SHOWING FJORTOFT'S THEOREM DOES NOT APPLY FOR DEFINING INSTABILITY FOR EARLY UNIVERSE THERMODYNAMIC POTENTIALS. ASKING IF NUCEATED PARTICLE RESULT AT/ BEFORE EW ERA DUE TO INJECTION OF MATTER-ENERGY AT THE BIG BANG?

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Abstract

This paper uses the "Fjortoft theorem" for defining necessary conditions for instability. The point is that it does not apply in the vicinity of the big bang. We apply this theorem to what is called by T. Padmanabhan a thermodynamic potential which becomes would be unstable if conditions for the applications of "Fjortoft's theorem" hold. In our case, there is no instability, so a different mechanism has to be appealed to. In the case of vacuum nucleation, we argue that conditions exist for the nucleation of particles as of the electroweak regime. Due to injecting material from a node point, in spacetime. This regime of early universe creation, coexits with the failure of applications of "Fjortoft" theorem in such a way as to give necessary and sufficient conditons for matter creation, in a way similar to the Higgs Boson.
.Keywords: Fjortoft theorem, thermodynamic potential, matter creation, Higgs Boson.

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1 Introduction

We first start off with a review of the classicial *Fjortoft theorem* [1] and from there apply it to an early universe thermodynamic potential described by T. Padamanabhan [2] in Dice 2010. The objective will be to show that one can come up with a first principle creation of nucleated "particles", likely from a semi classical stand point which can be introducing the creation of mass without appealing directly to the Higgs Boson in the first place. That due to the fact that the Fjortoft theorem does not apply.There is an inflection point for the speed up of acceleration of the universe which exists one billion years ago for reasons which we will introduce in this manuscript. But no such inflection point at the origin of the big bang itself, or at the electroweak era either.

2 Describing the Fjortoft theorem

From [1] we have that the theorem to be considered should be written up as follows, namely, look at

Fjortoft theorem:

A **necessary condition for instability** is that if z_* is a point in spacetime for which $\frac{d^2U}{dz^2} = 0$ for any given potential U, then there must be some value z_0 in the range $z_1 < z_0 < z_2$ such that

$$\left.\frac{d^2U}{dz^2}\right|_{z_0} \cdot \left[U(z_0) - U(z_*)\right] < 0 \tag{1}$$

For the proof, see [1] and also consider that the main discussion is to find instability in a physical system which will be described by a given potential U. Next, we will construct in the boundary of the EW era, a way to come up with an optimal description for U

3. Constructing an appropriate potential for using Fjortoft theorem in cosmology for the early universe cannot be done. We show why

To do this, we will look at T. Padamanabhan [2] and his construction of in Dice 2010 of thermodynamic potentials he used to have another construction of the Einstein GR equations. To start, T. Padamanabhan [2] wrote

If P_{cd}^{ab} is a so called Lovelock entropy tensor, and T_{ab} a stress energy tensor

$$
\begin{aligned}
&U(\eta^a) = -4 \cdot P_{ab}^{cd} \nabla_c \eta^a \nabla_d \eta^b + T_{ab}\eta^a\eta^b + \lambda(x)\, g_{ab}\eta^a\eta^b \\
&= U_{gravity}(\eta^a) + U_{matter}(\eta^a) + \lambda(x)\, g_{ab}\eta^a\eta^b \qquad (2) \\
&\Leftrightarrow U_{matter}(\eta^a) = T_{ab}\eta^a\eta^b ; U_{gravity}(\eta^a) = -4 \cdot P_{ab}^{cd} \nabla_c \eta^a \nabla_d \eta^b
\end{aligned}
$$

We now will look at

$$
\begin{aligned}
&U_{matter}(\eta^a) = T_{ab}\eta^a\eta^b \quad ; \qquad (3) \\
&U_{gravity}(\eta^a) = -4 \cdot P_{ab}^{cd} \nabla_c \eta^a \nabla_d \eta^b
\end{aligned}
$$

So happens that in terms of looking at the partial derivative of the top (2) equation, we are looking at

$$
\frac{\partial^2 U}{\partial\left(\eta^a\right)^2} = T_{aa} + \lambda(x)\, g_{aa} \qquad (4)
$$

Thus, we then will be looking at if there is a specified η_*^a for which the following holds.

$$
\frac{\left[\dfrac{\partial^2 U}{\partial\left(\eta^a\right)^2} = T_{aa} + \lambda(x)\, g_{aa}\right]_{\eta_0^a} *}{\left[\begin{array}{l} -4 \cdot P_{ab}^{cd}\left(\nabla_c \eta_0^a \nabla_d \eta_0^b - \nabla_c \eta_*^a \nabla_d \eta_*^b\right) + \\ T_{ab} \cdot \left[\eta_0^a\eta_0^b - \eta_*^a\eta_*^b\right] + \lambda(x)\, g_{ab} \cdot \left[\eta_0^a\eta_0^b - \eta_*^a\eta_*^b\right] \end{array}\right]} < 0 \qquad (5)
$$

What this is saying is that there is no unique point, using this η_*^a for which (5) holds. Therefore, we say there is no official point of **instability of** η_*^a due to (4). The Lagrangian structure of what can be built up by the potentials given in (4) with respect to η_*^a mean that we cannot expect an inflection point with respect to a 2nd derivative of a potential system. Such an inflection point designating a speed up of acceleration due to DE exists a billion years ago [3]. Also note that the reason for the failure for (5) to be congruent to (1) is due to

$$\left[\frac{\partial^2 U}{\partial\left(\eta^a\right)^2} = T_{aa} + \lambda\left(x\right) g_{aa}\right] \neq 0,\ for \forall\, \eta_*^a choices \tag{6}$$

What (6) tells us is that there is an embedding structure for early universe geometry, some of which may take the form of the following diagram.

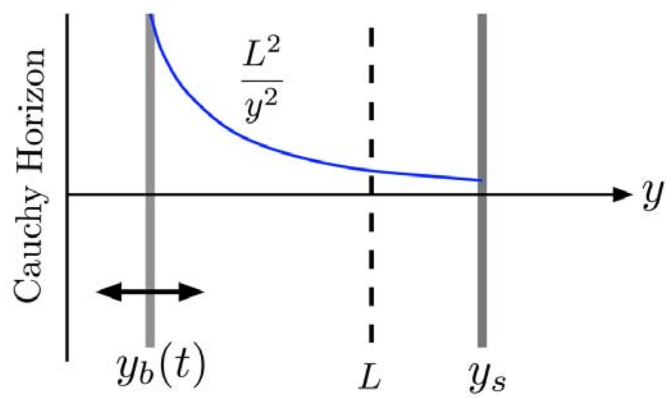

Figure 1, from [1]

4. **Working with a way to achieve energy injection into the universe, without appealing to Fjortoft theorem for alleged instabilities starting from Padmanabhan thermodynamic potential terms**

Padmanabhan[2] introduced the following discussion as to entropy, namely starting with energy, we have

$$E = \frac{1}{2} k_B \int dn T_{loc} \tag{7}$$

And the n value as in (7) is given by

$$dn = 32\pi \cdot P_{cd}^{ab} \cdot \varepsilon_{ab} \cdot \varepsilon^{cd} \cdot dA \tag{8}$$

Where P_{cd}^{ab} is a so called Lovelock entropy tensor, and ε_{ab} a bi normal on the co dimension -2 cross section, and then entropy is stated to be

$$S \propto \int_{\partial V} dn \propto \int_{\partial V} 32\pi \cdot P_{cd}^{ab} \cdot \varepsilon_{ab} \cdot \varepsilon^{cd} \sqrt{\sigma} d^{D-2}x \quad (9)$$

The end result, is that energy is induced via the temperature T_{loc} , while [2]

$$T_{loc} = N \frac{a^{\mu} n_{\mu}}{2\pi} = \text{local acceleration temperature} \quad (10)$$

Also, the change in n can be given by, if l_P is the Planck's length value[2]

$$\Delta n = \sqrt{\sigma}\, d^2 x / l_P \quad (11)$$

Looking at (9) and (11) we can make an argument that the change in number count given in (11) is really a holographic surface pheonmena, with N defined [2]

$$N = E / [(1/2) k_B T] \quad (12)$$

The upshot is that we can, as implied by Ng[4] easily reference a change in entropy via[4],[5],[6]

$$S \sim n \quad (13)$$

While having a change in n as due to a change in the spatial surface of spacetime as given in (11), we have to realistically infer that the local acceleration temperature (10) is from another pre universe contruction and that local instability is ruled out by (5) and (6). This leads us to ask as to what would be an acceptable way to form the formation of mass, i.e. say the mass of a graviton, via external factors introduced into our universe prior to the Electroweak era, in cosmology. To do that, look at if there are two branes on the AdS_5 space-time so that with one moving and one stationary, we can look at figure 1 as background as to introduce such external factors in our present space-time universe during its initial expansion phase

4. Fall out from adopting Figure 1 and that due to no instability in the Padamanabhan supplied potentials. i.e. a way to obtain graviton mass via a root finding method.

Using [7] what we find is that there are two branes on the AdS_5 space-time so that with one moving and one stationary, we can look at figure 1 which is part of the geometry used in the spatial decomposition of the differential operator acting upon the $h_{\bullet}$ Fourier modes of the h_{ij} operator [7] . As given by [7], we have that

$$\left[\partial_t^2 + k^2 - \partial_y^2 + \frac{3}{y}\cdot\partial_y\right]h_{\bullet} = 0$$

(14)

Using [8] (and also [7]) the solution to (14) above takes the form of having

$$h_{\bullet} = H_{ij} = e_{ij}\cdot\exp[i\cdot\omega\cdot t]\cdot(m\cdot y)^2\cdot A\cdot J_2\left(m\cdot y\right)$$

(15)

e_{ij} is a polarization tensor, and the function $J_2\left(my\right)$ is a 2nd order Bessel function [3] . A generalization offered by Durrer et al. [7], [8] leads to

$$h = \left\{\exp[i\cdot\omega\cdot t]\cdot(m\cdot y)^2\cdot A\cdot J_2\left(m\cdot y\right)\right\}\cdot\left(1+\frac{\pi}{4}\cdot(m\cdot\ell)^2\right)$$

(16)

With the factor of $\left(1+\frac{\pi}{4}\cdot(m\cdot\ell)^2\right)$ coming in due to a boundary condition upon the wall of a brane put in, i.e. looking at [7]. With the right hand side of (4) due to a domain wall tension of a brane.

$$-2\cdot\partial_y H_{ij} = \kappa_5\cdot\pi_{ij}^{(T)} \rightarrow 0 \qquad (17)$$

This will be in our example set as not equal to zero, in the right hand side, but equal to an extremely small parameter, namely

$$\partial_y H_{ij}\Big|_{y=yb} = \kappa_5\cdot\pi_{ij}^{(T)} \sim \xi^{+} \qquad (18)$$

With this turned into

$$\partial_y h\Big|_{y=yb} \sim \delta^{+} \qquad (19)$$

The right hand side of (19) represents very small brane tension, which is understandable. Then using [7],[8],[9] , i.e.

$$\partial_y h\Big|_{y=yb} = \partial_y\left\{\exp[i\omega t]\cdot(my)^2\cdot A\cdot J_2\left(my\right)\right\}\cdot\left(1+\frac{\pi}{4}\cdot(m\cdot\ell)^2\right)\Bigg|_{y=yb} \sim \delta^{+} \qquad (20)$$

And

$$J_2\left(my\right)=\frac{(my)^2}{2^2\cdot 2!}\cdot\left(1-\frac{(my)^2}{2^2\cdot 3}+\frac{(my)^4}{2^4\cdot 2!\cdot 3\cdot 4}-\frac{(my)^6}{2^6\cdot 4!\cdot 3\cdot 4\cdot 5}+...\right) \tag{21}$$

The upshot is, that afterwards,

$$\frac{(my)^4}{2^2\cdot 2!}\cdot\frac{1}{y}\left[\begin{array}{l}\left(1-\frac{(my)^2}{2^2\cdot 3}+\frac{(my)^4}{2^4\cdot 2!\cdot 3\cdot 4}-\frac{(my)^6}{2^6\cdot 4!\cdot 3\cdot 4\cdot 5}+...\right)\\ -\left(\frac{2\cdot(my)^2}{2^2\cdot 3}+\frac{4\cdot(my)^4}{2^4\cdot 2!\cdot 3\cdot 4}-\frac{6\cdot(my)^6}{2^6\cdot 4!\cdot 3\cdot 4\cdot 5}+...\right)\end{array}\right]$$
$$=\frac{\delta^+\cdot\exp\left[\mp i\omega t\right]}{A}\cdot\left[1-\frac{\pi}{4}\cdot\left(m\cdot\ell\right)^2\right]$$
(22)

Should the term

$$\frac{\delta^+\cdot\exp\left[\mp i\omega t\right]}{A}\cdot\left[1-\frac{\pi}{4}\cdot\left(m\cdot\ell\right)^2\right]\xrightarrow[\delta^+\to 0]{}0 \tag{23}$$

Then, (22) is acting much as in [7], and [8], whereas, one is recovering a simple numerical exercise as to obtain a suitable solution as given by (18), and (19) due to [1] where the domain tension of the brane vanishes. The novelty as to this approach given in (22) is to obtain a time dependent behavior of the mass of the graviton,

$$(my)=f(t)\Leftrightarrow m\equiv\frac{f(t)}{y} \tag{24}$$

Needless to say, (22) can only be solved for, numerically, i.e. fourth order polynomial solutions for quartic equations still give over simplified dynamics, especially if (24) holds, and makes things more complicated. This is all being done to keep fidelity with respect to [10], and [11] as a possible feature of brane world dynamics as reflected in [10],[11], as well as certain issues brought up in [12]

5 Conclusion, semi classical method of obtaining graviton mass procedure cannot be ruled out , and it impacts relic GW searches

For the semi classical sort of analogy referred to , look at [13], and [14], for examples of how quantum artifacts may be obtained via semi classical procedures. Also, let us consider if there is a massive graviton.

First of all, review the details of a massive graviton imprint upon h_{ij}, and then we will review the linkage between that and certain limits upon $h_{\bullet}$ *As read from Hinterbichler [15],if* $r = \sqrt{x_i x_i}$ *, and we look at a mass induced* h_{ij} *suppression factor put in of* $\exp(-m \cdot r)$*, then if*

$$h_{00}(x) = \frac{2M}{3M_{Planck}} \cdot \frac{\exp(-m \cdot r)}{4\pi \cdot r} \tag{17}$$

$$h_{0i}(x) = 0 \tag{18}$$

$$\begin{aligned} h_{ij}(x) &= \left[\frac{M}{3M_{Planck}} \cdot \frac{\exp(-m \cdot r)}{4\pi \cdot r} \right] \cdot \\ &\left(\frac{1 + m \cdot r + m^2 \cdot r^2}{m^2 \cdot r^2} \cdot \delta_{ij} - \left[\frac{3 + 3m \cdot r + m^2 \cdot r^2}{m^2 \cdot r^4} \right] \cdot x_i \cdot x_j \right) \end{aligned} \tag{19}$$

Here, we have that these h_{ij} values are solutions to the following equation, as given by [15], [16], with D a dimensions value put in.

$$\left(\partial^2 - m^2 \right) h_{\mu\nu} = -\kappa \cdot \left[T_{uv} - \frac{1}{D-1} \cdot \left(\eta_{uv} - \frac{\partial_\mu \partial_\nu}{m^2} \right) \cdot T \right] \tag{20}$$

To understand the import of the above equations, set

$$\begin{aligned} M &= 10^{50} \cdot 10^{-27} g \equiv 10^{23} g \propto 10^{61} - 10^{62} eV \\ M_{Plank} &= 1.22 \times 10^{28} eV \end{aligned} \tag{21}$$

We should use the $m_{massive-graviton} \sim 10^{-26} eV$ value in (21) above.

In reviewing what was said about (19),(20) we should keep in mind the overall Fourier decomposition linkage between $h_{\bullet}, h_{ij}$ which is written up as

$$h_{ij}(t, x; k) = \frac{1}{(2\pi)^{3/2}} \int d^3k \sum_{\bullet = +, \otimes} e^{ik \cdot x} e_{ij}^{\bullet} h_{\bullet}(t, y; k) \tag{22}$$

The bottom line is that the simple de composition with a basis in two polarization states, of $+, \otimes$ will have to be amended and adjusted , if one is looking at massive graviton states, and if we are going to have a coupling as given by (6), 4 dimensional zeroth order mass massive graviton values, and the input of information given in (17) to (20) as given by [7] Having a a simple set of polarization states as given by $+, \otimes$ will have to be replaced, mathematically by a different de composition structure, with the limit of massive gravitons approaching zero reducing to the simpler $+, \otimes$ basis states.

Needless to say, if semi classical methods can be fruitfully used to fill in the masses of a graviton, and we use emergent structures appropriately which are then put into (22), it could influence giving a semi classica interpretation as to entrophic origins of gravity, along the lines brought up by both t'Hooft , indirectly [17], and Lee [18] directly.

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