Gedankenexperiment for fluctuation of mass of a Graviton, based on the trace of a GR stress energy tensor-PrePlanckian conditions lead to gaining of Graviton mass, and Planckian Conditions lead to Graviton mass shrinking to 10^-62 grams

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Abstract. We will be looking at the energy of a graviton, based upon the Stress energy tensor, and from there ascertaining how fluctuations in early universe conditions impact the mass of a graviton. Physically the mass of the graviton would be shrinking right after Planck time and presumably it would be going to its equilibrium value of about 10^-62 grams, for its present day value. It, graviton mass, would increase up to the Plank time of about 10^-44 seconds.

1. Introduction, setting up for calculation of using the results of initial energy as due to $\delta t \Delta E = \frac{\hbar}{\delta g_{tt}} \equiv \frac{\hbar}{a^2(t)\cdot\phi}$ and comparing it to a more general energy expression given below

Start off with looking at from [1], a generalized energy expression with momentum also obeying, if m is for graviton mass. Begin with from [1]

$$p = \frac{h}{\lambda} \tag{1}$$

$$\begin{aligned} & p = \frac{h}{\lambda} \\ & \& E = pc + \frac{m^2c^2}{2E} \\ & \Rightarrow E \sim \frac{hc}{2\lambda}\left(1 \pm \sqrt{1 + \frac{4m^2c^4}{\left(\frac{hc}{\lambda}\right)^2}}\right) \sim \frac{hc}{2\lambda}\left(2 + \frac{2m^2\lambda^2c^4}{(h\cdot c)^2}\right), Or \sim \frac{hc}{2\lambda}\left(-\frac{2m^2\lambda^2c^4}{(h\cdot c)^2}\right) \end{aligned} \tag{2}$$

Next, from Giovannini [2], if T is the trace of the Stress-Energy tensor, we have that

$$\left(m = m_{graviton}\right)^2 = -\frac{\kappa}{6}T \tag{3}$$

$$E_{graviton} \sim \frac{hc}{2\lambda}\left(2 - \frac{\kappa T\lambda^2c^4}{3(h\cdot c)^2}\right), Or \sim \frac{hc}{2\lambda}\left(-\frac{\kappa T\lambda^2c^4}{3(h\cdot c)^2}\right) \tag{4}$$

If so, then, the fluctuation of energy would be represented, if $\lambda_{graviton} = \frac{2\pi v(velocity)_{graviton}}{\omega_{graviton}}$ and we have[3]

$$\left(\frac{v_{graviton}}{c}\right)^2 = 1 - \frac{m_{graviton}^2 c^4}{E_{graviton}^2} \tag{5}$$

Then If we go to look at what [1] $\lambda_{graviton} = \frac{2\pi v(velocity)_{graviton}}{\omega_{graviton}}$ then is saying, the above is then rendered as

$$\begin{aligned}
&\left(E_{graviton}\right)^2 \sim \left[\frac{hc}{2\lambda}\left(2 - \frac{\kappa T \lambda^2 c^4}{3(h\cdot c)^2}\right)\right]^2, Or \sim \left[\frac{hc}{2\lambda}\left(-\frac{\kappa T \lambda^2 c^4}{3(h\cdot c)^2}\right)\right]^2 \\
&\sim \frac{m_{graviton}^2 (rest-mass) c^4}{\left(1 - \left[v_{graviton}\left(velocity\right)/c\right]^2\right)} \\
&\Leftrightarrow m_{graviton}^2 (rest-mass) \sim \\
&\frac{\left(1-\left[v_{graviton}\left(velocity\right)/c\right]^2\right)c^2}{72\pi^2\hbar^2} \times \left[\kappa \cdot T(= traceT_{uv}) \cdot \left(\lambda_{graviton} = \frac{2\pi v(velocity)_{graviton}}{\omega_{graviton}}\right)\right]^2
\end{aligned} \tag{6}$$

2. **Utilizing Eq. (6) in terms of the initial fluctuation of the graviton mass.**
   From [4,5,6,7] use

$$\begin{aligned}
&T(= traceT_{uv}) \approx \Delta T_{tt} \sim \Delta\rho \sim \frac{\Delta E}{V^{(3)}} \\
&\frac{\Delta E}{V^{(3)}} = \frac{\hbar}{\delta t \cdot \delta g_{tt} \cdot V^{(3)}} \equiv \frac{\hbar}{\delta t \cdot V^{(3)} \cdot a^2(t) \cdot \phi} \\
&\Leftrightarrow \Delta m_{graviton}^2 (rest-mass) \sim \\
&\frac{\left(1-\left[v(velocity)_{graviton}/c\right]^2\right)c^2}{72\pi^2\hbar} \times \left[\frac{\kappa}{\delta t \cdot V^{(3)} \cdot a^2(t) \cdot \phi} \cdot \left(\frac{2\pi v(velocity)_{graviton}}{\Delta\omega_{graviton}}\right)\right]^2
\end{aligned} \tag{7}$$

3. **Identifying change in $\Delta\omega_{graviton}$: This is the input into Eq.(7), assuming** $v(velocity)_{graviton} \sim .98\% c(light-speed)$

We follow what to expect from $\Delta T_{tt} \sim \Delta\rho \sim \frac{\Delta E}{V^{(3)}}$ as given in [1, 2] for

$$\delta t \Delta E = \frac{\hbar}{\delta g_{tt}} \equiv \frac{\hbar}{a^2(t)\cdot\phi} \tag{8}$$

as a way to quantify energy density when we have what is coming from Weinberg [6] on initial energy density and then from there to say something about initial time step and also potential energy as given Padmanbhan [7] . Doing so will isolate out values of the Potential energy, as in [6] which will then be compared to [7]'s potential energy value, which in turn gets a value of time, which we will set by first considering the following evolution equation. From [6]

$$\ddot{\phi}+3H\dot{\phi}+\partial_{\phi}V(\phi)=0 \tag{9}$$

Then, look at $V(\phi)$ from [6] as having the value of, if M is related to mass, with α a variable parameter

$$V(\phi)=M^{4+\alpha}/\phi^{\alpha} \tag{10}$$

So, then the ϕ is given by [6]

$$\phi=\left(\frac{\alpha\cdot(\alpha+2)^2\cdot M^{4+\alpha}\cdot t^2}{6+\alpha}\right)^{\frac{1}{\alpha+2}} \tag{11}$$

And also look at Padmanabhan's generalized inflaton potential [7], of comparing Eq.(2) with Eq.(12) below

$$V=\frac{3H^2}{8\pi G}\cdot\left(1+\frac{\dot{H}}{3H^2}\right) \tag{12}$$

We have the Hubble parameter, if before Planck time, during Plank time $\dot{H}=\pm\delta H$

$$\begin{aligned}
&H=H_{initial}e^{\pm\delta t}\Leftrightarrow\dot{H}=\pm\delta H,\\
&\dot{H}=+\delta H \quad if \quad Before \quad Planckian \quad time\\
&\dot{H}=-\delta H \quad if \quad Planckian \quad time \quad zone
\end{aligned} \tag{13}$$

Then, we could get the following variance in time, $\tilde{t}\sim\Delta t$

$$\begin{aligned}
&\phi=\left(\frac{\alpha\cdot(\alpha+2)^2\cdot M^{4+\alpha}\cdot t^2}{6+\alpha}\right)^{\frac{1}{\alpha+2}}\approx\left(\frac{8\pi G M^{4+\alpha}}{(\pm\delta-3H)\cdot H}\right)^{\frac{1}{\alpha}}\\
&\Leftrightarrow\tilde{t}=\left(\frac{M^{\left(\frac{4+\alpha}{2\alpha}\right)\cdot(2-\alpha)}}{H_{initial}\exp(\pm\delta\cdot t)}\right)\cdot\left(\frac{6+\alpha}{\alpha\cdot(2+\alpha)^2}\right)^{\frac{1}{\alpha+2}}\cdot\left(\frac{8\pi G}{(\pm\delta-3\cdot H_{initial}\exp(\pm\delta\cdot t))}\right)^{\frac{1}{\alpha}}
\end{aligned} \tag{14}$$

4. Finding how to use this value of $\tilde{t}\sim\Delta t$ in order to estimate a relic GW frequency

If so, then, up to a point, in the Pre Plankian regime of space time, according to the signs on Eq.(13) and Eq.(14) and [4,5] for the change in $\delta t\Delta E=\frac{\hbar}{\delta g_{tt}}\equiv\frac{\hbar}{a^2(t)\cdot\phi}$ Set then, in early universe conditions, let us set, if we are considering gravitons, that we will set, say that the expression below would be for pre Planckian times, with t < 10^ -44 seconds. . The upshot would be that there would be a GW frequency, in many cases, as a result of pre Planckian physics of greater than or equal 10 ^ 32 Hz, which would be red shifted down to about 10 ^ 10 Hz, i.e. a 22 order of magnitude drop, in the present era. This is assuming $a^2(initial) \sim 10^{-110}$, as well as we are assuming N ~ 10^ 37, as seen in [4,5]

$$
\begin{aligned}
&\delta t \Delta E = \frac{\hbar}{\delta g_{tt}} \equiv \frac{\hbar}{a^2(t)\cdot\phi} = \delta t \cdot N_{gravitons} \cdot \hbar \cdot \omega_{graviton} \\
&\Leftrightarrow \omega_{graviton-initial} \approx \frac{1}{N_{gravitons}\cdot a^2(t)\cdot\phi} \\
&\approx \frac{1}{N_{gravitons}\cdot a^2(t)} \cdot \frac{\left(\frac{6+\alpha}{\alpha\cdot(2+\alpha)^2}\right)^{\frac{-1}{\alpha+2}} \cdot \left(\frac{8\pi G}{\left(\pm\delta - 3\cdot H_{initial}\exp(\pm\delta\cdot t)\right)}\right)^{\frac{-1}{\alpha}}}{\left(\frac{M^{\left(\frac{4+\alpha}{2\alpha}\right)\cdot(2-\alpha)}}{H_{initial}\exp(\pm\delta\cdot t)}\right)}.
\end{aligned}
\tag{15}
$$

The M as given in this would correspond to the Mass value of the universe, which is roughly 3 x 10^{55} g (where g is for grams.). [8] .

5. Conclusion: Putting Eq. (15) into Eq.(7) . What it says, physically

Note that time in Eq.(14) remains finite but very small, as it came out less than 10 to the minus 44 power seconds, less than Planck time, with the parameter α usually larger than 2. Time, in Eq. (14) as estimate is actually negative, unless we have that we chose in Eq. (14) the Pre Planckian option, which is saying that likely Planck time may not be the earliest sub division of time as we know it. This last point above will be important in our future research. As well as entropy production models due to discussions in [9,10,11,12] in terms of entropy generation in the Pre Planckian era. The entropy values will influence the N used in Eq. (15) above. After this is set, for Eq. (15) we put Eq.(15) into Eq. (7) and thereby obtain

$$\Delta m^2_{graviton}(rest-mass) \sim \frac{\left(1-\left[v(velocity)_{graviton}/c\right]^2\right)c^2}{72\pi^2\hbar}$$
$$\times\left[\frac{\kappa}{\delta t\cdot V^{(3)}}\cdot\frac{\left(2\pi v(velocity)_{graviton}\right)}{\left(\frac{M^{4+\alpha}}{H_{initial}\exp\left(\pm\delta\cdot t\right)}\right)^{\frac{1}{\alpha}}}\right]$$
$$\times\left(\frac{1}{N_{gravitons}}\cdot\frac{\left(\frac{6+\alpha}{\alpha\cdot\left(2+\alpha\right)^2}\right)^{\frac{-1}{\alpha+2}}}{\left(\frac{M^{\left(\frac{4+\alpha}{2\alpha}\right)\cdot(2-\alpha)}}{H_{initial}\exp\left(\pm\delta\cdot t\right)}\right)}\right)^{-2} \tag{16}$$

The first term of Eq.(16) roughly cancels with the number of gravitons, which approximately leaves

$$\Delta m^2_{graviton}(rest-mass) \sim \frac{c^2}{72\pi^2\hbar}$$
$$\times\left[\frac{\kappa}{\delta t\cdot V^{(3)}}\cdot\frac{\left(2\pi v(velocity)_{graviton}\right)}{\left(\frac{M^{4+\alpha}}{H_{initial}\exp\left(\pm\delta\cdot t\right)}\right)^{\frac{1}{\alpha}}}\right]$$
$$\times\left(\frac{\left(\frac{6+\alpha}{\alpha\cdot\left(2+\alpha\right)^2}\right)^{\frac{-1}{\alpha+2}}}{\left(\frac{M^{\left(\frac{4+\alpha}{2\alpha}\right)\cdot(2-\alpha)}}{H_{initial}\exp\left(\pm\delta\cdot t\right)}\right)}\right)^{-2} \tag{17}$$

The change in graviton mass is not so much affected by N, entropy count , as this is partly neutralized by the near speed of light conditions, for massive gravitons. What is left though is the variation in total mass, M is divided by $H_{initial}\exp\left(\pm\delta\cdot t\right)$, which expands during the Pre Planckian space-time regime, and which shrinks right after Planckian time is breached, in the Planckian era (the Universe begins a massive deceleration. The term α would usually be expected to be less than 2.

Physically what this is saying is that the mass of the graviton would be shrinking right after Planck time and presumably it would be going to its equilibrium value of about 10^-62 grams, for its present day value. It, graviton mass, would increase up to the Plank time of about 10^-44 seconds.

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