

**Bounds upon Graviton Mass – using the difference  
between graviton propagation speed and HFGW transit  
speed to observe post-Newtonian corrections to  
gravitational potential fields**

**Updated to take into account early universe cosmology and  
Penrose's cyclic conformal cosmology**

Andrew Beckwith  
Chongqing University Department of Physics;  
E-mail: [abeckwith@uh.edu](mailto:abeckwith@uh.edu)  
Chongqing, PRC, 400044

The author presents a post-Newtonian approximation based upon an earlier argument in a paper by Clifford Will as to Yukawa revisions of gravitational potentials, in part initiated by gravitons having explicit mass dependence in their Compton wave length. Prior work with Clifford Will's idea was stymied by the application to binary stars and other such astrophysical objects, with non-useful frequencies topping off near 100 Hertz, thereby rendering Yukawa modifications of Gravity due to gravitons effectively an experimental curiosity which was not testable with any known physics equipment. This work improves on those results.

Key words: Graviton mass, Yukawa potential, Post Newtonian Approximation

## 1. Introduction

Post-Newtonian approximations to General Relativity have given physicists a view as to how and why inflationary dynamics can be measured via deviation from simple gravitational potentials. One of the simplest deviations from the Newtonian inverse power law is a Yukawa potential modification of gravitational potentials. It is apparent that a graviton's mass (assuming it is massive) would factor directly into the Yukawa exponential term modification of gravity. This present paper tries to indicate how a smart experimentalist could use a suitably configured gravitational wave detector as a way to obtain more realistic upper bounds for the mass of a graviton, and explores how to use this idea as a template to investigate modifications of gravity along the lines of a Yukawa potential modification as given by Clifford Will. **Appendix A** summarizes why we think gravitons should be massive, i.e. having a small rest mass. We will show how our findings dovetail with a larger than Planck length radius of the initial universe, and its connections with both cyclic conformal cosmology (Penrose) and recycled information (from previous cycles) into a new universe. Presumably the information transferred via massive Gravitons will be responsible for setting Planck's constant at a particular value at the onset of a new universe.

Secondly, this paper will address an issue of great import to the development of experimental gravity. Namely, if an upper mass to the graviton mass is identified; can an accelerator physicist use the theoretical construction Eric Davis posited in his book in the section "Producing Gravitons via Quantization of the coupled Maxwell-Einstein fields" for obtaining an experimental bound to the graviton mass, to refine our understanding of graviton Synchrotron radiation. A brief review of Chen, Chen, and Noble's application of the Gersenshtein effect will be made, to potentially improve their statistical estimates of the range of graviton production.

## 2. Giving an upper bound to the mass of a graviton.

The easiest way to ascertain the mass of a graviton is to investigate if or not there is a slight difference in the speed of graviton 'particle' propagation and that of HFGW in transit from a 'source' to the detector. Visser's (1998) mass of a graviton paper presents a theory which passes the equivalence test, but which has possible problem with depending upon a non-dynamical background metric. Note that gravitons are assumed by both Visser, and also in Clifford Will's write up of experimental GR, to have mass

This document also accepts the view that there is a small graviton mass, which the author has estimated to be on the order of  $10^{-60}$  kilograms. This is small enough so the following approximation is valid. Here,  $v_g$  is the speed of graviton 'propagation',  $\lambda_g$  is the Compton wavelength of a graviton with  $\lambda_g = h/m_g c$ , and  $f \approx 10^{10}$  Hertz in line with L. Grischuck's treatment of relic HFGWs. In addition, the high value of relic HFGWs leads to naturally fulfilling  $hf \gg m_g c^2$  so that

$$v_g/c \approx 1 - \frac{1}{2} \cdot (c/\lambda_g \cdot f)^2 \quad (1)$$

But equation (1) above is an approximation of a much more general result which may be rendered as

$$\left(v_g/c\right)^2 \equiv 1 - \left(m_g c^2/E\right)^2 \quad (2)$$

The terms  $m_g$  and E refers to the graviton rest mass and energy, respectively. Now Physics researchers can ascertain what E is, with experimental data from a gravitational wave detector, and the next question needs to be addressed, relating to Visser's model. Namely; if D is the distance between a detector and the source of a HFGW/ Graviton emitter source

$$1 - v_g/c = 5 \times 10^{-17} \cdot \left[ \frac{200 \text{Mpc}}{D} \right] \cdot \left( \frac{\Delta t}{1 \text{sec}} \right) \quad (3)$$

The above formula depends upon,  $\Delta t = \Delta t_a - (1+Z) \cdot \Delta t_e$  with where  $\Delta t_a$  and  $\Delta t_e$  are the differences in arrival time and emission time of the two signals (HFGW and Graviton propagation), respectively, and Z is the redshift of the source.

Specifically, the situation for HFGW is that for early universe conditions, that  $Z \geq 1100$ , in fact for very early universe conditions in the first few milliseconds after the big bang, that  $Z \sim 10^{25}$ . This is an enormous number.

The first question which needs to be asked is, if the Visser non-dynamical background metric is correct, for early universe conditions so as to avoid the problem of the limit of small graviton mass does not coincide with pure GR, and the predicted perihelion advance, for example, violates experiment. A way forward would be to configure data sets so in the case of early universe conditions that one is examining appropriate  $Z \gg 1100$  but with extremely small  $\Delta t_e$  times, which would reflect upon generation of HFGW before the electro weak transition, and after the INITIAL onset of inflation.

I.e. a Gravitational wave detector system should be employed as to pin point experimental conditions so to high accuracy, the following is an adequate presentation of the difference in times,  $\Delta t$ . I.e.

$$\Delta t = \Delta t_a - (1+Z) \cdot \Delta t_e \rightarrow \Delta t_a - \varepsilon^+ \approx \Delta t_a \quad (4)$$

The closer the emission times for production of the HFGW and Gravitons are to the time of the initial nucleation of vacuum energy of the big bang, the closer we can be to experimentally using equation (4) above as to give experimental criteria for stating to very high accuracy the following.

$$1 - v_g/c \cong 5 \times 10^{-17} \cdot \left[ \frac{200 \text{Mpc}}{D} \right] \cdot \left( \frac{\Delta t_a}{1 \text{sec}} \right) \quad (5)$$

More exactly this will lead to the following relationship which will be used to ascertain a value for the mass of a graviton. By necessity, this will push the speed of graviton

propagation very close to the speed of light. In this, we are assuming an enormous value for D

$$v_g/c \cong 1 - 5 \times 10^{-17} \cdot \left[ \frac{200Mpc}{D} \right] \cdot \left( \frac{\Delta t_a}{1sec} \right) \quad (6)$$

This equation (6) relationship should be placed into  $\lambda_g = h/m_g c$ , with a way to relate this above value of  $(v_g/c)^2 \cong 1 - (m_g c^2/E)^2$ , with an estimated value of E as an average value from field theory calculations, as well as to make the following argument rigorous, namely

$$\left[ 1 - 5 \times 10^{-17} \cdot \frac{200Mpc}{D} \cdot \frac{\Delta t_a}{1sec} \right]^2 \cong 1 - \left( \frac{m_g c^2}{E} \right)^2 \quad (7)$$

A suitable numerical treatment of this above equation, with data sets could lead to a range of bounds for  $m_g$ , as a refinement of the result given by Clifford Will for graviton Compton wavelength bounded behavior for a lower bound to the graviton mass, assuming that  $h$  is the Planck's constant.

$$\begin{aligned} \lambda_g \equiv \frac{h}{m_g c} &> 3 \times 10^{12} km \cdot \left( \frac{D}{200Mpc} \cdot \frac{100Hz}{f} \right)^{1/2} \cdot \left( \frac{1}{f \Delta t_a} \right)^{1/2} \\ &\cong 3 \times 10^{12} km \cdot \left( \frac{D}{200Mpc} \cdot \frac{100Hz}{f} \right)^{1/2} \cdot \left( \frac{1}{f \Delta t_a} \right)^{1/2} \end{aligned} \quad (8)$$

The above equation (8) gives an upper bound to the mass  $m_g$  as given by

$$m_g < \left( \frac{c}{h} \right) / 3 \times 10^{12} km \cdot \left( \frac{D}{200Mpc} \cdot \frac{100Hz}{f} \right)^{1/2} \cdot \left( \frac{1}{f \cdot \Delta t_a} \right)^{1/2} \quad (9)$$

Needless to say, an estimation of the bound for the graviton mass  $m_g$ , and the resulting Compton wavelength  $\lambda_g$  would be important to get values of the following formula for experimental validation

$$V(r)_{gravity} \cong \frac{MG}{r} \exp(r/\lambda_g) \quad (10)$$

Clifford Will gave for values of frequency  $f \equiv 100$  Hertz enormous values for the Compton wavelength, i.e. values like  $\lambda_g > 6 \times 10^{19} km$ . Such enormous values for the Compton wavelength make experimental tests of equation (10) practically infeasible.

Values of  $\lambda_g \approx 10^{-5}$  centimeters or less for very high HFGW data makes investigation of equation (10) above far more tractable.

### 3. Application to Gravitational Synchrotron radiation, in accelerator physics

Eric Davis, quoting Pisen Chen's article written in 1994 estimates that a typical storage ring for an accelerator will be able to give approximately  $10^{-6} - 10^3$  gravitons per second. Quoting Pisen Chen's 1994 article, the following for graviton emission values for a circular accelerator system, with  $m$  the mass of a graviton, and  $M_p$  being the Planck mass.  $N$  as mentioned below is the number of 'particles' in a ring for an accelerator system, and  $n_b$  is an accelerator physics parameter for bunches of particles, which for the LHC is set by Pisen Chen to the value of 2800, and  $N$  for the LHC is about  $10^{11}$ . And, for the LHC Pisen Chen sets  $\gamma$  at  $0.88 \times 10^2$ , with  $\rho[m] \approx 4300$ . Here,  $m \sim m_{graviton}$  acts as a mass charge.

$$N_{GSR} \sim 5.6 \cdot n_b^2 \cdot N^2 \cdot \frac{m^2}{M_p^2} \cdot \frac{c \cdot \gamma^4}{\rho} \quad (11)$$

The immediate consequence of the prior discussion would be to obtain a more realistic set of bounds for the graviton mass, which could considerably refine the estimate of  $10^{11}$  gravitons produced per year at the LHC, with realistically  $365 \times 86400 \text{ seconds} = 31536000 \text{ seconds}$  in a year, leading to  $3.171 \times 10^3$  gravitons produced per second. Refining an actual permitted value of bounds for the accepted graviton mass,  $m$ , as given above, while keeping  $M_p \sim 1.2209 \times 10^{19} \text{ GeV}/c^2$  would allow for a more precise value for gravitons per second which significantly enhances the chance of actual detection, since right now for the LHC there is too much general uncertainty about where to place a detector for actually capturing / detecting a graviton.

### 4. Conclusion, falsifiable tests for the Graviton are closer than the physics community thinks

The physics community now has an opportunity to experimentally infer the existence of gravitons as a knowable and verifiable experimental datum with the onset of the LHC as an operating system. Even if the LHC is not used, Pisen Chen's parameterization of inputs from the table right after his equation (8) as inputs into equation (11) above will permit the physics community to make progress toward the detection of Gravitons for, say the Brookhaven laboratory site circular ring accelerator system. See **Appendix B** for that table. Tony Rothman's statement about needing a detector the size of Jupiter to obtain a single experimentally falsifiable set of procedures is defensible only if the wave-particle duality induces so much uncertainty as to the mass of the purported graviton, that worst case model building and extraordinarily robust parameters for a Rothman style graviton detector have to be put in place.

A suitably configured detector can help with bracketing a range of masses for the graviton, as a physical entity subject to measurements, without needing to be so massive. Such an effort requires obtaining rigorous verification of the approximation used to the

effect that  $\Delta t = \Delta t_a - (1+Z) \cdot \Delta t_e \rightarrow \Delta t_a - \varepsilon^+ \approx \Delta t_a$  is a defensible approximation. Furthermore, having realistic estimates for distance  $D$  as inputs into equation (9) above is essential.

The expected pay offs of making such an investment would be to determine the range of validity of equation (10) , i.e. to what degree is gravitation as a force is amendable to post Newtonian approximations.

The author asserts that equation (10) can only be realistically be tested and vetted for sub atomic systems, and that with the massive Compton wavelength specified by Clifford Will cannot be done with low frequency gravitational waves.

Furthermore, a realistic bounding of the graviton mass would permit a far more precise calibration of equation (11) as given by Pisen Chen in his 1994 article. We refer the reader to **Appendix C** for how we expect that Eq. (11) and **Appendix A**, Eq. (A4) may be combined to yield experimentally falsifiable tests for a massive graviton.

Note that **Appendix D** gives the details of how Yurov links both initial inflation and the speed up of acceleration of the universe a billion years ago. Also, if gravitons are linkable to DE, as stated by Beckwith's Journal of cosmology publication (2011), in the present era, and if gravitons are super partnered with Gravitinos as stated by Beckwith (2013), Kauffman's non zero initial radius becomes essential, and we also have a description of how the fine structure constant over time, as given by Appendix C, Eq. (C2) , could be invariant. That in turn would lead to Planck's constant being invariant from cosmological cycle to cycle without invoking the Anthropic principle. As well as also keeping track of how the following would be possible at the electro weak era.

Note, from Valev,

$$m_{graviton}|_{RELATIVISTIC} < 4.4 \times 10^{-22} h^{-1} eV / c^2 \quad (12)$$

$$\Leftrightarrow \lambda_{graviton} \equiv \frac{\hbar}{m_{graviton} \cdot c} < 2.8 \times 10^{-8} \text{ meters}$$

Extending M. Marklund *et al.* and Valev , some gravitons may become larger , i.e. due to red shifting as given by Clifford Will.

$$\lambda_{graviton} \equiv \frac{\hbar}{m_{graviton} \cdot c} < 10^4 \text{ meters or larger} \quad (13)$$

The author maintains that the information necessary for both Eq. (12) and Eq. (13) plus space-time geometry , as well as DM and DE linked as given by Beckwith(2013) states require the finite initial radius result (Kauffman) with initially in the electro weak era, tiny HFGW as given by Eq.(12) super partnered with gravitinos. We hope for experimental confirmation, as soon as possible.

## Appendix A: Indirect support for a massive graviton

We follow the recent work of Steven Kenneth Kauffmann, which sets an upper bound to concentrations of energy, in terms of how he formulated the following equation specifying an inter-relationship between an initial radius  $R$  for an expanding universe, and a “gravitationally based energy” expression we will call  $T_G(r)$  which lead to ???, with manipulations. We start off with Kauffmann’s

$$R \cdot \left( \frac{c^4}{G} \right) \geq \int_{|r''| \leq R} T_G(r + r'') d^3 r'' \quad (\text{A1})$$

Kauffmann calls  $\left( \frac{c^4}{G} \right)$  a “Planck force” which is relevant due to the fact we will employ Eq. (A1) at the initial instant of the universe, in the Planckian regime of space-time. Also, we make full use of setting for small  $r$ , the following:

$$T_G(r + r'') \approx T_{G=0}(r) \cdot \text{const} \sim V(r) \sim m_{\text{Graviton}} \cdot n_{\text{Initial-entropy}} \cdot c^2 \quad (\text{A2})$$

I.e. what we are doing is to make the expression in the integrand proportional to information leaked by a past universe into our present universe, with Ng style quantum infinite statistics use of

$$n_{\text{Initial-entropy}} \sim S_{\text{Graviton-count-entropy}} \quad (\text{A3})$$

Then Eq. (A1) will lead to

$$\begin{aligned} R \cdot \left( \frac{c^4}{G} \right) &\geq \int_{|r''| \leq R} T_G(r + r'') d^3 r'' \approx \text{const} \cdot m_{\text{Graviton}} \cdot \left[ n_{\text{Initial-entropy}} \sim S_{\text{Graviton-count-entropy}} \right] \\ \Rightarrow R \cdot \left( \frac{c^4}{G} \right) &\geq \text{const} \cdot m_{\text{Graviton}} \cdot \left[ n_{\text{Initial-entropy}} \sim S_{\text{Graviton-count-entropy}} \right] \quad (\text{A4}) \\ \Rightarrow R &\geq \left( \frac{c^4}{G} \right)^{-1} \cdot \left[ \text{const} \cdot m_{\text{Graviton}} \cdot \left[ n_{\text{Initial-entropy}} \sim S_{\text{Graviton-count-entropy}} \right] \right] \end{aligned}$$

Here,  $\left[ n_{\text{Initial-entropy}} \sim S_{\text{Graviton-count-entropy}} \right] \sim 10^5$ ,  $m_{\text{Graviton}} \sim 10^{-62}$  grams, and

**1 Planck length =  $l_{\text{Planck}} = 1.616199 \times 10^{-35}$  meters**

where we set  $l_{\text{Planck}} = \sqrt{\frac{\hbar G}{c^3}}$  with  $R \sim l_{\text{Planck}} \cdot 10^\alpha$ , and  $\alpha > 0$ . Typically  $R \sim l_{\text{Planck}} \cdot 10^\alpha$  is about  $10^3 \cdot l_{\text{Planck}}$  at the outset, when the universe is the most compact. The value of  $\text{const}$  is chosen based on common assumptions about contributions from all sources of early universe entropy, and will be more rigorously defined in a later paper.

## Appendix B: Graviton paper table from Pisen Chen

<b>Storage Rings</b>	<b>PEP-11</b>	<b>LEP-1</b>	<b>LEP-II</b>	<b>HERA</b>	<b>LHC</b>
$\varepsilon [GeV]$	<b>9</b>	<b>50</b>	<b>100</b>	<b>880</b>	<b>7000</b>
$\gamma [10^3]$	<b>18</b>	<b>100</b>	<b>100</b>	<b>7.5</b>	<b>.88</b>
$N [10^{10}]$	<b>3.8</b>	<b>45</b>	<b>45</b>	<b>10</b>	<b>10</b>
$n_b$	<b>1700</b>	<b>4</b>	<b>4</b>	<b>210</b>	<b>2800</b>
$l [cm]$	<b>3.46</b>	<b>6.24</b>	<b>6.24</b>	<b>27.7</b>	<b>18.4</b>
$\rho [m]$	<b>500</b>	<b>4300</b>	<b>4300</b>	<b>1035</b>	<b>4300</b>
<b>Gravitational SR</b>					
$\omega_0 [kHz]$	<b>600</b>	<b>70</b>	<b>70</b>	<b>290</b>	<b>70</b>
$N_{GSR} [10^{-7} \text{ sec}^{-1}]$	<b><math>1.3 \times 10^3</math></b>	<b>38</b>	<b>150</b>	<b><math>6 \times 10^6</math></b>	<b><math>18 \times 10^8</math></b>
<b>Resonant conversion</b>					
$\omega_c [10^9 GHz]$	<b>3.5</b>	<b>70</b>	<b>560</b>	<b>.12</b>	<b><math>4.8 \times 10^{-5}</math></b>
$N_{Res} [10^{-7} \text{ sec}^{-1}]$	<b>.1</b>	<b>.1</b>	<b>,3</b>	$10^3$	$2 \times 10^5$

## Appendix C: How to get stricter bounds to Eq. (A4) above

To start, we can first review briefly what was done by Beckwith in 2011, in the Journal of Cosmology. In this publication, Beckwith outlined how there may be a contribution via a minimally massive graviton as to re acceleration of the universe. Here the value of  $m_{Graviton} \sim 10^{-62}$  grams to get a speed up of acceleration of cosmological expansion a billion years ago. This though, does not cleave to the essence of the problem, though, as seen in growing neutrino mass theories and cosmology, there conceivably could be growing mass for early universe gravitons. The author thinks not, and appeals to what was done in another publication, a talk in Italy 2011 (see pages 36-43) where a variant of Penrose cyclic conformal cosmology is employed as a means to recycle prior universe information in order to have a uniform Planck's constant, per cycle – via a consistent small graviton mass.

Note that recently in La Thuile, Italy (2013) in Rencontres De Moriond, Beckwith outlined a relationship between Gravitons and Gravitinos which implies that at or before the electro weak era, i.e. that due to a revision of SUSY, the up to TeV mass of gravitinos at or before the electro weak era with Gravitinos super partnered with gravitons leads to a

non zero initial cosmological radius. Furthermore, as stated in FXQI, in a discussion by Tom Ray, *No singularity at the Schwarzschild radius not only confirms the quantum nature of the cosmological initial condition, it implies non-quantization of classical space-time. For if the quantum field does not collapse, the universal wavefunction, which is continuous (Kauffmann concludes, " ... only the universe itself, with its cosmological redshift, is actually capable of 'containing' the arbitrarily high frequencies of a quantum field") is physically real and dark energy isn't*".

This end result leads to a finite initial radius of space-time, not zero, with enough information transported from a prior universe to the present so as to preserve the continuity of physical constants from space-time collapse to rebirth, again and again. Note that the almost infinite amount of energy within a radii within a Planck value ( but not smaller) is enough to get Gravitinos formed which are super partered via re done SUSY as stated by Beckwith (2013) to obtain during the Electro weak regime massive Gravitons obeying the equation of state , as given by Maggiore

$$\left(\partial_{\mu}\partial^{\sigma} - m_{graviton}\right) \cdot h_{\mu\nu} = \left[\sqrt{32\pi G} + \delta^{+}\right] \cdot \left(T_{\mu\nu} - \frac{1}{3}\eta_{\mu\nu}T^{\mu}_{\mu} + \frac{\partial_{\mu}\partial_{\nu}T^{\mu}_{\mu}}{3m_{graviton}}\right) \quad (C1)$$

Furthermore, we state that both the Graviton and Gravitino would have to be consistent, with respect to the well known De Broglie matter-wave hypothesis, with the resultant consistency of a constant fine structure constant ,which does not vary over time, as given by Beckwith (2010a,b), so that there would be constant fine structure values, as given by

$$\tilde{\alpha} \equiv e^2/\hbar \cdot c \equiv \frac{e^2}{d} \times \frac{\lambda}{hc} \quad (C2)$$

The idea that Planck's constant would remain consistent is also stated by R. Penrose in his recent book. Accordingly; the author views that a minimum entropy of 10^5 as a transfer mechanism from prior to present space time is important and should be reviewed, as it gives constant values equal to the present value of Planck's constant from cycle to cycle. Cyclic conformal cosmology, and tests confirming its initial CMBR pattern, would do much to add such a plausible explanation showing how consistency in Planck's constant from cycle to cycle can be maintained. Lastly; the author appeals to a calculation given by Giovanni, to the effect that if the Penrose supposition of

$$10^{10^90} \approx 10^{Final-entropy-Gravitons=S_{FINAL-GRAVITONS}} \quad (C3)$$

~ Phase space due to Gravitons

is true (as given by Penrose) then the relationship given by Giovanni in his book for entropy that the present entropy of the universe, i.e. about 10<sup>88</sup> – 10<sup>90</sup> is obtained by integrating from 10<sup>-11</sup> Hertz down to 10<sup>-19</sup> Hertz would do much to argue for a constant graviton mass, as given above. Furthermore, this could be with work also connected with what the author referred to as first and second inflation, as given by his work in 2010. This would be a project warranting serious investigation. First inflation is

the typical inflation given in cosmology, whereas the 2<sup>nd</sup> inflation is the speed up of the universe, as referenced in Beckwith's 2011 publications.

### Appendix D What if an inflaton partly re-emerges in space-time dynamics? At $z \sim .423$ ?

Padmanabhan has written up how the 2<sup>nd</sup> Friedman equation which for  $z \sim .423$  may be simplified to read as

$$\dot{H}^2 \cong \left[ -2 \frac{m}{a^4} \right] \quad (D1)$$

would lead to an inflaton value of  $\phi$ , when put in, for scale factor behavior as given by  $a(t) \propto t^\lambda, \lambda = (1/2) - \varepsilon^+, 0 \leq \varepsilon^+ \ll 1$ , of, for the inflaton and inflation of (Padmanabhan)

$$\phi(t) = \int dt \cdot \sqrt{-\frac{\dot{H}}{4\pi G}} \quad (D2)$$

Assuming a decline of  $a(t) \propto t^\lambda, \lambda = (1/2) - \varepsilon^+, 0 \leq \varepsilon^+ \ll 1$ , Eq. (D3) yields

$$\phi(t) \sim \sqrt{\frac{2m}{4\pi G}} \cdot [2\varepsilon^+] \cdot t^{2-\varepsilon^+} \quad (D3)$$

As the scale factor of  $a(t) \propto t^\lambda, \lambda = (1/2) - \varepsilon^+, 0 \leq \varepsilon^+ \ll 1$  had time of the value of roughly  $a(t) \propto t^\lambda, \lambda = (1/2) - \varepsilon^+, 0 \leq \varepsilon^+ \ll 1$  have a power law relationship drop below  $a(t) \propto t^{1/2}$ , the inflaton took Eq. (D3)'s value which may have been a factor as to the increase in the rate of acceleration, as noted by the  $q(z)$  factor, given in Beckwith's Journal of cosmology publication. Note that there have been analytical work projects relating the inflaton, and its behavior to entropy via noting that inflation stopped when the inflaton field settled down into a lower lower energy state. The way to relate an energy state to the inflaton is, if  $a(t) = a_0 t^\lambda$ , then in the early universe, one has a potential energy term of (Padmanabhan)

$$V(\phi) = V_0 \cdot \exp \left[ -\sqrt{\frac{16\pi G}{\lambda}} \cdot \phi(t) \right] \quad (D4)$$

A situation where both  $\lambda = (1/2) - \varepsilon^+$  grows smaller, and, temporarily,  $\phi(t)$  takes on Eq. (D3)'s value, even if the time value gets large, and also, if acceleration of the cosmic expansion is taken into account, then there is infusion of energy by an amount  $dV$ . The entropy  $dS \cong dV/T$ , will lead, if there is an increase in  $V$ , as given by Eq. (D4) a situation where there is an effective increase in entropy. If there is, as will be related to later, in page eight, circumstances, where  $S \approx N =$  number of graviton states (as stated by Y. Ng)

Linking the two analytically, partly due to Yurov's suggestion would in the mind of the author, clinch a constant graviton mass. The Yurov suggestion will be worked upon seriously by the author in future publications and is crucial to making initial and final graviton mass, about the same order of magnitude.

### **Acknowledgements**

This work is supported in part by National Nature Science Foundation of China grant No110752. The author thanks Jonathan Dickau for his review and suggestions for improvement given over several months in 2012 and 2013.

## **Bibliography**

A. Beckwith, Applications of Euclidian Snyder Geometry to the Foundations of Space Time Physics", <http://vixra.org/abs/0912.0012>, v 6 (newest version) [February 2010a]

[Andrew Beckwith](http://vixra.org/abs/1003.0194), "Applications of Euclidian Snyder Geometry to Space Time Physics & Deceleration Parameter ( DE Replacement?) Analysis of Linkage Between 1st, 2nd Inflation?", <http://vixra.org/abs/1003.0194> [ 2010b]

A.W. Beckwith, <http://journalofcosmology.com/BeckwithGraviton.pdf>, Identifying a Kaluza Klein Treatment of a Graviton Permitting a Deceleration Parameter  $Q(z)$  as an Alternative to Standard DE, November, 2011a

Andrew Beckwith, The Nature of Semi-Classical Nature of Gravity Reviewed, and Can We Use a Graviton Entanglement Version of the EPR Experiment to Answer if the Graviton is Classical or Quantum in Origin?" <http://vixra.org/abs/1109.0011>, November 2011b

Andrew Beckwith," If a Machian Relationship Between Gravitons and Gravitinos Exists, What Does Such a Relationship Imply as to Scale Factor and Quinssence Evolution and the Evolution of DM?", <http://vixra.org/abs/1303.0224>, March 2013

Pisen Chen, "Resonant Photon-Graviton Conversion in E M fields: From Earth to Heaven", SLAC Pub 6666, September (1994)

Eric Davis, "Producing Gravitons via Quantization of the Coupled Maxwell Fields," in Frontiers of Propulsion Science, Progress in Astronautics and Aeronautics Series, Vol. 227, eds. M. G. Millis and E. W. Davis, AIAA Press, Reston, VA, (2009)

Steven Kauffmann, " A Self Gravitational Upper bound On Localized Energy Including that of Virtual Particles and Quantum Fields, which Yield a Passable Dark Energy Density Estimate", PUT IN WHICH VERSION OF THE DOCUMENT. I CITE THE EQN ON PAGE 12

M. Giovannini, *A Primer on the Physics of the Cosmic Microwave Background*, World Press Scientific, Singapore, Republic of Singapore, 2008

M. Maggiore, *Gravitational Waves , Volume 1 : Theory and Experiment*, Oxford Univ. Press(2008)

M. Marklund, G. Brodin, and P. Shukla, *Phys. Scr.* **T82** 130-132 (1999).

Y.J. Ng, *Entropy* **10**(4), pp441-461 (2008); Y.J. Ng and H. van Dam, *Found Phys* **30**, pp795–805 (2000)

Y.J. Ng and H. van Dam, *Phys. Lett.* **B477**, pp429–435 (2000)

Y.J. Ng, “Quantum Foam and Dark Energy”, in the conference International workshop on the Dark Side of the Universe, [http://ctp.bue.edu.eg/Workshops/4th International Workshop on The Dark Side of the Universe/Talks/Monday/Quantum From And Dark Energy.pdf](http://ctp.bue.edu.eg/Workshops/4th%20International%20Workshop%20on%20The%20Dark%20Side%20of%20the%20Universe/Talks/Monday/Quantum%20Foam%20and%20Dark%20Energy.pdf) – missing link --

T. Padmanabhan, *An Invitation to Astrophysics*, World Scientific series in Astronomy and Astrophysics, Vol. 8

R. Penrose, *Cycles of Time*, The Bodley Head, 2010, London, UK

D. Valev, *Aerospace Res. Bulg.* 22:68-82, 2008; ; <http://arxiv.org/abs/hep-ph/0507255>.

Matt Visser,” Mass of the Graviton, arXiv: gr-qc/ 9705051 v2 Feb 26, 1998

Clifford Will, “Bounding the Mass of the Graviton using Gravitational-Wave observations of inspiralling compact Binaries”, arXiv: gr-qc/ 9709011 v1 Sept 4, 1997

Clifford Will, “The confrontation between General Relativity and Experiment”, *Living Rev. of Relativity*, 9, (2006),3, <http://www.livingreviews.org/lrr-2006-3>

A. Yurov; arXiv: hep-th/028129 v1, 19 Aug, 2002