“Qualms Concerning the Inflationary Scenario” article revisited while considering both gravitons and the derivative of a GR stress energy tensor as a counter poise to the alleged breakdown of inflation.

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Abstract. The following questions is asked, If one takes the covariant derivative of a Stress-energy representation of early universe massive gravitons, is the derivative of the Graviton stress tensor equal to zero ? If so, then in what range of astrophysics does this occur, and when does this formalism break down? Lavenda and Davies argued that the derivative of a generalized GR stress energy tensor being zero in itself is insufficient to show that the 1st law of thermodynamics alone holds. If the full Stress-Energy tensor expression for GR is written out, there is a stress energy tensor component involving GW alone which we highlight. The problem as to this test is if the derivative of the Stress energy tensor, for gravitons as written by Visser is brought up. This Visser stress energy tensor for massive gravitons will not even satisfy the 1st thermodynamic law. We bring this up as a counter point to an article written by Lavenda and Davies purporting to claim that the Tolman test for a first law of thermodynamics which they generalize to first and second law of thermodynamics for inflationary cosmology. We show a breakdown of a zero value for the derivative of the Stress energy tensor for early universe massive gravitons and this derivative of the massive Graviton Stress energy tensor (Visser) will not even satisfy the first law of thermodynamics according to the Tolman criteria. Note that if the Visser Massive Graviton Stress energy tensor scenario does not hold then the Lavenda and Davies objection to inflation is upheld.

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INTRODUCTION

We examine Visser’s [1] treatment of a stress energy tensor and then go to what Lavenda and Davies [2] stated in their 1992 article about a derivative of a stress-energy tensor in order to ascertain what range of parameters is needed in order to have fidelity with respect to the Tolman [3] treatment as to GR and the first law of thermodynamics. Where Lavenda and Davies [2] develop their theme is in claiming that for general relativity, that the covariant derivative of the stress energy tensor being zero, if one has inflation, is a combination of the first and second laws of thermodynamics. What we show is that the Tolman [3] treatment of GR, if we restrict the stress energy tensor for initial production of gravitons, is commonly not even in fidelity with respect to the first law of thermodynamics as given by Tolman [3]. The consequence being that to disprove inflation, that one has to come up with a different thermodynamic criteria. **Appendix A** is the generalized GR stress energy tensor we are considering. The breakdown of this tensor’s behavior comes from its GW component. We highlight the GW/Graviton contribution which violates the Lavenda and Davies criterion exactly. We first start off with the representation of a stress energy tensor for gravitons obeying [4] , namely $h \equiv \eta^{uv} h_{uv} = Trace \cdot (h_{uv})$ and $T = Trace \cdot \left(T^{uv}\right)$ that

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

Our work uses Visser's [1] analysis of non zero graviton mass for both T and h. 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

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

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

$$h_{uv} \equiv 2\frac{GM}{r}\cdot\left[\exp\left(\frac{-m_g r}{\hbar}\right)\right]\cdot\left(2\cdot V_\mu V_\nu + \eta_{uv}\right) \tag{3}$$

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

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

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

$$\hbar^2\omega^2 \cong m_g^2 c^4\cdot\left[1/\left(1-\breve{A}\right)\right] > 0 \tag{5}$$

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

According to Kim [5] , 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 [5] 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 permitting an evaluation of Eq. (2), covariant derivative of Eq.(2) and the Tolman conjecture as to the first law of thermodynamics.

Looking at Eq. (6) is the same as looking at the following, analyzing how[6]

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

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. The two values, as well as ascertaining when one can use $\frac{MG}{r}\sim 1/5$ or smaller, 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. The author believes that such a configuration would be occurring in most generation of gravitons at, or before the Electro Weak transition point in early cosmology evolution. We shall next look at what the Tolman [3] representation of the 1st law of thermodynamics, which we will be applying to Eq. (2) of course keeping fidelity with respect to the stability condition alluded to in Eq. (7) above. To do this, note that the Tolman [3] representation for the first law of thermodynamics is:

$$\frac{\partial}{\partial x_k}T_{ik} = 0 \tag{8}$$

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

$$\left[\left(\frac{\hbar}{l_P^2\lambda_g^2}\right)\cdot\left(\frac{GM}{r}\right)\cdot\exp\left(\frac{r}{\lambda_g}\right)+\left(\frac{GM}{r}\right)^2\right]=Const=c_1 \tag{9}$$

The approximation we make in understanding what is being said here is that the spatial parameter, r, is of the order of $r \sim l_P = Planck-length$, so as we take a small value of r, to quadratic behavior, and see how the parameters first fit together to find fidelity with respect to the first law of thermodynamics as given by Tolman[3]. If $\breve{B}=\left(\left[1/\lambda_g\right]-c_1\cdot\frac{l_P^2\lambda_g^2}{\hbar\cdot GM}\right)^{-1}$ is put into a quadratic version of Eq.(9) so we can identify the quadratic equation about equal to zero, for small r, we have

$$r^2+\breve{B}\cdot r+GM\cdot\breve{B}\cong 0 \tag{10}$$

$$\breve{B}<0 \tag{11}$$

$$r\approx\left(-\breve{B}/2\right)\cdot\left(1\pm\sqrt{1-4GM/\breve{B}}\right)$$
$$\Rightarrow\left[1/\lambda_g\right]>c_1\cdot\frac{l_P^2\lambda_g^2}{\hbar\cdot GM} \tag{12}$$

For large M, and for small wavelength, this inequality is satisfied, but it means that one must have a massive initial generating graviton source, and also a small wavelength. I.e. is this possible ? Only if there are very small initial wavelengths at/ before the electro weak regime. I.e. a wave length perhaps as small as Planck length. The problem is that in doing so, and this appears to be intuitive and obvious that one has a contradiction with Eq. (7) [6]

Either the analysis given for Eq. (12) is faulty, which would mean that one is not going to have the Tolman [3] criteria for the Stress energy tensor, as a derivative, satisfied, for stable gravitons, leading to no connection with the first law of thermodynamics for initial graviton production, or we have to say that there is no stability possible for early gravitons, which is tantamount to saying there is no early universe generation of GW, something which is contradicted by Durrer's [7] treatment of early universe plasma waves generating early universe GW.

Conclusion: ARGUING THAT THE INITIAL CONFIGURATION FOR GRAVITON PRODUCTION REFLECTS NON COMPLIANCE WITH TOLMAN'S FIRST LAW OF THERMODNAMICS.

The entire proof of the shakiness of the Tolman [3] conjecture for GR and the first law of thermodynamics opens up the door for either Penrose cyclic cosmology, or other such treatments which may explain, with further research how a massive graviton may also lead to information exchange between a prior to our present universe as has commented upon by Beckwith[8] . Note that Beckwith[8] has used Y. Ng's [9] counting algorithm with regards to entropy, and non zero mass (massive) gravitons , where

$$S\approx N\cdot\left(\log\left[V/\lambda^3\right]+5/2\right)\approx N \tag{13}$$

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

$$I=S_{total}/k_B\ln 2=\left[\#operations\right]^{3/4}\sim 10^7 \tag{14}$$

as implying at least one operation per unit graviton, with gravitons being one unit of information, per produced graviton[7]. **Note,** Smoot [11]gave initial values of the operations as

$$\left[\#operations\right]_{initially}\sim 10^{10} \tag{15}$$

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. (17) from a prior to a present universe, once initial conditions of inflation may be examined experimentally, i.e. looking at inputs into[8], i.e. The fine structure constant given in [8]

$$\tilde{\alpha} \equiv e^2/\hbar \cdot c \equiv \frac{e^2}{d} \times \frac{\lambda}{hc} \tag{16}$$

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 Eq (12) above. But we also argue that such an approach would make mincemeat out of a literal interpretation of either Eq. (8) , and then by extension the framework used by Lavenda and Davies[2] to argue that Eq. (8) is consistent with respect to not one ,but the first two laws of thermodynamics, used to allegedly falsify inflation. This assumes using formalism from [12] as a consistency check on the GWs. Note that Dr. Lavenda has informed me that he views the Ng S~ n [9] , i.e. Entropy as proportional to a numerical account as inappropriate and that Eq.(13) should not be considered at all for General relativity. The Author will work with Dr. Lavenda in trying to replace Eq. (13) with a better approximation in the future. Note that if the Visser Massive Graviton Stress energy tensor does not hold then the Lavenda and Davies objection to inflation is upheld. We will revisit this argument using the material from [15] in future research about early universe gravitons.

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

To do this we look at, from [14] 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 and the like. ρ has a gravitational radiation component . Effectively, Eq. (A1) has $\rho = \rho_{GW} + \rho_{Everything-else}$ such that

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

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