NLED Gedankenexperiment for initial temperature, particle count, and entropy affected by initial degrees of freedom in early universe cosmology , with two cases, one where $\Delta E \Delta t_{time} \doteq \hbar \equiv 1$ and another when it doesn't (increases initial entropy)

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Abstract. **We initially look at a non singular universe representation of entropy, with statistical inference based on Ha's presentation in the ICGC2011 meeting. We conclude with work akin to what Mukhanov worked with in early Universe cosmology in terms of in terms of $\Delta E \Delta t_{time} \doteq \hbar \equiv 1$ leading to an initial time step of the order of Planck time, as opposed to the GR equation which postulates time set at t = 0 initially. We then compare this to when $\delta g_{tt} \cdot \Delta T_{tt} \geq \frac{\hbar}{V^{(4)}}$**

1. Introduction, setting up for calculation of using the results of initial temperature T as a way to answer initial time step value, initial energy, and also entropy of the universe, from first principles. This when $\Delta E \Delta t_{time} \doteq \hbar \equiv 1$ as compared to $\delta g_{tt} \cdot \Delta T_{tt} \geq \frac{\hbar}{V^{(4)}}$

We follow what Ha wrote up [1] that there is a way to outline some basic thermodynamic arguments pertinent to quantum gravity. Our first move will be outlining equations of state, thermodynamically speaking as far as entropy, internal energy and a partition function given by Ng [2] as to 'infinite quantum statistics' which can be used, then to extract, first an initial temperature, T, which then can be linked to the energy per degree of freedom of the initial cosmological configuration. The temperature T so identified with, is proportional to energy per degree of freedom, and if the degrees of freedom as initially configured, by Kolb and Turner [3] are as high as $g_{*S} = 106$, or higher, that number of degrees of freedom can be configured to read as contributing to an initial energy configuration as given by

$$E_{initial} = g_{*s}(initial) \cdot \left[\frac{1}{2} \cdot k_B \cdot T_{initial} \right] \equiv \frac{g_{*s}(initial)}{2} \cdot T_{initial} \quad (1)$$

Then in the spirit of Mukhanov [4] using $\Delta E \Delta t_{time} \doteq \hbar \equiv 1$ to have, here

$$\Delta t_{time}(initial) = 1 / E_{initial} = \frac{2}{g_{*s}(initial) \cdot T_{initial}} \quad (2)$$

Then, we go to the Entropy, and state it is due to calculation given by Kolb and Turner [3]

$$S(initial) \sim n(particle-count) \approx g_{*s}(initial)\cdot V_{volume}\cdot\left(\frac{2\pi^2}{45}\right)\cdot\left(T_{initial}\right)^3 \quad (3)$$

Our article will be developed by making sense of the above formalism, and we start by getting $T_{initial}$

2. Calculating $T_{initial}$ $\Delta E \Delta t_{time} \doteq \hbar \equiv 1$

To do this, we will be appealing to the thermodynamic identities identified by Ha [1] which are given by , with a reformulation of entropy due to [3] on the left hand side as given by

$$S(initial)\left[\approx g_{*s}(initial)\cdot V_{volume}\cdot\left(\frac{2\pi^2}{45}\right)\cdot\left(T_{initial}\right)^3\right] = k_B \ln(Z) + \frac{U}{T_{initial}} \quad (4)$$

Here, U is the internal energy , and Z is the partition function. For the sake of connections to Ng's work [2] on infinite quantum statistics, we identify

$$Z(\inf - statistics) \sim \left[\frac{V_{volume}}{\lambda^3\left(wavelength\right)}\right]^N = Z_N \quad (5)$$

Then the internal energy, was given by [1] will lead to an equation of state we will render as

$$\begin{aligned} &\frac{V_{Vol}}{N}\cdot\left(\frac{V_{Vol}}{\lambda^3\left(wavelength\right)}\right)\cdot g_S\cdot T^4 + \frac{\partial\left(\frac{V_{Vol}}{\lambda^3\left(wavelength\right)}\right)}{\partial\left(1/k_B T\right)} \\ &\equiv \frac{V_{Vol}}{N}\cdot\left(\frac{V_{Vol}}{\lambda^3\left(wavelength\right)}\right)\cdot g_S\cdot T^4 + \frac{\partial\left(\frac{V_{Vol}}{\lambda^3\left(wavelength\right)}\right)}{\partial\left(1/T\right)} \cong 0^+ \end{aligned} \quad (6)$$

Our approximation afterwards is to do the following, namely have the wavelength related to energy as given by Gasiorowitz [5] as given by

$$\lambda = 2\pi \big/ E_{Energy} \doteq 2\pi \Big/ \left(\left.\frac{T}{2}\right|_{Deg.of.freedom}\right) \quad (7)$$

Then, we have the following break down as far as an initial temperature dependent value of initial space-time which will be referenced later , as to its implications as to structure formation and possible graviton production

$$
\begin{aligned}
&\frac{V_{Vol}}{N}\cdot\left(\frac{V_{Vol}}{\lambda^3\left(wavelength\right)}\right)\cdot g_S\cdot T^4+\frac{\partial\left(\frac{V_{Vol}}{\lambda^3\left(wavelength\right)}\right)}{\partial\left(1/T\right)} \\
&\doteq\frac{V_{Vol}}{N}\cdot\left(\frac{T^7}{64\pi^3}\right)\cdot g_S+\frac{\partial\left(\frac{(1/T)^{-3}}{64\pi^3}\right)}{\partial\left(1/T\right)} \\
&\doteq\frac{V_{Vol}}{N}\cdot\left(\frac{T^7}{64\pi^3}\right)\cdot g_S-3\cdot\frac{(1/T)^{-4}}{64\pi^3}\cong 0 \\
&\Leftrightarrow\frac{V_{Vol}}{N}\cdot\left(\frac{T^3}{64\pi^3}\right)\cdot g_S\cong\frac{3}{64\pi^3} \\
&\Leftrightarrow T_{initial}\cong\left(\frac{N}{V_{Vol}\cdot g_S}\right)^{1/3}=\left(\frac{N}{g_S}\right)^{1/3}\cdot 10^{-\alpha}\cdot L_{Planck}^{-1}
\end{aligned}
\tag{8}
$$

If say, $\alpha\sim 3-4$, and $g_s\sim 106$, and the initial temperature is of the order of $10^{35}\,Kelvin$, the above Eq. (8) gives a road map as to admissible values of N, i.e. say N as a measure of entropy according to the Ng. [2] approximation of entropy according to infinite quantum statistics as by the identification by Ng [2] of , if N ~ n(particle count), where we have L_{Planck} as the Planck length, then [2]

$$
S(entropy)\sim n(particle-count) \tag{9}
$$

Then,

$$
t_{initial}\sim\frac{2}{g_*^{2/3}}\cdot\frac{10^{\alpha}}{N}\cdot L_{Planck} \tag{10}
$$

Then, up to a point, if the above is in terms of seconds, and N sufficiently large, we could be talking about an initial non zero entropy, along the lines of the number of nucleated particles, at the start of the cosmological era. As given by

$$
S(initial)\sim\left(N\doteq n\right)\sim\frac{2}{g_*^{2/3}}\cdot\frac{10^{\alpha}}{t_{initial}}\cdot L_{Planck} \tag{11}
$$

Initial entropy would be small, but non zero, and would be affected by g_* strongly, i.e. the initial degrees of freedom assume would play a major role as far as how initial entropy and initial time steps would be initiated.

3. **Graviton mass, i.e. the major elephant in the room (heavy gravity) and Baryon density formation. When $\Delta E\Delta t_{time}\doteq\hbar\equiv 1$ as opposed to $\delta g_{tt}\cdot\Delta T_{tt}\geq\frac{\hbar}{V^{(4)}}$**

As of recently. The following argument has been given as to forming a cosmological constant, Namely due to [6] the following can be scaled as to the present Einstein 'constant'

$$\Lambda_{Einstein-Const.} = 1 \big/ l^2_{Radius-Universe} \tag{12}$$

Then if we assume that due to [6] is extended by [7]

$$m_{graviton} = \frac{\hbar}{c} \cdot \sqrt{\frac{(2\Lambda)}{3}} \approx \sqrt{\frac{(2\Lambda)}{3}} \tag{13}$$

Here we can view the possibility of considering the following, namely [6] is extended by [7] so we can we make the following identification?

$$N = N_{graviton}\Big|_{r_H} = \frac{c^3}{G \cdot \hbar} \cdot \frac{1}{\Lambda} \approx \frac{1}{\Lambda} \tag{14}$$

Should the N above, be related to entropy, and Eq. (14) be similar as Eq. (12), then depending upon how the dependence of N in Eq. (11) goes with g_*, i.e. degrees of freedom, there conceivably could be some difference in how the mass of a graviton scaled, with perhaps the initial graviton mass having the following dependence, namely if g_* increased, then the mass of a graviton would also change. This supposition has to be balanced against the following identification, namely, as given by Padmanabhan[8]

$$\Lambda_{Einstein-Const.Padmanabhan} = 1 \big/ l^2_{Planck} \cdot \left(E/E_{Planck}\right)^6 \tag{15}$$

Note, if the $E_{Planck} \sim 10^{28} eV$, and $m_{graviton} \sim 10^{-32} eV$, and $E \sim N_{graviton} \cdot m_{graviton}$ we may get variation in the initial graviton mass. But should the energy in the numerator in Eq. (15) be given as say by Eq. (1) above, then there would have been defacto quintessence, i.e. variation in the "Einstein constant" , which would have a large impact upon mass of the graviton, with a sharp decrease in g_* being consistent with an evolution to the ultra light value of the Graviton , with initial frequencies of the order of say

$$\omega_{initial}\Big|_{r_H \sim 1 meter} \sim 10^{21} Hz \tag{16}$$

And, in material given by Gorbunov, and Rubanov, [9] initial moves toward an effective baryon mass density given by. If $m_{proton-mass}$ is proton mass, $\varsigma(3)$ = 1.20… and $\eta_{Baryon-photon}$ baryon to Photon ratio which holds even in z < 1100 (when there was baryon-photon coupling, before first light of the CMBR) where there is a relationship between the wavelength, as given by Eq. (7), temperature and the inverse of Eq. (7) which would influence admissible initial frequencies, as given by Eq. (16) above. Furthermore the temperature dependence of wavelength and its inverse as shown by frequency, above, would be saying that the baryon density as given in early universe evolution has a temperature dependence. As given by [9]

$$\rho_{Baryon} \sim .75 \cdot m_{proton-mass} \cdot \eta_{Baryon-photon} \cdot \frac{2 \cdot \varsigma(3)}{\pi^2} \cdot T^3 \tag{17}$$

We claim that the dynamics of how Eq. (17) could be established would effect later structure formation especially if the temperature T is sensitive to changes in g_*, as Z decreases. Among other things

4. What if there is a difference in the case of modification of the HUP?

We will be using the approximation given by Unruh [10,11], of a generalization we will write as

$$\begin{aligned}(\Delta l)_{ij} &= \frac{\delta g_{ij}}{g_{ij}} \cdot \frac{l}{2} \\ (\Delta p)_{ij} &= \Delta T_{ij} \cdot \delta t \cdot \Delta A\end{aligned} \tag{18}$$

We will be then working to obtain a situation for which if we use the following, from the Roberson-Walker metric[3,4].

$$\begin{aligned}g_{tt} &= 1 \\ g_{rr} &= \frac{-a^2(t)}{1-k\cdot r^2} \\ g_{\theta\theta} &= -a^2(t)\cdot r^2 \\ g_{\phi\phi} &= -a^2(t)\cdot \sin^2\theta \cdot d\phi^2\end{aligned} \tag{19}$$

Following Unruh [5] , write then, an uncertainty of metric tensor as, with the following inputs

$$a^2(t) \sim 10^{-110}, r \equiv l_P \sim 10^{-35} meters \tag{20}$$

Then, if $\Delta T_{tt} \sim \Delta\rho$ [3,4,5]

$$\begin{aligned}&V^{(4)} = \delta t \cdot \Delta A \cdot r \\ &\delta g_{tt} \cdot \Delta T_{tt} \cdot \delta t \cdot \Delta A \cdot \frac{r}{2} \geq \frac{\hbar}{2} \\ &\Leftrightarrow \delta g_{tt} \cdot \Delta T_{tt} \geq \frac{\hbar}{V^{(4)}}\end{aligned} \tag{21}$$

Then, if $T_{ii} = diag(\rho, -p, -p, -p)$, then

$$\Delta T_{tt} \sim \Delta\rho \sim \frac{\Delta E}{V^{(3)}} \tag{22}$$

Then,

$$\begin{aligned}&\delta t \Delta E \geq \frac{\hbar}{\delta g_{tt}} \neq \frac{\hbar}{2} \\ &Unless \quad \delta g_{tt} \sim O(1) \\ &\& \delta g_{tt} \sim a^2(t)\cdot\phi << 1\end{aligned} \tag{23}$$

We will pick for the basis of analysis the following, namely if ϕ is an inflaton, then we have, here

If we have $S_{initial}(with[\delta g_{tt}])$ for the entropy, in this situation with $\delta g_{tt} << 1$, then by Eq. (23), we get

$$
\begin{aligned}
&\delta t \Delta E = \frac{\hbar}{\delta g_{tt}} \equiv \frac{\hbar}{a^2(t)\cdot\phi} << \hbar \\
&\Leftrightarrow S_{initial}(with[\delta g_{tt}]) = (\delta g_{tt})^{-3} S_{initial}(without[\delta g_{tt}]) >> S_{initial}(without[\delta g_{tt}])
\end{aligned}
\tag{24}
$$

I.e. the fluctuation $\delta g_{tt} << 1$ dramatically boost initial entropy. Not what it would be if $\delta g_{tt} \approx 1$

5. Conclusion. Are there any circumstances for which $\delta g_{tt} \approx 1$? Yes, when there is Planckian time but otherwise it can get very small, for times << Planckian time. Consequences outlined

How could one actually have

$$
\delta g_{tt} \sim a^2(t)\cdot\phi \xrightarrow[\phi \sim Very\,Large]{} 1 \tag{25}
$$

In short, we would require an enormous 'inflaton' style ϕ valued scalar function, and $a^2(t) \sim 10^{-110}$ How could ϕ be initially quite large ? Within Planck time the following for mass holds, as a lower bound

$$
m_{graviton} \geq \frac{2\hbar^2}{(\delta g_{tt})^2 l_P^2} \cdot \frac{(E-V)}{\Delta T_{tt}^2} \tag{26}
$$

Here,

$$
K.E. \sim (E-V) \sim \dot{\phi}^2 \propto a^{-6} \tag{27}
$$

Then

$$
\dot{\phi} \sim a^{-3} \Leftrightarrow \phi \sim t \cdot a^{-3} + H.O.T \tag{28}
$$

If $a^2(t) \sim 10^{-110}$, then $\Leftrightarrow a^{-3} \sim 10^{165}$ with the result that Eq.(28) is very large for t > Planck time. However, for pre Plankian physics, with time << Planck time, we can have situations for which the time is effectively zero, while $a^2(t) \sim 10^{-110}$ is the smallest possible scale factor, leading to, by quantum bounces, a situation in which $\delta g_{tt} << 1$ for Pre Plankian times, which do not have a zero scale factor.

Why we pursued this datum of an initial non zero entropy ? In a word, to preserve the fidelity of physical law from cosmological cycle to cycle. I.e. and also from Giovanni[10] , with the upper end to graviton frequencies calculated as follows [10]

$$S_{gravitons-present.era} = V(volume) \times \int_{v0}^{v1} r(v)dv$$
$$\approx (10^{29})^3 \times \left(H_1 / M_p\right)^3 \sim (10^{29})^3 \sim 10^{87} \qquad (29)$$
$$\Leftrightarrow v0 \sim 10^{-18} Hz \,\&\, v1 \sim 10^{11} Hz$$

Our scaling law, as given above, as far as to the implications of Eq.(24) will generally, for graviton producing phenomenology, with the initial Graviton volume effectively initially non zero will then argue that even with Eq. (29) and a simple scaling of Eq. (29) as for entropy, that initial entropy will still not go to zero, so as to imply that S ~ N (graviton) will not have the RHS going to zero. So let us examine the consequences.

We claim that the entropy , non zero , but leading to this derivation, as given by earlier parts of our document is fully in fidelity with this above calculation. Secondly, any such calculations as we engage in have to have fidelity with respect to the limits given in [11], and of course we will investigate if there is any relationship with the more string theory version of this argument given by Cai, in [12] has an abbreviated version of entropy as part of a generalized information measurement protocol which we will render as having T.F.A.E.

$$\Lambda \sim \tilde{N} \Leftrightarrow$$
$$e^{\tilde{N}} states \Leftrightarrow \qquad (30)$$
$$set \quad of \quad all \quad \Lambda\left(\tilde{N}\right) \quad of \quad space-times$$

The consequences of the proportionality of a graviton count , if $N \sim \tilde{N}$, or what have you will lead to the possibility of variation of , which is what we would have, if we take Eq.(29) literally, or variations in the case of

$$\Lambda\left(\tilde{N}\right) \sim \Lambda\left(N\right) \neq 0 \qquad (31)$$
$$\& e^{\tilde{N}} \geq 1$$

There would then by Eq. (30) at least 1 physical state, and that there would be possible variation in the Planck 'constant' with a minimum non zero value, with the result that $\Lambda\left(\tilde{N}\right) \sim \Lambda\left(N\right) \neq 0$. I.e. non zero initial entropy, a non zero $\Lambda\left(\tilde{N}\right) \sim \Lambda\left(N\right) \neq 0$ and also at least one physical state, even in Pre Planckian space-time conditions, due to $e^{\tilde{N}} \geq 1$. We will be examining the consequences of the above in further publications.

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References

[1] Y. K. Ha, " An Underlying theory for Gravity", Proceedings of the 7th international conference on Gravity and Cosmology, (ICGC2011), Journal of physics: Conference series

484(2014), 012061; http://iopscience.iop.org/1742-6596/484/1/012061/pdf/1742-6596_484_1_012061.pdf

[2] Y. Jack Ng, "Holographic foam, dark energy and infinite statistics," Phys. Lett. B, 657, (2007), pp. 10-14 Y.Jack Ng,"Article: Spacetime Foam: From Entropy and Holography to Infinite Statistics and Nonlocality" Entropy 2008, 10(4), 441-461; DOI: 10.3390/e10040441

[3] E.Kolb, M. Turner, *The Early Universe*, Frontiers in physics, Vol 69, Chicago, Illinois, USA, 1990

[4] Y. Mukhanov, *Physical Foundations of Cosmology*, Cambridge University Press, Cambridge, UK, 2005

[5] S. Gasiorowitz, *Quantum Physics* , Wiley Interscience, Boston Massachusetts, USA, 1973

[6] A. F. Ali, S. Das "Cosmology from Quantum Potential", Physics Letters B 741, (2015), 276-279

[7] I. Haranas and I. Gkigkitzis, "The Mass of Graviton and Its Relation to the Number of Information according to the Holographic Principle***",*** International Scholarly Research Notices, Volume 2014 (2014), Article ID 718251, 8 pages, http://www.hindawi.com/journals/isrn/2014/718251/

[8] T. Padmanabhan, http://ned.ipac.caltech.edu/level5/Sept02/Padmanabhan/Pad1_2.html

[9] D. Gornbunov, V. Rubakov, *Introduction to the Theory of the Early Universe, Cosmological Perturbations and Inflation theory*, World Scientific Publishing Co. Pte.Ltd, Hakensack, New Jersey, USA, 2011

[10] M. Giovannini *A primer on the Physics of the Cosmic Microwave Background* , World Scientific, Singapore, Republic of Singapore, 2008

[11] **A. Goldhaber, M. Nieto, "Photon and Graviton Mass Limits", Rev.Mod.Phys.82:939-979,2010, http://arxiv.org/abs/0809.1003'**

[12] R-C. Cai, "Some Remarks on Constant Curvature Spaces", pp. 234-250, in *Superstring Theory,* K. Liu, and S-T. Yau, (Advanced Lectures in Mathematics,) Higher Education Press, Beijing, PRC (2005)