8] for mass and radii, from primordial conditions $\frac{GM}{r} \sim \frac{c^4}{2H^2}$

$$\frac{\hbar^2}{l_P^2 \lambda_g^2} \cdot \frac{c^4}{2H^2} \cdot \exp\left(\frac{c}{H\lambda_g}\right) + \left(\frac{c^4}{2H^2}\right)^2 = c_1 \qquad (14)$$

This will give a prediction for enormous GW wavelengths, i.e. maybe up to several light years in length, assuming the enormous value for radii of the universe as given by Eq. (10) in line with Visser's $\lambda_g \sim 6 \times 10^{22}$ meters.

3. Conclusion: THE INITIAL CONFIGURATION FOR RELIC GRAVITON PRODUCTION REFLECTS, A CLASSICAL ARGUMENT GIVING ULTRA LOW GW FREQUENCY

The argument so presented about a 'final' graviton mass from relic GW production ties in with the supposition of massive red shifting, but without reference directly to inflation. While this result is consistent with Visser's stress energy tensor, it should be viewed as preliminary, as a basis of analysis and not the final word. The ultra low graviton frequency so alluded may be amended if there is a way to review the contribution of primordial GW stress energy tensors to other terms as given by Appendix A below which the author will investigate later on. If massive red shifting of relic GW and gravitons is not forced by circumstances, then indeed, as given by [2] and [3] a re thinking of what we think we know of the existence of inflation may be in order.

.

Appendix A: The generalized Stress Energy component of GR considered. Which part we evaluate.

To do this we look at, from [11] a GR Einstein stress energy tensor we write as, with u_a the four vector velocity. Also, ρ is the relativistic energy density, q_a the relativistic momentum density , and p is pressure, and π_{ab} the relativistic anisotropic stress tensor due to viscosity, magnetic fields. ρ has a gravitational radiation component . Effectively, Eq. (A1) has $\rho = \rho_{GW} + \rho_{Everything-else}$ such that

$$\begin{aligned} & T_{ab} = \rho u_a u_b + q_a u_b + u_a q_b p h_{ab} + \pi_{ab} \\ & \Leftrightarrow T_{ab} = T_{GW/Gravtitons} + T_{everthing-else} \end{aligned} \qquad (A1)$$

References

1. M. Visser, http://arxiv.org/pdf/gr-qc/9705051v2
2. 2 B. H. Lavenda and J. Dunning-Davies,"Qualms concerning the inflationary scenario", Foundation of physics letters, Volume 5, number 2, 1990; http://milesmathis.com/dunning.pdf
3. R. C. Tolman,"Relativity and Cosmology",Clarion press, Oxford, UK, 1934
4. M. Maggiore, *Gravitational Waves, Volume 1 : Theory and Experiment,* Oxford Univ. Press(2008).
5. M.Novello and R P Neves, "The mass of the graviton and the cosmological constant", Class. Quantum Grav. **20** (2003) L67–L73
6. N. D. Birrell and P.C. W. Davies," Quantum Fields in Curved Space", Cambridge University Press, 1999
7. J. Y. Kim , http://arxiv.org/pdf/hep-th/0109192v3
8. D. Valev, "Estimation of the total mass and energy of the Universe", http://arxiv.org/pdf/1004.1035.pdf
9. A. Beckwith, http://vixra.org/abs/1006.0027
10. R. Durrer, http://arxiv.org/pdf/1303.7121.pdf; R. Durrer, Massimiliano Rinaldi , Phys.Rev.D79:063507,2009, http://arxiv.org/abs/0901.0650
11. G. Ellis, R. Maartens, and M.A. H. MacCallum;"Relativistic Cosmology", Cambridge University press,2012,Cambridge, U.K