What can be said about (massive) Graviton Stability? & Is there DM generated DE ?

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Abstract

A thought experiment:

1st :Can gravitons be stable if they have mass ?

2nd : If so, did a DM generated KK particle, with tiny 4 D mass contribute to DE a billion years ago ?

- (indirectly touching upon)
- To what degree is gravity an emergent field that is partly/largely classical with extreme nonlinearity, or a QM/quantum field theory phenomenon?

Math – Physics representation of core issues of higher dimensional contribution

- Start off with a basic statement of strength of matter - graviton interaction, assuming KK graviton
- $$\Im = -\frac{\kappa}{2} \cdot \sum_n \int d^4 x h_{uv}^n \cdot T^{uv} \sim 1/M_{PL}^2 \quad \textbf{(1)}$$

The stress energy tensor comes from the standard model, and the h term is from using a KK graviton interactions model , up to the n th mode.

Does the last slide hold if we make the following modification of a KK tower of gravitons ?

- Modification put in, as seen in later to mimic DE
- Suggestion to look at, here, is to consider what if
- $m_n(Graviton) = \frac{n}{L} + 10^{-65}$ grams? **(2)**

Issue to raise

- ***Work presented by Maggiore, specifically delineated for non zero graviton mass, due to Fiertz Lagrangian , obtaining as a limit***

$$-3m_{graviton}^{2}h = \frac{\kappa}{2}\cdot T \qquad \textbf{(3)}$$

- **Does the above Eqn(3) permit a frequency range for massive Gravitons which permits stability for Massive Gravitons** ?

From working with Eqn (1) and from Vissers treatment of (massive) gravitons

- This is Vissers (<u>massive</u>) Graviton Stress energy tensor, as a start

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

Eqn (1), Eqn (4), with work leads to a positive, real frequency squared value ,

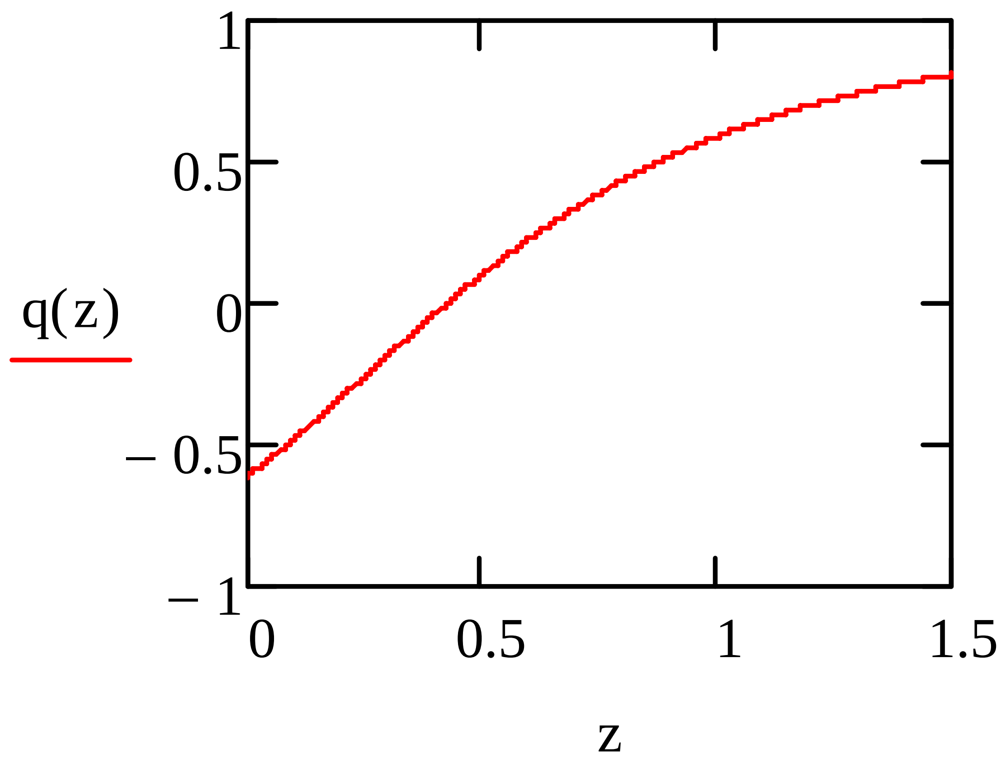
- In order to obtain a non imaginary, real (massive graviton frequency), **<u>need Eqn(5) below:</u>**

We claim that application leads to the result of the next page 1 billion years ago as put in <u>slide 8 (next slide)</u>

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

Jerk calculation leads to, if one has a stable, non zero 4-D graviton mass

- If we define the jerk $q = -\frac{\ddot{a}a}{\dot{a}^2}$



Assuming a brane world

Z (red shift value). Change in sign for Z ~.42 is almost one billion years ago, corresponding to reacceleration of the universe, i.e

Basic results of Alves, et al. (2009), using their parameter values, with an additional term of "dark flow" added, corresponding to one KK additional dimensions.

Issue is that a 4 dimensional Graviton with small mass violates principle of correspondence- complimentarity

- How important is such a violation ?

Explanation may show reason for G. Smoots values of information, initially

- See the following for the G. Smoot lecture

http://chalonge.obspm.fr/Paris07_Smoot.pdf

For brane world, use these evolution equations

Friedman equation, subsequently modified

$$\dot{a}^2 = \left[\left(\frac{\rho}{3M_4^2} + \frac{\Lambda_4}{3} + \frac{\rho^2}{36M_{Planck}^2} \right) a^2 - \kappa + \frac{C}{a^2} \right] \qquad (6)$$

Density equation, with non- zero graviton mass

$$\rho \equiv \rho_0 \cdot \left(\frac{a_0}{a} \right)^3 - \left[\frac{m_g c^6}{8\pi G \hbar^2} \right] \cdot \left(\frac{a^4}{14} + \frac{2a^2}{5} - \frac{1}{2} \right) \qquad (7)$$

For LQG, use these evolution equations

Friedman equations, assuming 'constant' momentum , a.k.a. <u>Eqn(8)</u>

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{\kappa}{3}\cdot\rho \qquad \left(\frac{\dot{a}}{a}\right)^2 \equiv \frac{\kappa}{6}\cdot\frac{p_\phi^2}{a^6} \qquad \left(\frac{\ddot{a}}{a}\right) = -\frac{2\cdot\kappa}{3}\cdot\rho$$

Density equation is the same

$$\rho \equiv \rho_0\cdot\left(\frac{a_0}{a}\right)^3 - \left[\frac{m_g c^6}{8\pi G\hbar^2}\right]\cdot\left(\frac{a^4}{14} + \frac{2a^2}{5} - \frac{1}{2}\right)$$

Infinite Quantum statistics. From the work presented in the Paris observatory, July 2009

Start with

$$Z_N \sim \left(\frac{1}{N!}\right)\cdot\left(\frac{V}{\lambda^3}\right)^N \qquad S \approx N \cdot \left(\log\left[V/N\lambda^3\right] + 5/2\right)$$

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

V stands for volume of nucleation regime space. “particles” nucleate from ‘vacuum’ in QM

For DM. V for nucleation is HUGE. Graviton space V for nucleation is tiny , well inside inflation/ Therefore, the log factor drops OUT of entropy S if V chosen properly. For small V, then

$$\Delta S \approx \Delta N_{gravitons} \qquad \textbf{(9)}$$

Main point is to establish the Partition Function

L. A. Glinka (2007): identification of $$\Omega = \frac{1}{2|u|^2 - 1}$$

as a partition function (u is one the Bogoliubov transformation's coefficients) due to the quantum gas approach, to get Fock's space quantum information theory-based Boltzmann-Von Neumann entropy $$S \equiv \ln \Omega$$

1. Derivation by Glinka explicitly uses the Wheeler-DeWitt equation of quantum geometrodynamics, being the model of Quantum Gravity
2. The question is the linkage of Wheeler-DeWitt theory with String theory

PROBLEMS TO CONSIDER:
Ng's result quantum counting algorithm is a **STRING THEORY** result.
Glinka applies **QUANTUM GRAVITY**. Are the approaches **Equivalent ?**

Can we make a linkage between Glinka's quantum gas argument, and a small space version/ application of Ng's Quantum infinite statistics?

In addition, if the quantum graviton gas is correct, can we model emergent structure of gravity via linkage between Ng particle count, and Q.G.G argument?

More on the Glinka quantum gas hypothesis, part 1

- Starting point to Glinka's Quantum gas, in terms of numerical count

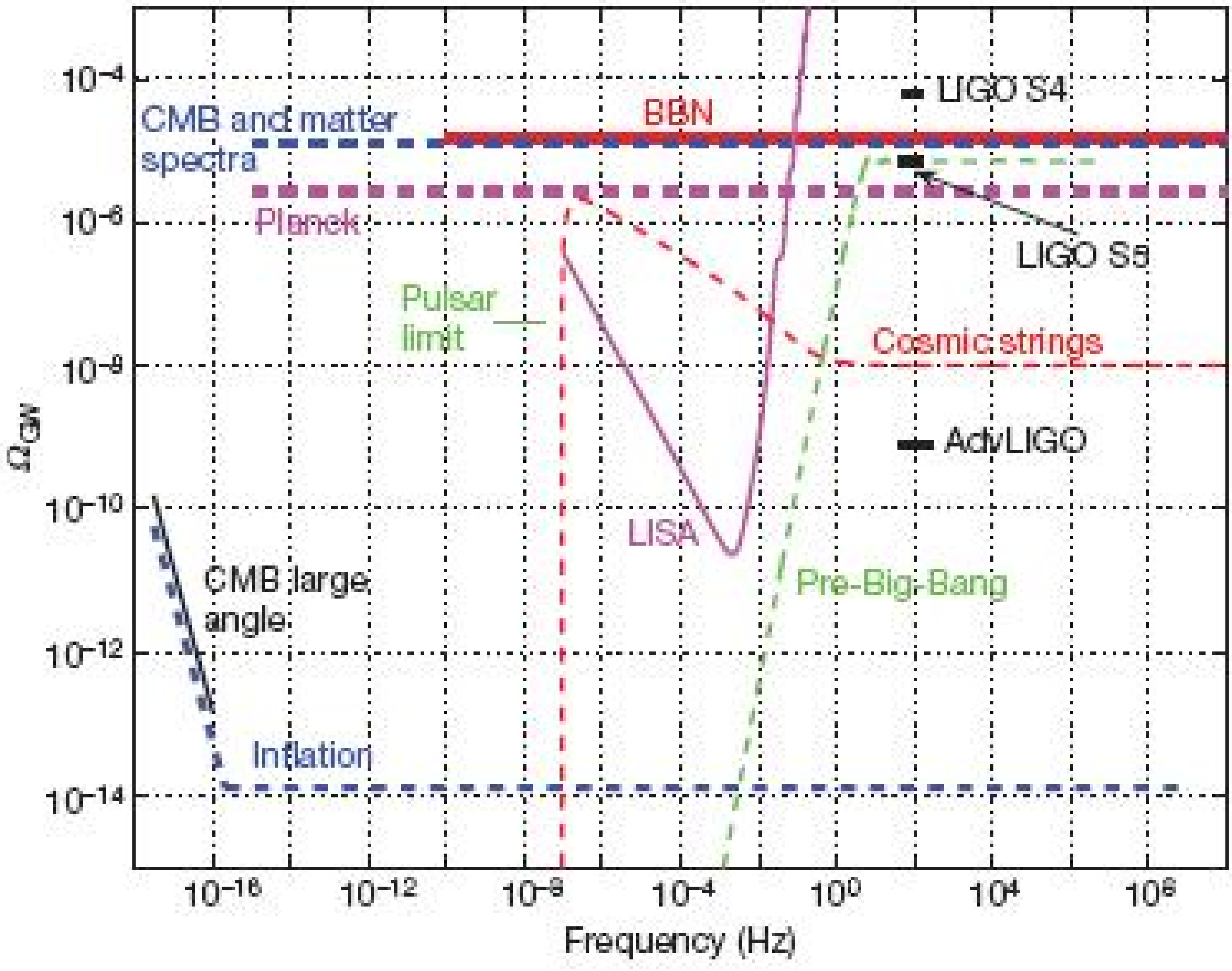
- $$n_f = [1/4] \cdot \left[\sqrt{\frac{v(a_{initial})}{v(a)}} - \sqrt{\frac{v(a)}{v(a_{final})}} \right] \quad (10)$$

More on the Glinka Quantum gas hypothesis, part 2

- Relevant to understanding the role of

- $$\Omega_{gw}(\nu) \cong \frac{3.6}{h_0^2} \cdot \left[\frac{n_f}{10^{37}} \right] \cdot \left(\frac{\nu}{1kHz} \right)^4 \quad (11)$$

See B. P. Abbott et al.



Breakdown of field theory with respect to massive gravitons in limit

$$m_{graviton} \to 0$$

The massless equation of the graviton evolution equation takes the form

$$\partial_{\mu}\partial^{\mu}h_{\mu\nu} = \sqrt{32\pi G}\cdot\left(T_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}T^{\mu}_{\mu}\right)$$

Consider what happens with a graviton mass

$$m_{graviton} \neq 0$$

From Maggiore (2008):

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

The mismatch between these two equations when

$$m_{graviton} \to 0$$

Is largely due to, even if graviton mass goes to zero

$$m_{graviton} h_{\mu}^{\mu} \neq 0$$

$$m_{graviton} \cdot h_{\mu}^{\mu} = -\left\lfloor \sqrt{32\pi G} + \delta^{+} \right\rfloor \cdot T_{\mu}^{\mu}$$

Try semiclassical model of graviton, as kink-anti kink pair

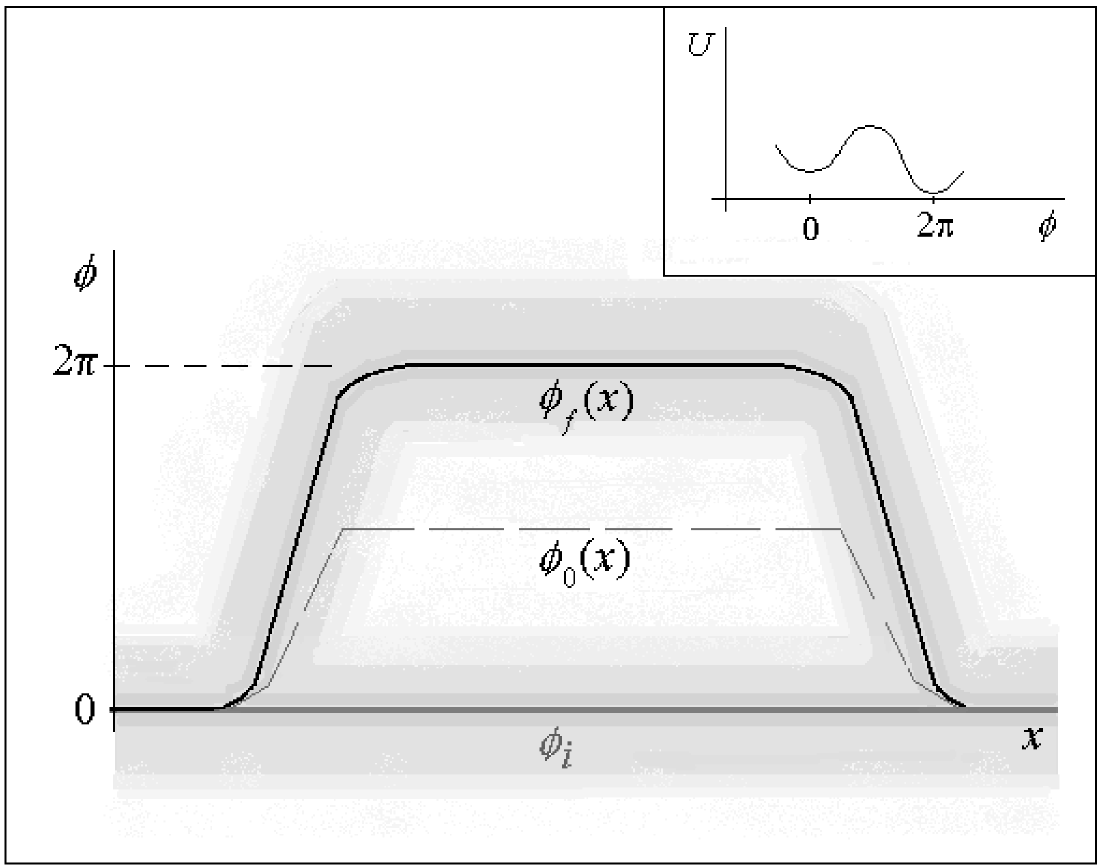
- How does this fit in with t'Hooft's deterministic QM?

- From a 1+ dimensional kink-antikink

$$\Psi_{i,f}\ \left[\phi(\mathbf{x})\right]\Big|_{\phi\equiv\phi_{ci,cf}} = c_{i,f}\cdot\exp\left\{-\int d\mathbf{x}\ \alpha\left[\phi_{C i,f}(\mathbf{x})-\phi_0(\mathbf{x})\right]^2\right\},$$

From density wave physics, 1+ dimensions

Kink-antikinks lead to a vacuum wave function. The LHS is a kink; the RHS is an antikink.



The wave functional could have t’Hooft equivalence class structure added, in 4 to 5 dimensions

- T’Hooft used in 2006 an equivalence class argument as an embedding space for simple harmonic oscillators, as given in his Figure 2, on page 8 of his 2006 article.

- “Beneath Quantum Mechanics, there may be a deterministic theory with (local) information loss. This may lead to a sufficiently complex vacuum state.” - t’Hooft

- The author submits, that a kink-anti kink formulation of the graviton, when sufficiently refined, may indeed create such a vacuum state, as a generalization of Fig 2.

The small mass of the graviton would be for energy in

$$\Delta E \Delta t \geq \hbar$$

- Having said this, the author is fully aware of the String theory HUP variant

$$\Delta x \geq \frac{\hbar}{\Delta p} + \frac{l_s^2}{\hbar} \Delta p$$

- The idea would be to possibly obtain a way to look at counting for GW detectors

$$h_0^2 \Omega_{gw}(f) \cong \frac{3.6}{2} \cdot \left[\frac{n_f [graviton] + n_f [neutrino]}{10^{37}} \right] \cdot \left(\frac{\langle f \rangle}{1kHz} \right)^4$$

The following is claimed:

If n (graviton) is obtained, then higher dimensional geometry may be relevant to transmitting information via gravitons from prior to present universes

- How much information can be carried by an individual graviton?
- Assume $\Delta S \approx \Delta N_{gravitons}$
- Use Seth Lloyd's

$$I = S_{total} / k_B \ln 2 = \left[\# operations\right]^{3/4} = \left[\rho \cdot c^5 \cdot t^4 / \hbar\right]^{3/4}$$

10^7 relic gravitons yields at or more than 10^7 operations!

This value implies that per graviton, as nucleated at least 4 dimensions, there is at least **one unit** of information associated with the graviton (assuming there is at least **some relationship** between an operation and information)

10^7 or higher amounts of prior universe information transmitted to our cosmos?

Resolutions of questions about cosmological constants ?

- **<u>1st Conclusion</u>, one needs a reliable information packing algorithm! I.e. for a wave length , as input into the fine structure constant, we need spatial / information limits defined for geometry**
- $\Delta S \approx \Delta N_{gravitons} \approx 10^{7}$ **is only a beginning**

<u>2nd Conclusion</u>, assumed GW detector sensitivity limits need a comprehensive look over, re do

<u>Final inquiry, making sense of the supposed "radius of the Universe" calculation</u>

- Matt Roos, has put in a foundational way of testing, via experiment, how to calculate a supposed 'radius of the universe'
- $$r_U \equiv \frac{1}{H \cdot \sqrt{|\Omega - 1|}} \qquad (12)$$

Tweaking parameters of H, and $\Omega \equiv \rho(t)/\rho_{critical}$ from our inquiry

- The choice of *H*, and of density , as in the
- equation below will allow the dynamics of
- how the universe expands mesh with a fuller
- understanding of structure formation.

$$\Omega \equiv \rho(t)/\rho_{critical} \tag{13}$$

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Finally a good book summary with up to date summaries

- From “ Series in High Energy physics, Cosmology and Gravitation” - Taylor and Francis (publishers)

- - Particle and Astroparticle Physics (2008)

- By Utpal Sarkar