Isolating a minimum radius of the universe consistent with the production of at least 1 unit of entropy, at the start of inflation

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Abstract

We begin by examining a general expression of entropy, and its links to a minimum radius of the universe. We derive an expression for the production of at least 1 unit of entropy, which translates to a value of Planck length in radii to 1000 times Planck radii, for the quantum bubble of space-time which dependent upon, of all things, the initial Hubble expansion rate value. If the Hubble parameter has the value of 10^ 10 GeV, we see a minimum radial length of the Universe of about 1 billion times Planck length. If the Hubble parameter is of 10^19 GeV, the minimum radial length of the universe would be about one Planck length, which is surprising to put it mildly. The higher the initial temperate is, up to a point, the more likely the initial entropy is closer to the Causal barrier mentioned in an earlier publication by the author

Key words. Causal barrier, Inflaton, Mininum entropy (non zero), initial radii (of universe)

I. Introduction, the preliminaries

We begin with the expression given in [1, 2, 3], with F the free energy, and S the entropy so that

$$\begin{aligned} & F = -k_B T \ln Z \\ & S = -\left(\frac{\partial F}{\partial T}\right)_{V,N} \sim k_B T \ln Z \\ & \propto n(entropy - count) \end{aligned} \quad \textbf{(1)}$$

The end result is that we will approximate the entropy count as given by the last line of Eq. (1) so that we can refer to an article in [4] for which there exists a critical Hubble parameter, H_I for which we have by [1] a $H_I = 10^{10} GeV$ value, which will be shown to have $n(entropy - count) \sim 1$, with a radius of the universe of about 1000 times Planck length. Also, where if we have instead, $H_I = 10^{18} GeV$ we have $n(entropy - count) \sim 1$ with a radius of the Universe of about one Planck length. After this is done, we will then comment upon the value of the square of the average inflaton value given by [5] Where the square, of the inflaton, is given as follows, with a single inflaton given in Eq. (2) as follows:

$$\left\langle \phi^2 \right\rangle = \frac{3H_I^2}{8\pi^2 m^2} \cdot \left(1 - \exp\left[-\frac{2m^2}{3H_I} \cdot (t - t_0) \right] \right)$$
$$\approx \frac{3H_I^3 \cdot (t - t_0)}{8\pi^2} \quad if \; (t - t_0) << 3H_I / m^2 \tag{2}$$
$$\&$$
$$\phi = \sqrt{\left\langle \phi^2 \right\rangle} = \frac{H_I}{2\pi} \cdot \sqrt{H_I \Delta t}$$

With the substitution of m as the mass of a graviton, as given in [6], i.e. about 10^-62 grams, the inequality leading to a graviton mass induced behavior of the inflaton which we will comment upon fully while making use of Δt which is discussed in [7, 8]. In doing so, if one wants close to a Pre-Planckian length and time step, the preference would be to use $H_I = 10^{18} GeV$, which then gets to the issue of interpretation of what to make of the following, from [9], i.e. if g^* refers to initial degrees of freedom, then we will interpret several different cases for Eq. (3) below, with different mass scale ideas in, and different initial temperature scenarios.

$$H_{Early-Universe} \sim 1.66 \cdot \sqrt{g^*} \cdot \frac{T_{Early-Universe}}{M_{mass-scale}} \tag{3}$$

We will discuss all this and more in the subsequent analysis. Our final points will be using a comment from Rudin, as to outer measures [10] and its relationship to the causal structure brought up in [11] and [12]

II. The basic analysis to consider

What we are looking at first of all, is if Eq. (1) is true, and Entropy is a counting algorithm, which is not so far fetched, then by use of [4] for entropy, and H_I as well as [3] for **S (entropy) $\propto$ n (particle count)** then

$$S = -\left(\frac{\partial F}{\partial T} \right)_{V,N} \sim k_B T \ln Z$$
$$S \propto n(entropy - count) \tag{4}$$
$$\sim \frac{H_I^3}{180\pi} \cdot \left[Volume(space - time) \right]$$

Then, we have that

$$S \propto n(entropy - count)$$
$$\sim \frac{H_I^3}{180\pi} \cdot \left[Volume(space - time) \right] \tag{5}$$
$$\sim \frac{H_I^3}{180\pi} \cdot \left[\beta^3 \times l_{Planck}^3 \right]$$

We then will pick the smallest possible entropy value of n as equal to 1. Then what we are looking at is

$$\beta \sim \left[\frac{H_I^3}{180\pi}\right]^{-1/3} \qquad (6)$$

We will look at two cases for our analysis, and the first one is with the [5] value of $H_I = 10^{10} GeV$

III. What if $H_I = 10^{10} GeV$? Consequences for Eq. (6)

Here we first normalize the $H_I = 10^{10} GeV$ with regards to the Planck Mass. The Planck Mass is [13]

$$M_{Planck} \approx 4.341\times10^{-9} \text{ kg} = 2.435 \times 10^{18} \text{ GeV}/\ c^2 \qquad (7)$$

We will set c = 1 a, normalize the Planck mass to be = 1. If so then we write

$$H_I = 10^{10} GeV \xrightarrow[Planck-Unit-Normalization, wtih\ M_{Planck} \to 1]{} \frac{10^{-8}}{2.435} \qquad (8)$$

If so then, we will have Eq. (6) rendered to be

$$\beta \sim \left[\frac{H_I^3}{180\pi}\right]^{-1/3} \sim \left[\frac{180\pi \times (2.435)^3}{10^{-24}}\right]^{1/3} \sim 10^8 \times 2.435 \times 8.267 \sim 10^8 \times 20.13 \sim 2 \times 10^9 \quad (9)$$

By inspection, it means in order to have Eq. (6) of the order of magnitude of about 1, or less, we need to look at

$$H_I = 10^{19} GeV \xrightarrow[Planck-Unit-Normalization, wtih\ M_{Planck} \to 1]{} \frac{10^1}{2.435} \sim 4.106 \qquad (10)$$

I.e. H_I would be at least a billion times larger than $H_I = 10^{10} GeV$, in order to have Planck length of radii of the initial configuration of space time for at least 1 unit of entropy production. With the lower value of H_I as specified in [5] we would have then an initial radii of Planck length times one billion for about 1 unit of entropy production of our analysis.

IV. Consequences of $H_I = 10^{19} GeV \sim \frac{10^1}{2.435} \sim 4.106 \quad instead \quad of \quad H_I = 10^{10} GeV \sim \frac{10^{-8}}{2.435}$

Going back to the Eq. (3) it depends upon what we choose the Mass, in the denominator, to be, of which if it is Planck Mass, and we normalize that to 1, then we have at the boundary of about a Planck length for a 1 entropy value, i.e. one count of a primordial particle, but at an insanely high initial temperature, of the order of Planck temperature of about 1.417×10^{32} kelvin , or about 1.22×10^{19} GeV, for the given production of 1 unit of Planck mass. Note that Planck length is about, in simple units set about being $1.616229(38)\times10^{-35}$ m so this means that the radii of the universe even with

$$H_I = 10^{10} GeV \xrightarrow[Planck-Unit-Normalization, wtih \ M_{Planck} \to 1]{} \frac{10^{-8}}{2.435}$$
$$\Rightarrow Radius(Universe) \quad for \quad n \geq 1 \quad about \quad 10^{-26} meters$$
$$H_I = 10^{19} GeV \xrightarrow[Planck-Unit-Normalization, wtih \ M_{Planck} \to 1]{} \frac{10^{1}}{2.435} \sim 4.106 \tag{11}$$
$$\Rightarrow Radius(Universe) \quad for \quad n \geq 1 \quad about \quad 10^{-35} meters$$

V. Conclusion. Planck radii in length for initial configuration of universe could lead to one unit of entropy production. Consequences? Ultra High temperatures. What else?

What we would have to go back to, then would be the Dowker Structure of space-time as given in [12] and that would place a premium upon also understanding the role of [11]

$$\left(\frac{R_c|_{initial} \sim c \cdot \Delta t}{l_{Planck}} \right) \sim \vartheta(1) \tag{12}$$

I.e. what we are asserting is that at Planck temperature, we are observing a convergence close to the value of where we may have the initiation of a Causal structure. If so, then is Entropy, initially created at the START pf causal structure, due to an opportune selection of a special unit of Δt . I.e. note that in [8] we did suggest that the formation of the arrow of time, so done, would be a precursor of entropy, i.e. that that our argument may in itself be a first principle proof that the arrow of time, as initially formed, is a precursor for at least 1 unit of entropy created, and that this would be commensurate with making sense of

$$\phi = \sqrt{\langle \phi^2 \rangle} = \frac{H_I}{2\pi} \cdot \sqrt{H_I \Delta t} \tag{13}$$

I.e. if we satisfy Eq. (11), Eq. (12), Eq. (13) in the case of $H_I = 10^{19} GeV \sim \frac{10^1}{2.435} \sim 4.106$ we are also asserting that the formation of an Inflaton, according to [5] , is in our estimation simultaneous with the formation of causal structure as indicated by Eq. (12), as well as giving more inputs into the Padmadabhan model we used in [8] for the inflaton, i.e. [14] , as well as the idea given by Corda as to the Gravity's breath suggestion he made the author aware of which the author finds quite pleasing to contemplate[15].

In doing so, in the formation of Causal structure, so long as it does not contravene the outer measure definition given in [10] requirements linked toward getting Eq. (11) satisfied, we are not in trouble, at least mathematically for the time being. We will be using the nonsingular approach pioneered by [16] and [17] and we should do our best to avoid problems in our analysis which may contradict the LIGO results of [18] and [19], especially if each single count of n, as referenced to entropy is in common with gravtions. Also, our analysis should be further refined to take into account [20], which may be with initial instrument refinements doable. Even so, we also point to [20] as having relevance to early universe work in our future endeavors [21]

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