How a Minimum time step and Formation of Initial Causal structure in space-time is linked to an enormous initial Cosmological constant.

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Abstract

We use a root finder procedure to obtain Δt were we use an inflaton value due to use of a scale factor $a \sim a_{\min} t^{\gamma}$ if we furthermore use $\delta g_{tt} \sim a_{\min}^{2} \cdot \phi_{initial}$ as the variation of the time component of the metric tensor g_{tt} in Pre-Planckian Space-time up to the Planckian space-time initial values. In doing so, conclude with very restricted limit values for Δt of the order of less than Planck time, leads to an enormous value for the initial Cosmological constant.

Key words Inflaton physics, causal structure, non Linear Electrodynamics.

I. Framing the initial inquiry

Volovik [1] derives in page 24 of his manuscript a description of a total vacuum energy via an integral over three dimensional space

$$E_{Vac}(N) = \int d^3 r \cdot \varepsilon(n) \tag{1}$$

The integrand to be considered is , using a potential defined by $U = \frac{c^2 m}{n}$ as given by Volovik for weakly interacting Bose gas particles, as well as

$$\varepsilon(n) = \frac{1}{2} U \cdot n^2 + \frac{8}{15\pi^2 \hbar^3} m^{3/2} U^{5/2} n^{5/2} = \frac{1}{2} \cdot c^2 \cdot \left[n \cdot m + \frac{4}{15} \cdot \left(\frac{m^5}{\hbar^2 \cdot \sqrt{c}} \right) \cdot \frac{1}{n^2} \right] \tag{2}$$

For the sake of argument, m, as given above will be called the mass of a graviton, n a numerical count of gravitons in a small region of space, and afterwards, adaptations as to what this expression means in terms of entropy generation will be subsequently raised. A simple graph of the 2nd term of Eq. (.2) with comparatively large m and with $\hbar = c = 1$ has the following qualitative behavior. Namely for

$$\text{E1} = \left[c^2 / 2 \right] \cdot \left[\frac{4}{15} \cdot \left(\frac{m^5}{\hbar^2 \cdot \sqrt{c}} \right) \cdot \frac{1}{n^2} \right] \tag{3}$$

E1 $\neq 0$ when n is very small, and E1 = 0 as $n \to 10^{10}$ at the onset of inflation. This will tie in directly with a linkage between energy and entropy, as seen in the construction, looking at what Kolb [2] put in, i.e.

$$\rho = \rho_{radiation} = (3/4) \cdot \left[\frac{45}{2\pi^2 g_*} \right]^{1/3} \cdot S^{4/3} \cdot r^{-4} \tag{4}$$

Here, the idea would be, to make the following equivalence, namely look at,

$$\left[\left[\frac{\Lambda_{Max} r^4}{8\pi G} \right] \cdot (4/3) \cdot \left[\frac{2\pi^2 g_*}{45} \right]^{1/3} \right]^{3/4} \sim S_{initial} \tag{5}$$

We furthermore, make the assumption of a minimum radius of

$$R_{initial} \sim \frac{1}{\#} \ell_{Ng} < l_{Planck} \tag{6}$$

This Eq. (6) will be put as the minimum value of r, in Eq. (5), where we have in this situation[3,4]

$$\# bits \sim \left[\frac{E}{\hbar} \cdot \frac{l}{c} \right]^{3/4} \approx \left[\frac{Mc^2}{\hbar} \cdot \frac{l}{c} \right]^{3/4} \tag{7}$$

And if M is the total space-time energy mass, for initial condition and E1 is the main fluctuation in energy we have to consider, if $\Delta E \sim E1$, as well as [3,4]

$$S_{initial} \sim n_{graviton} \sim initial \quad graviton \quad count \tag{8}$$

Then what can be said about the inter relationship of graviton counts, and the onset of Causal structure?

2. Examination of the minimum time step, in Pre-Planckian Space-time as a Root of a Polynomial Equation.

We initiate our work, citing [5] to the effect that we have a polynomial equation for the formation of a root finding procedure for Δt , namely if

$$\Delta t\cdot\left|\left(\sqrt{\frac{8\pi GV_0}{\gamma\cdot(3\gamma-1)}}\cdot\Delta t-1\right)-\frac{\left(\sqrt{\frac{8\pi GV_0}{\gamma\cdot(3\gamma-1)}}\cdot\Delta t-1\right)^2}{2}+\frac{\left(\sqrt{\frac{8\pi GV_0}{\gamma\cdot(3\gamma-1)}}\cdot\Delta t-1\right)^3}{3}-...\right| \tag{9}$$

$$\approx\left(\sqrt{\frac{\gamma}{\pi G}}\right)^{-1}\frac{48\pi\hbar}{a_{\min}^2\cdot\Lambda}$$

From here, we then cited, in [5], using [6] a criteria as to formation of entropy, i.e. if Λ is an invariant cosmological 'constant' and if Eq. (10) holds, we can use the existence of nonzero initial entropy as the formation point of an arrow of time.

$$S_\Lambda\Big|_{Arrow-of-time}=\pi\cdot\left(\frac{R_c\big|_{initial}\sim c\cdot\Delta t}{l_{Planck}}\right)^2\neq 0 \tag{10}$$

This leads to the following, namely in [5] we make our treatment of the existence of causal structure, as given by writing its emergence as contingent upon having

$$\left(\frac{R_c\big|_{initial}\sim c\cdot\Delta t}{l_{Planck}}\right)\sim\vartheta(1) \tag{11}$$

The rest of this article will be contingent upon making the following assumptions. FTR

$$\begin{aligned}
&\Delta E\sim E1\\
&S_{initial}\sim n_{graviton}\sim initial\quad graviton\quad count\\
&\left[\left[\frac{\Lambda_{Max}r^4}{8\pi G}\right]\cdot(4/3)\cdot\left[\frac{2\pi^2 g_*}{45}\right]^{1/3}\right]^{3/4}\sim S_{initial}\\
&\Leftrightarrow\left[\left[\frac{\Lambda_{Max}r^4}{8\pi G}\right]\cdot(4/3)\cdot\left[\frac{2\pi^2 g_*}{45}\right]^{1/3}\right]^{3/4}\sim n_{graviton}\\
&\Delta E\sim E1\sim V_0\\
&r\sim R_{initial}\sim\frac{1}{\#}\ell_{Ng}<l_{Planck}
\end{aligned} \tag{12}$$

In short, our view, is that the formation of a minimum time step, if it satisfies Eq. (11) is a necessary and sufficient condition for the formation of an arrow of time, at the start of cosmological evolution we have a necessary and sufficient condition for the initiation of an arrow of time.with causal structure , along the lines of Dowker, as in [7] and given more detail by Eq. (12) above as inputs into Eq (10) and Eq. (11) ie. Planck length is set equal to 1 and.

$$\frac{\Delta E \Delta t}{Volume} \sim \left[\hbar \Big/ Volume \cdot \left(\delta g_{tt} \sim a_{\min}^{2} \cdot \phi_{initial} \right) \right] \Big|_{\Pr e-Planckian} \xrightarrow[(\Pr e-Planckian)\to(Planckian)]{} \Delta E \Delta t \sim \hbar \big|_{Planckian} \tag{13}$$

i.e. the regime of where we have the initiation of causal structure, if allowed would be contingent upon the behavior of [5,8,9]

$$\begin{aligned} & g_{tt} \sim \delta g_{tt} \approx a_{\min}^{2} \phi_{initial} << 1 \\ & \xrightarrow[\Pr e-Planck \to Planck]{} \delta g_{tt} \approx a_{\min}^{2} \phi_{Planck} \sim 1 \\ & \Leftrightarrow \left(\frac{R_c \big|_{initial} \sim c \cdot \Delta t}{l_{Planck}} \right) \sim \vartheta(1) \Big|_{Planck} \end{aligned} \tag{14}$$

i.e. the right hand side of Eq. (14) is the square of the scale factor, which we assume is ~ 10^-110, due to '[4,10], and an inflaton given by [4,11]

So, the question well will be leading up to is what does Eq. (9), Eq. (12), and Eq. (13), tell us about graviton production, and the causal foundation condition stated at Eq. (14)?

1. Conclusion, so what is the root of our approximation for a time step?

Here for the satisfying of Eq. (14) is contingent upon $R_c \big|_{initial} \sim c \cdot \Delta t$ as an initial event horizon, of our bubble of space-time being of the order of magnitude of Planck Length,

$$\begin{aligned} & \frac{\Delta E}{Volume} \Big|_{\Pr e-Planck} \sim \left[\hbar \Big/ \left(\Delta t \cdot \left(Volume \equiv \left(\frac{l_{Ng}}{\#} \right)^{3} \right) \cdot \left(\delta g_{tt} \sim a_{\min}^{2} \cdot \phi_{initial} \right) \right) \right] \Bigg|_{\Pr e-Planckian} \\ & \sim \frac{c^{2} \cdot m_{graviton}{}^{2}}{30 \hbar^{2} \sqrt{c} \cdot} \cdot \left(Volume \equiv \left(\frac{l_{Ng}}{\#} \right)^{3} \right)^{-1} \cdot \left(\frac{1}{n_{boson} = n_{graviton}} \right)^{2} \\ & \xrightarrow[(\Pr e-Planckian)\to(Planckian)]{} \Delta E \big|_{\text{Planckian}} \sim \frac{\hbar}{\Delta t} \Big|_{Planckian} \cdot \left(Volume \equiv \left(l_{Planck} \right)^{3} \right)^{-1} \sim \frac{\hbar}{\Delta t} \Big|_{Planckian} \end{aligned} \tag{15}$$

A convenient normalization would be to have

$$\begin{aligned} & r \sim R_{initial} \sim \frac{1}{\#} \ell_{Ng} < l_{Planck} \\ & \& \ell_{Ng} \sim l_{Planck} \equiv 1 \\ & \& r \sim R_{initial} \sim \frac{1}{\#} \end{aligned} \tag{16}$$

If so then, eq. (14) would read as a causal formation transformation we would give as

$$
\begin{aligned}
& r \sim R_{initial} \sim \frac{1}{\#}\ell_{Ng} < l_{Planck} \\
& \& \ell_{Ng} \sim l_{Planck} \equiv 1 \\
& \& r \sim R_{initial} \sim \frac{1}{\#} \\
& \& \hbar \equiv c \equiv 1 \\
& \left.\frac{\Delta E}{Volume}\right|_{\Pr e-Planck} \sim \left[1 \Big/ \left(\Delta t \cdot \left(Volume \equiv \left(\frac{1}{\#}\right)^3 \right) \cdot \left(\delta g_{tt} \sim a_{\min}^2 \cdot \phi_{initial} \right) \right) \right]\Bigg|_{\Pr e-Planckian} \\
& \sim \frac{{m_{graviton}}^2}{30} \cdot \left(Volume \equiv \left(\frac{1}{\#}\right)^3 \right)^{-1} \cdot \left(\frac{1}{n_{boson} = n_{graviton}} \right)^2 \\
& \xrightarrow[(\Pr e-Planckian)\to(Planckian)]{} \Delta E\big|_{Planckian} \sim \left.\frac{1}{\Delta t}\right|_{Planckian}
\end{aligned}
\tag{17}
$$

And then we would have the following equation if we make the following further normalization, as to Planck Mass, and Graviton mass, namely Planck Mass ~ 2.17645e-5 grams, whereas M(graviton) ~ 2.1e-62 grams, i.e. If Planck Mass = 1 in normalization, then M(graviton) ~ 10^-57

$$
\begin{aligned}
& \left.\frac{\Delta E}{Volume}\right|_{\Pr e-Planck} \sim \left[1 \Big/ \left(\Delta t \cdot \left(Volume \equiv \left(\frac{1}{\#}\right)^3 \right) \cdot \left(\delta g_{tt} \sim a_{\min}^2 \cdot \phi_{initial} \right) \right) \right]\Bigg|_{\Pr e-Planckian} \\
& \sim \frac{10^{-114}}{30} \cdot \left(\frac{\#^3}{\left(n_{boson} = n_{graviton}\right)^2} \right) \sim \frac{10^{-114}}{30} \\
& \xrightarrow[(\Pr e-Planckian)\to(Planckian)]{} \Delta E\big|_{Planckian} \sim \left.\frac{1}{\Delta t}\right|_{Planckian} \sim \mathrm{O}(1)
\end{aligned}
\tag{18}
$$

i.e. we would roughly have

$$
\frac{10^{-114}}{30} \xrightarrow[(\Pr e-Planckian)\to(Planckian)]{} \left.\frac{1}{\Delta t}\right|_{Planckian} \sim \mathrm{O}(1) \tag{19}
$$

This outlines the enormity of the change from Pre Planckian to Planckian physics. If this is true, it indicates the enormity of the Pre Planckian to Planckian transformation. If we assume that $a_{\min}^2$ remains invariant, it means that the contribution of the inflaton becomes almost infinitely larger. I.e. $a_{\min}^2$ ~ 10^ - 110 in size.

So, if we have

$$
\Delta E\big|_{\Pr e-Planckian} \sim \frac{10^{-114}}{30} \cdot \left(\frac{\#^3}{\left(n_{boson} = n_{graviton}\right)^2} \right) \sim \frac{10^{-114}}{30} \sim V_0 \tag{20}
$$

And if $\left.\Delta E\right|_{\mathrm{Pr}e-\mathrm{P}lanckian} \sim \frac{10^{-114}}{30}$ So that we have

$$\Delta t \cdot \left| \left(\sqrt{\frac{8\pi \cdot \left(\left.\Delta E\right|_{\mathrm{Pr}e-\mathrm{P}lanckian} \right)}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right) - \frac{\left(\sqrt{\frac{8\pi \left(\left.\Delta E\right|_{\mathrm{Pr}e-\mathrm{P}lanckian} \right)_0}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right)^2}{2} + \frac{\left(\sqrt{\frac{8\pi \cdot \left(\left.\Delta E\right|_{\mathrm{Pr}e-\mathrm{P}lanckian} \right)}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right)^3}{3} - \ldots \right| \qquad (21)$$

$$\approx \left(\sqrt{\frac{\gamma}{\pi}} \right)^{-1} \frac{48\pi}{a_{\min}^2 \cdot \Lambda}$$

As

$$\Delta t \cdot \left| \left(\sqrt{\frac{8\pi \cdot \left(\frac{10^{-114}}{30} \right)}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right) - \frac{\left(\sqrt{\frac{8\pi \left(\frac{10^{-114}}{30} \right)}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right)^2}{2} + \frac{\left(\sqrt{\frac{8\pi \cdot \left(\frac{10^{-114}}{30} \right)}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right)^3}{3} - \ldots \right| \qquad (22)$$

$$\approx \left(\sqrt{\frac{\gamma}{\pi}} \right)^{-1} \frac{48\pi}{a_{\min}^2 \cdot \Lambda}$$

Or more approximately as

$$\Delta t \cdot \left| \left(\sqrt{\frac{10^{-114}}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right) - \frac{\left(\sqrt{\frac{10^{-114}}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right)^2}{2} + \frac{\left(\sqrt{\frac{10^{-114}}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right)^3}{3} - \ldots \right| \qquad (23)$$

$$\approx \left(\sqrt{\frac{\gamma}{\pi}} \right)^{-1} \frac{48\pi}{a_{\min}^2 \cdot \Lambda}$$

Now, set $\Lambda_{initial} = \Lambda$

$$
\Delta t \cdot \left| \left(\sqrt{\frac{10^{-114}}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right) - \frac{\left(\sqrt{\frac{10^{-114}}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right)^2}{2} + \frac{\left(\sqrt{\frac{10^{-114}}{\gamma \cdot (3\gamma - 1)}} \cdot \Delta t - 1 \right)^3}{3} - ... \right|
$$

$$
\begin{aligned}
&\approx \left(\sqrt{\frac{\gamma}{\pi}} \right)^{-1} \frac{48\pi}{\left(a_{\min}^2 \sim 10^{-110} \right) \cdot \Lambda_{initial}} \\
&\approx \Delta t \le t_{Planck} \sim 1 \\
&\Leftrightarrow \frac{48\pi}{\left(a_{\min}^2 \sim 10^{-110} \right) \cdot \Lambda_{initial}} \sim \Delta t \le t_{Planck} \sim 1 \\
&\Leftrightarrow \Lambda_{initial} \ge 10^{112}
\end{aligned} \tag{24}
$$

This is on the order of the Cosmological constant, as computed by [12] and Peskins, in [13] so that the Pre Planckian Cosmological constant would have an enormous value on par with the Quantum field theory estimate of the Plancks constant, in Pre Planckian space-time.[12,13]

This so happens to be consistent with Eq.(5) of our document. It also has some similarities with the ideas given in [14]

Finally this should be seen in the light of [15, 16, 17] which establishes a non linear electrodynamic treatment of initial singularities, which the author views a credible, as an alternative to [18] and the Penrose Singularity theorem.

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