Inquiry as to if Higher Dimensions Can be Used to Unify DM and DE, if Massive Gravitons Are Stable

Andrew Walcott Beckwith[a]

[a]*American Institute of Beam Energy Propulsion / Physics, Life Member,*

Abstract: The following questions are raised. First, can there be a stable (massive) graviton? If so, does this massive graviton, as modeled by KK DM, with a modification of slight 4 dimensional space mass, contribute to DE, at least in terms of re acceleration ? The answer, if one assumes that the square of a frequency for graviton mass is real valued and greater than zero appears to be affirmative. The author, finds evidence that re acceleration of the universe one billion years ago in a higher dimensional setting can be justified in terms of a modification of standard KK DM models, if one considers how an information exchange between present to prior universes occurs, which the author thinks mandates more than four dimensional space time.

Keywords: KK dark matter, DE, re acceleration parameter, massive gravitons.
PACS: 04.50.Cd, 14.70.Kv, 14.80.Rt, 95.35.+d, 95.36.+x, 98.80.-k

INTRODUCTION

As presented in the introduction the article asks first for criteria for massive graviton stability, and then applies stable massive (4 D) gravitons in terms of a KK DM model, with small 4 D graviton mass to obtain re acceleration of the universe a billion years ago. The re acceleration, so presented, is a way to obtain DE, at least in terms of a macro effect in cosmological structure. To look at the problem of massive graviton stability, the author applies a modification[1,2] of Maartens[3] KK representation of DM, with small mass in 4 D, and then using Visser's [4] treatment of a stress energy tensor, comes up with obtaining the square of frequency, of a massive graviton, which is both positive and real valued. The author concludes with a summary of Yurov's[5] double inflation which contribute to understanding figure 1 results which show re acceleration a billion years ago, due to the existence of a stable massive graviton. This would permit a better understanding of Smoot's [6] values for initial information content of the universe as specified in his Paris Observatory talk, 2007.

Identification of Graviton Stability Requirements from Graviton Frequency

If the graviton is, with small mass, stable, then its macro effects show up in the deceleration parameter behavior, indicating re acceleration a billion years ago. We look at work presented by Maggiorie,[7] which specifically delineated for non zero graviton mass, where we write $h \equiv \eta^{uv} h_{uv} = Trace \cdot (h_{uv})$ and $T = Trace \cdot \left(T^{uv}\right)$ that

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

Our work uses Visser's[4] 1998 analysis of non zero graviton mass for both T and h. We will use the above equation with a use of particle count n_f for a way to present initial GW relic inflation density using the definition given by Maggiore [1,2,7] as a way to state that a particle count

$$\Omega_{gw} \equiv \frac{\rho_{gw}}{\rho_c} \equiv \int_{f=0}^{f=\infty} d(\log f) \cdot \Omega_{gw}(f) \Rightarrow h_0^2 \Omega_{gw}(f) \cong 3.6 \cdot \left[\frac{n_f}{10^{37}}\right] \cdot \left(\frac{f}{1kHz}\right)^4 \tag{2}$$

where n_f is the frequency-based numerical count of gravitons per unit phase space. To do so, let us give the reasons for using Visser's [4] values for T and h above, in Eqn. (1).

We begin our inquiry by initially looking at a modification of what was presented by R. Maartens [3] , as done by Beckwith [1,2]

$$m_n(Graviton) = \frac{n}{L} + 10^{-65} \text{ grams} \tag{3}$$

On the face of it, assignment of a mass of about 10^{-65} grams for a 4 dimensional graviton, allowing for $m_0(Graviton - 4D) \sim 10^{-65}$ grams[1,2] violates all known quantum mechanics, and is to be avoided. Numerous authors, including Maggiore[7] have demonstrated how adding a term to the Fiertz Lagrangian for gravitons, and assuming massive gravitons leads to results which appear to violate field theory

Visser's Treatment of a Stress Energy Tensor for Massive Gravitons

Visser[4] in 1998, stated a stress energy treatment of gravitons along the lines of

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

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

$$h_{uv} \equiv 2 \frac{GM}{r} \cdot \left[\exp\left(\frac{-m_g r}{\hbar}\right)\right] \cdot \left(2 \cdot V_\mu V_\nu + \eta_{uv}\right) \tag{5}$$

If one adds velocity 'reduction' put in with regards to speed propagation of gravitons[5]

$$v_g = c \cdot \sqrt{1 - \frac{m_g^2 \cdot c^4}{\hbar^2 \omega_g^2}} \tag{6}$$

One can insert all this into Eqn. (1) to obtain a real value for the square of frequency > 0, i.e.

$$\hbar^2 \omega^2 \cong m_g^2 c^4 \cdot \left[1 \big/ \left(1 - \breve{A}\right)\right] > 0 \tag{7}$$

$$\breve{A} = \left\{1 - \frac{1}{6 m_g c^2}\left(\frac{\hbar^2}{l_P^2 \lambda_g^2} \cdot \exp\left[-\frac{r}{\lambda_g} + \frac{m_g \cdot r}{\hbar}\right] + \left(\frac{MG}{r}\right) \cdot \exp\left(\frac{m_g r}{\hbar}\right)\right)\right\}^2 \tag{8}$$

According to Kim [8], if the square of the frequency of a graviton, with mass, is >0, and real valued, it is likely that the graviton is stable, with regards to perturbations. Kim's article [11] is with regards to Gravitons in brane / string theory, but it is likely that the same dynamic for semi classical representations of a graviton with mass. Conditions for a positive value of the square of frequency in Eqn. (7) is the same as analyzing conditions for when the following inequality holds, in terms of parameter space values for the variables in Eqn. (9) below. Eqn. (9) allows for stable giant gravitons.

$$0 < \frac{1}{6 m_g c^2}\left(\frac{\hbar^2}{l_P^2 \lambda_g^2} \cdot \exp\left[-\frac{r}{\lambda_g} + \frac{m_g \cdot r}{\hbar}\right] + \left(\frac{MG}{r}\right) \cdot \exp\left(\frac{m_g r}{\hbar}\right)\right) < 1 \tag{9}$$

Given Eqn. (9) Being Satisfied for Stable Giant Gravitons, How to Obtain Re Acceleration of the Universe a Billion Years Ago

Beckwith[1,2] used a version of the Friedman equations as inputs into the deceleration parameter using Maarten's[3]

$$\dot{a}^2 = \left[\left(\frac{\tilde{\kappa}^2}{3}\left[\rho + \frac{\rho^2}{2\lambda}\right]\right) a^2 + \frac{\Lambda \cdot a^2}{3} + \frac{m}{a^2} - K\right] \tag{10}$$

Maartens [3] also gives a 2nd Friedman equation, as

$$\dot{H}^2 = \left[-\left(\frac{\tilde{\kappa}^2}{2} \cdot [p + \rho] \cdot \left[1 + \frac{\rho^2}{\lambda}\right]\right) + \frac{\Lambda \cdot a^2}{3} - 2\frac{m}{a^4} + \frac{K}{a^2}\right] \tag{11}$$

Also, if we are in the regime for which $\rho \cong -P$, for red shift values z between zero to 1.0-1.5 with exact equality, $\rho = -P$, for z between zero to **.5.** The net effect will be to obtain, due to Eq. (12)**,** and use $a \equiv [a_0 = 1]/(1+z)$. As given by Beckwith[1,2]

$$q = -\frac{\ddot{a}a}{\dot{a}^2} \equiv -1 - \frac{\dot{H}}{H^2} = -1 + \frac{2}{1 + \tilde{\kappa}^2 [\rho / m] \cdot (1+z)^4 \cdot (1 + \rho \ \ /2\lambda)} \approx -1 + \frac{2}{2 + \delta(z)} \tag{12}$$

Eq. (12) assumes $\Lambda = 0 = K$, and the net effect is to obtain, a substitute for DE, by presenting how gravitons with a small mass done with $\Lambda \neq 0$, even if curvature **K** =0

Re Acceleration of the Universe, at Z ~.423 due to Giant Gravitons?

In a revision of Alves *et. al,* [9] Beckwith[1,2] used a higher-dimensional model of the brane world and Marsden[3] KK graviton towers. The density ρ of the brane world in the Friedman equation as used by Alves *et. al*[9] is use by Beckwith[1,2] for a non-zero graviton

$$\rho \equiv \rho_0 \cdot (1+z)^3 - \left[\frac{m_g \cdot (c=1)^6}{8\pi G (\hbar = 1)^2} \right] \cdot \left(\frac{1}{14 \cdot (1+z)^3} + \frac{2}{5 \cdot (1+z)^2} - \frac{1}{2} \right) \tag{13}$$

I.e. Eqn. (3) above is making a joint DM and DE model, with all of Eq. (12) being for KK gravitons and DM, and 10^{-65} grams being a 4 dimensional DE. Eq. (13) is part of a KK graviton presentation of DM/ DE dynamics. Beckwith[1,2] found at z ~ **. 423**, a billion years ago, that acceleration of the universe increased, as shown in Figure 1.

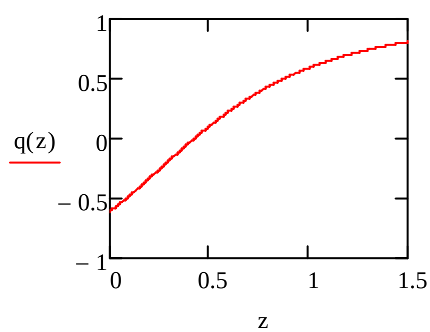

FIGURE 1 : Reacceleration of the universe based on Beckwith [1,2] (note that q < 0 if z< .423).

Given Eqn. (9), and Figure 1, Can Initial Inflation be Linked to Figure 1's Results ?. Examining Yurov's "Double Inflation"

The following is speculative, and if confirmed through additional research would be a major step toward a cosmological linkage between initial inflation, and re acceleration of the universe one billion years ago. Look at A. Yurov's [5] double inflation hypothesis, i.e. Claim: there exist one emergent complex scalar field Φ and that its evolution in both initial inflation and re acceleration is linked. I.e. he states that this scalar field would.account for both 1st and 2nd inflation

- Potential in both cases chaotic inflation of the type [5]

$$V = \vec{\vec{m}}^2 \Phi^* \Phi \tag{14}$$

The "mass" term would be, then, as Beckwith[1,2] understands it, for early universe versions of the Friedman equation

$$\vec{\vec{m}} \approx \sqrt{\frac{3}{8}} \cdot \left[\sqrt{\frac{3H^2}{4\pi G}}\Bigg|_{time \sim 10^{-35}\sec} + \sqrt{\frac{3H^2}{4\pi G}}\Bigg|_{time \sim 10^{-44}\sec} \right] \tag{15}$$

Furthermore, its bound would be specified by having

$$\left|\vec{\vec{m}}\right| \leq \left[\frac{l^2}{4}\right] \tag{16}$$

The term, l would be an artifact of five dimensional space time, as provided in a metric as given by Maarten's [3] as

$$dS^2\Big|_{5-\dim} = \frac{l^2}{z^2} \cdot \left[\eta_{uv} dx^\mu dx^\nu + dz^2\right] \tag{17}$$

The 2nd scalar fields as Yurov [5] writes them contributing to the 2nd inflation, which Beckwith represents in figure 1 are:

$$\phi_{0,-} = \sqrt{2/3} \cdot \vec{\vec{m}} \cdot \left[t_{1st-EXIT} \sim 10^{-35}\sec\right] \tag{18}$$

And

$$\phi_+ = \left[\phi_{0,+}^3 - \sqrt{3/2} \cdot \frac{3M^2 t}{\vec{\vec{m}}}\right]^{1/3} \tag{19}$$

As Beckwith sees it, making a full linkage between Yurov's formalism[5] for double inflation, Beckwith's Figure 1, and initial inflationary dynamics, as referenced by obtaining $n_f \approx 10^6 \, to \cdot 10^7$ would be to make the following relations between Yurov's[5] versions of the Friedman equations, and what Beckwith[1,2] did, in terms of Figure 1 above.

$$H^2 = \frac{1}{6} \cdot \left[\dot{\phi}^2 + \vec{\vec{m}}^2 \phi^2 + \frac{M^2}{\phi^2}\right] \leftrightarrow \left(\frac{\tilde{\kappa}^2}{3}\left[\rho + \frac{\rho^2}{2\lambda}\right]\right) + \frac{m}{a^4} \tag{20}$$

As well as having:

$$\dot{H} = V - 3H \leftrightarrow \dot{H} \cong \frac{2m}{a^4} \qquad (21)$$

The left hand side of both Eqn (20) and Eqn (21) are Yurov's[5], and the right hand side of both Eqn. (20) and Eqn (21) above are Beckwith's adaptation of modification of Maarten's [3] brane theory work which was used in part to obtain the results given in FIGURE 1 above, i.e. the behavior of massive gravitons one billion years ago to mimic DE in terms of the re acceleration parameter. Filling in the details for Eqn (14) to Eqn (21) would, if confirmed and linked to Figure 1 above a way to come up with a more comprehensive cosmological picture of the linkage of geometry and space time evolution than what exists today. The author, Beckwith ,asserts that making the inter relationships between the Yurov[5] and Figure 1 Friedman equation choices work involves making the following assumption which may be falsified by experiment.

$$\frac{3H^2}{4\pi G} >> V(t)\Big|_{time \sim 10^{-44}\,\mathrm{sec}} \qquad (22)$$

i.e. that the potential energy, V, of initial inflation is initially over shadowed by the contributions of the Friedman equation, H, at the onset of inflation. If this Eqn. (22) is false, or falsified, then the form of making inter relationships between the components of Eqn (20) and Eqn (21) probably should be re considered.

CONCLUSION

The end result of a massive graviton may also lead to information exchange between a prior to our present universe as has commented upon by Beckwith[1,2.] . Note that Beckwith[1,2] has used Y. Ng's counting algorithm[10] with regards to entropy, and non zero mass (massive) gravitons , where

$$S \approx N \cdot \left(\log\left[V/\lambda^3\right] + 5/2\right) \approx N \qquad (23)$$

Furthermore, making an initial count of gravitons with $S \approx N \sim 10^7$ gravitons[7,] with Seth Lloyd's [2,11]

$$I = S_{total} / k_B \ln 2 = \left[\#operations\right]^{3/4} \sim 10^7 \qquad (24)$$

as implying at least one operation per unit graviton, with gravitons being one unit of information, per produced graviton[7]. Note**,** Smoot [6] gave initial values of the operations as

$$\left[\#operations\right]_{initially} \sim 10^{10} \qquad (25)$$

It would be useful to determine if there were inter connections between the parameter space defined by Eqn. (9) above , in terms of input variables, and optimal conditions as well for both Eqn (24) and Eqn. (25) to be confirmed experimentally. In addition, the author hopes for understanding optimal space time geometric conditions for the development of KK particle physics allowing for implementation of Eqn (24) above, which assumes stable giant gravitons are possible. The number of operations , if tied into bits of 'information' may allow for space time linkages of the following value of the fine structure constant, as given in Eqn. (26) below from a prior to a present universe, once initial conditions of inflation may be examined experimentally, i.e. looking at inputs into [1,2]

$$\tilde{\alpha} \equiv e^2 / \hbar \cdot c \equiv \frac{e^2}{d} \times \frac{\lambda}{hc} \tag{26}$$

After this is done, then the next step would be to look at inputs into the near the present time value for a Friedman equation, leading to fuller understanding of Eqn (12) above. All this is possible if a non brane theory version of stability of the graviton, is obtained, if an extension of Kim's [8] frequency based criteria as to giant graviton stability is confirmed, experimentally. It would also confirm Alcubierre's[12] energy flux expression for GW, which the author used . Finally the author hopes that filling in the steps to give exact representations of Eqn. (14) to Eqn (21) can commence in the future with researchers smart enough to do that job.

Finally, the author would like to more fully understand more on how to apply Valev's[13] graviton wave length calculations, as given by

$$\begin{aligned} & m_{graviton}\Big|_{RELATIVISTIC} < 4.4 \times 10^{-22}\, h^{-1} eV / c^2 \\ & \Leftrightarrow \lambda_{graviton} \equiv \frac{\hbar}{m_{graviton} \cdot c} < 2.8 \times 10^{-8}\, meters \end{aligned} \tag{27}$$

The inter relationship of that wave length calculation with Alcubierre's gravity wave energy flux[12] as given by Eqn. (28) below was commented upon by Beckwith in an inexact form in his DSU 2010 talk on June 5th, in the morning

$$\frac{dE}{dt} = \left[\lim r \to \infty\right]\left[\frac{r^2}{16\pi}\right]\oint\left|\int_{-\infty}^{t} \Psi_4 dt'\right|^2 \cdot d\Omega \tag{28}$$

Key to making better use of an inter relationship between Eqn. (27) and Eqn. (28), as the author, Beckwith, calls it would be a better understanding of the observationally based Friedman equation, as given below by Sanders [14], namely

$$H_{friedman} \equiv \left[\left(T_{temp}\right)^2 / c\right] \cdot \sqrt{N(T_{temp})} \cdot \sqrt{\frac{4\pi G \cdot \hat{a}}{3}} \tag{29}$$

The electro weak boundary of the number of degrees of freedom, as presented by Kolb and Turner[15]

$$N(T_{temp})\big|_{Electro-weak} \sim 10^2 \qquad (30)$$

In contrast, early universe, near the big bang values may have $N(T_{temp}) \sim 10^3$. Obviously, obtaining better values of the degrees of freedom, as Beckwith [16] tried to do, June 5, 2010 , in early to later universe conditions would be of crucial importance toward that goal. Note, also, that if Eqn. (6) had graviton speed as the speed of light, that none of the graviton stability considerations would apply, and this analysis , as given above would be moot.

ACKNOWLEDGMENTS

Dr. Lukasz Glinka is thanked for encouraging the author to think of semi-classical and Wheeler-DeWitt style issues applied to physics, and their relevance to the research areas of cosmology and gravity. Dr. Fangyu Li of Chongqing University (China) is thanked for lending his personal notes to give substance to the content of page 10 of the companion document that complements this article , plus his week-long hospitality to the author in China .Dr. Christian Corda is thanked for encouraging the author to explore semi-classical issues in GW and in GR, and who forwarded the Alves et al. document to the author to expand the author's scientific horizon. In addition, the author thanks the DSU 2010 staff for their hospitality and the author thanks Dr. Debasish Majumdar of the Saha Institute, India, for insuring the author addressed giant graviton stability in his write up for DSU 2010. All these individuals affected the presentation of this document as given on June 5th ,2010 [16]

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