Geddankenexperiment examining how Kinetic energy would dominate Potential energy, in pre Planckian space-time physics

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Abstract. We use Padmabhan's "Invitation to Astrophysics" formalism of a scalar field evolution of the early universe, from first principles, to show something which seems counter intuitive. How could , just before inflation, KINETIC energy be larger than potential energy in pre Planckian physics, and what physics mechanism is responsible for the Planckian physics result that Potential energy is far larger than KINETIC energy. This document answers that question, as well as provides a mechanism for the dominance of KINETIC energy in Pre Planckian space-time, as well as its reversal in the Planckian era of cosmology. the KE initially proportional to $\rho_w \propto a^{-3(1-w)} \sim g^* T^4$, with g^* initial degrees of freedom, and T the initial temperature just before the onset of inflation. Our key assumption is the smallness of curvature, as given in the first equation, which permits adoption of the Potential energy and Kinetic energy formalism used, in the Planckian and Pre Planckian space-time physics.

i. Introduction

We begin with a review from T. Padmanabhan [1] as to the foundations of a scalar field and a potential field, in terms of cosmological evolution. Following that, we are adding more detail as to a supposition by W J Handley et al, as to how the Kinetic energy would be much larger than the Potential energy [2] as to the dominance of Kinetic energy over potential energy. Here, we offer a mechanism for how this may happen. We also state that the KE we postulate is due to formalism we work with while we are reviewing Padmanbhan [1] , scalar evolution of cosmology, and how it relates to Kinetic and Potential energy values In doing this, we are reviewing near flat space solutions , given on page 247 of [1] to the effect that if we take imaginary time, that we will be able to then get a dominant value to what we will call $\dot{\phi}^2\left(\tau_{\Pr e-Planckian-time}\right)\Big|_{\tau_{\Pr e-Planckian-time}=\frac{\pm i \times 10^{-44} s}{10^{-44} s}}$ in an interval of space time which is before Planck time interval. In doing so, we are assuming that the near flat space result for minimum curvature holds, even in the Planckian regime, as given by A.W.Beckwith [3]

$$
\begin{aligned}
T_{00} = \rho_{Energy-density} &= \frac{-\left(g_{00}=1\right)}{16\cdot\pi}\cdot\left(\frac{3\tilde{k}_{Curvature-measure}}{a^2_{initial-scale-factor}}+\Lambda_{initial-value}\right) \\
\Leftrightarrow \tilde{k}_{Curvature-measure} &= -\frac{a^2_{initial-scale-factor}}{3}\times\left[\left(16\cdot\pi\cdot\left(\rho_{Energy-density}=\left[\frac{S_{initial-Entropy}\cdot m_{graviton}}{V^{(3)}}\right]\right)\right)+\Lambda_{initial-value}\right]
\end{aligned}
\tag{1}
$$

If the curvature measure, above is almost zero, then we can use from [1] , page 246

$$\frac{\dot{a}}{a} = \sqrt{\frac{8\pi G}{3}} \cdot \left[V(\phi) + \frac{\dot{\phi}}{2} \right]^{1/2} \tag{2}$$

If so, then using the Potential energy and Kinetic energy values from [1], page 247 we can write the following

$$\begin{aligned}
& V(t) = \frac{3H^2}{8\pi G} \cdot \left(1 + \frac{\dot{H}}{3H^2} \right) \\
& \phi(t) = \int dt \cdot \sqrt{-\frac{\dot{H}}{4\pi G}} \\
& H = \frac{2}{t \cdot \left(1 + \frac{p}{\rho} \right)} \sim \frac{2 \cdot t^{-1}_{REAL-TIME}}{\xi^+} \\
& \Rightarrow \phi(t) \sim \sqrt{\frac{1}{4\pi G}} \cdot \frac{1}{\xi^+} \cdot \log \left[\frac{t_{final-real-time}}{t_{initial-real-time}} \right] \\
& \Rightarrow \dot{\phi}^2(t) \sim \frac{1}{4\pi G} \cdot \left(\frac{1}{\xi^+} \right)^2 \cdot \left(\frac{1}{t_{real-time}} \right)^2 \\
& \& \\
& V(t) \sim \frac{3}{2\pi G} \cdot \left(\frac{1}{\xi^+} \right)^2 \cdot \left[\left(\frac{1}{t_{real-time}} \right)^2 \cdot \left(1 + \left(\frac{1}{t_{real-time}} \right)^2 \right) \right]
\end{aligned} \tag{3}$$

The term $V(t)$ is for Potential energy, and it is by inspection >> $\dot{\phi}^2(t)$ in the Planckian space-time regime which is the Kinetic energy component, provided that time here is a real co-ordinate.

We will, for now on, to keep this real time non dimensional, make the following identification with

$$t_{real-time} = \frac{t_{measured-time}}{t_{Planck} \sim 10^{-44} s} \tag{4}$$

For the sake of identification, we will be assuming that Eq.(3) and Eq.(4) are in the present universe and that ξ^+ is extraordinarily small.

ii. Re examination of Eq. (3) and Eq.(4) in a pre universe configuration

Our supposition is that Eq. (4) in the matter of Pre Planckian space time, say in a boundary of 2 times Planck time to buttress the repeating cyclical universe we are assuming as possibility given by Penrose

[4] , is changed then to take into the quantum bounce analogy we think should be looked at [5] as given by C. Rovelli and F. Vidotto

$$t_{real-time} = \frac{t_{measured-time}}{t_{Planck} \sim 10^{-44} s} \xrightarrow[\Pr e-Planckian]{} \tau_{\Pr e-Planckian-time} = i \cdot \frac{t_{measured-time}}{t_{Planck} \sim 10^{-44} s} = i \cdot t_{real-time} \tag{5}$$

In a boundary of $\tau_{\Pr e-Planckian-time} \sim \frac{\pm i \times 10^{-44} s}{10^{-44} s}$ i.e. about a bounce area, of space time, then there would be this switch, so then in this regime, we would re write the relevant evaluative time for the Potential and Kinetic energy as $\tau_{\Pr e-Planckian-time} \sim \frac{\pm i \times 10^{-44} s}{10^{-44} s}$.

Pick the following point of evaluation, namely at the transit point between the plus to the minus regions of $\tau_{\Pr e-Planckian-time} \sim \frac{\pm i \times 10^{-44} s}{10^{-44} s}$ that we are looking at a Vanishing Potential energy, but a Kinetic energy which would be very different from Zero.

$$\dot{\phi}^2 \left(\tau_{\Pr e-Planckian-time} \right) \Big|_{\tau_{\Pr e-Planckian-time} = \frac{\pm i \times 10^{-44} s}{10^{-44} s}} \sim \frac{1}{4\pi G} \cdot \left(\frac{1}{\xi^+} \right)^2 \cdot \left(\frac{1}{\tau_{\Pr e-Planckian-time}} \right)^2 < 0$$

$$\& \tag{6}$$

$$V(\tau_{\Pr e-Planckian-time}) \Big|_{\tau_{\Pr e-Planckian-time} = \frac{\pm i \times 10^{-44} s}{10^{-44} s}} \sim \frac{3}{2\pi G} \cdot \left(\frac{1}{\xi^+} \right)^2 \cdot \left[\left(\frac{1}{\tau_{\Pr e-Planckian-time}} \right)^2 \cdot \left(1 + \left(\frac{1}{\tau_{\Pr e-Planckian-time}} \right)^2 \right) \right] = 0$$

The fact we have a very large non zero $\dot{\phi}^2 \left(\tau_{\Pr e-Planckian-time} \right) \Big|_{\tau_{\Pr e-Planckian-time} = \frac{\pm i \times 10^{-44} s}{10^{-44} s}}$ going into the $\tau_{\Pr e-Planckian-time} \sim \frac{\pm i \times 10^{-44} s}{10^{-44} s}$ region, as a Pre Planckian bounce bubble, with this flipping to $t_{real-time} = \frac{t_{measured-time}}{t_{Planck} \sim 10^{-44} s}$ with the result that.

$$\dot{\phi}^2 \left(\tau_{\Pr e-Planckian-time} \right) \Big|_{\tau_{\Pr e-Planckian-time} = \frac{\pm i \times 10^{-44} s}{10^{-44} s}}$$

$$\xrightarrow[\tau_{\Pr e-Planckian-time} \to t_{real-time}]{} V(t_{real-time}) \sim \frac{3}{2\pi G} \cdot \left(\frac{1}{\xi^+} \right)^2 \cdot \left[\left(\frac{1}{t_{real-time}} \right)^2 \cdot \left(1 + \left(\frac{1}{t_{real-time}} \right)^2 \right) \right] \neq 0 \tag{7}$$

In making this evaluation, we are assuming that there could be use of the following for relic Gravitational waves. ,i.e. for Eq.(7) to hold we will be looking at a time interval which may be specified by [6]

$$\left(\delta t\right)^2_{emergent} = \frac{\sum_i m_i l_i \cdot l_i}{2\cdot\left(E-V\right)} \to \frac{m_{graviton} l_P \cdot l_P}{2\cdot\left(E-V\right)} \tag{8}$$

Initially, as postulated by Babour [6,7] this set of masses, given in the emergent time structure could be for say the planetary masses of each contribution of the solar system. Our identification is to have an initial mass value, at the start of creation, for an individual graviton. . So If $\left(\delta t\right)^2_{emergent} = \delta t^2 \sim t_{real-time} = \frac{t_{measured-time}}{t_{Planck} \sim 10^{-44} s}$ Then there may be gravitons which are [8]

$$m_{graviton} \geq \frac{2\hbar^2}{\left(\delta g_{tt}\right)^2 l_P^2} \cdot \frac{(E-V)}{\Delta T_{tt}^2} \tag{9}$$

This would entail assuming relic gravitation generated by a massive graviton bounded below by

$$m_{graviton} \geq \frac{2\hbar^2}{\left(\delta g_{tt}\right)^2 l_P^2} \cdot \frac{(E-V)}{\Delta T_{tt}^2} \xrightarrow[\tau_{\Pr e-Planckian-time}=\frac{\pm i\times 10^{-44} s}{10^{-44} s}]{} \frac{2\hbar^2}{\left(\delta g_{tt}\right)^2 l_P^2} \cdot \frac{\left| \dot{\phi}^2\left(\tau_{\Pr e-Planckian-time}\right)\Big|_{\tau_{\Pr e-Planckian-time}=\frac{\pm i\times 10^{-44} s}{10^{-44} s}} \right|}{\Delta T_{tt}^2} \tag{10}$$

And the magnitude of K.E. as defined by

$$(E-V) \sim \left| \dot{\phi}^2\left(\tau_{\Pr e-Planckian-time}\right)\Big|_{\tau_{\Pr e-Planckian-time}=\frac{\pm i\times 10^{-44} s}{10^{-44} s}} \right| \tag{11}$$

iii. Conclusion.

Our hypothesis, as to Eq. (11) is equivalent to what is frequently postulated as an energy density as given by Kolb and Turner [9] . Needless to Eq. (7) and Eq.(11) are stated as hypothesis, and we are also saying that the magnitude of Eq. (9) is equivalent to results for a quantum bounce with T the initial temperature just before the onset of inflation..

$$\rho_w \propto a^{-3(1-w)} \sim g^* T^4 \tag{12}$$

We will be attempting to get full analytical connection between Eq.(12) and Eq. (11) by our next publication

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