The Zero Point of Time

Introduction

For what follows we should note that $R^2 = x^2 + y^2 + z^2 + w^2$ forms an hyperboloid of two 3-dimensional sheets with

$$\begin{aligned} x &= \mathbf{1}Rcosh\chi \\ y &= \mathbf{i}Rsinh\chi cos\theta \\ z &= \mathbf{j}Rsinh\chi sin\theta cos\phi \\ w &= \mathbf{k}Rsinh\chi sin\theta sin\phi \end{aligned}$$

where $\{\mathbf{1}, \mathbf{i}, \mathbf{j}, \mathbf{k}\}$ is the set of quaternions. The right sheet has $R > 0$ and the left $R < 0$. The distance btween the two sheets is $2R$. Letting $T = Rcosh\chi$ act as a proxy for time we have that distance equals $2T$. If $2T \leq \Delta t$ then time t can pass from one sheet to the other without passing through $t = 0$ (due to quantum uncertainty where $\Delta t \geq \hbar/2\Delta E$). $R < 0$ has parity and time reversal and so can represent CPT symmetry and hence an anti-matter realm.

$$\begin{aligned} \frac{\partial}{\partial R} &= \frac{\partial x}{\partial R}\frac{\partial}{\partial x} + \frac{\partial y}{\partial R}\frac{\partial}{\partial y} + \frac{\partial z}{\partial R}\frac{\partial}{\partial z} + \frac{\partial w}{\partial R}\frac{\partial}{\partial w} \\ \frac{\partial}{\partial \chi} &= \frac{\partial x}{\partial \chi}\frac{\partial}{\partial x} + \frac{\partial y}{\partial \chi}\frac{\partial}{\partial y} + \frac{\partial z}{\partial \chi}\frac{\partial}{\partial z} + \frac{\partial w}{\partial \chi}\frac{\partial}{\partial w} \\ \frac{\partial}{\partial \theta} &= \frac{\partial x}{\partial \theta}\frac{\partial}{\partial x} + \frac{\partial y}{\partial \theta}\frac{\partial}{\partial y} + \frac{\partial z}{\partial \theta}\frac{\partial}{\partial z} + \frac{\partial w}{\partial \theta}\frac{\partial}{\partial w} \\ \frac{\partial}{\partial \phi} &= \frac{\partial x}{\partial \phi}\frac{\partial}{\partial x} + \frac{\partial y}{\partial \phi}\frac{\partial}{\partial y} + \frac{\partial z}{\partial \phi}\frac{\partial}{\partial z} + \frac{\partial w}{\partial \phi}\frac{\partial}{\partial w} \end{aligned}$$

where

$$\begin{pmatrix} \frac{\partial x}{\partial R} & \frac{\partial y}{\partial R} & \frac{\partial z}{\partial R} & \frac{\partial w}{\partial R} \\ \frac{\partial x}{\partial \chi} & \frac{\partial y}{\partial \chi} & \frac{\partial z}{\partial \chi} & \frac{\partial w}{\partial \chi} \\ \frac{\partial x}{\partial \theta} & \frac{\partial y}{\partial \theta} & \frac{\partial z}{\partial \theta} & \frac{\partial w}{\partial \theta} \\ \frac{\partial x}{\partial \phi} & \frac{\partial y}{\partial \phi} & \frac{\partial z}{\partial \phi} & \frac{\partial w}{\partial \phi} \end{pmatrix}$$

$$
= \begin{pmatrix}
\mathbf{1} cosh\chi & \mathbf{i} sinh\chi cos\theta & \mathbf{j} sinh\chi sin\theta cos\phi & \mathbf{k} sinh\chi sin\theta sin\phi \\
\mathbf{1} R sinh\chi & \mathbf{i} R cosh\chi cos\theta & \mathbf{j} R cosh\chi sin\theta cos\phi & \mathbf{k} R cosh\chi sin\theta sin\phi \\
0 & -\mathbf{i} R sinh\chi sin\theta & \mathbf{j} R sinh\chi cos\theta cos\phi & \mathbf{k} R sinh\chi cos\theta sin\phi \\
0 & 0 & -\mathbf{j} R sinh\chi sin\theta sin\phi & \mathbf{k} R sinh\chi sin\theta cos\phi
\end{pmatrix}
$$

Then

$$
\begin{aligned}
h_R^2 &= \langle \frac{\partial}{\partial R}, \frac{\partial}{\partial R} \rangle = (\frac{\partial x}{\partial R})^2 + (\frac{\partial y}{\partial R})^2 + (\frac{\partial z}{\partial R})^2 + (\frac{\partial w}{\partial R})^2 = \mathbf{1} \\
h_\chi^2 &= \langle \frac{\partial}{\partial \chi}, \frac{\partial}{\partial \chi} \rangle = (\frac{\partial x}{\partial \chi})^2 + (\frac{\partial y}{\partial \chi})^2 + (\frac{\partial z}{\partial \chi})^2 + (\frac{\partial w}{\partial \chi})^2 = -\mathbf{1} R^2 \\
h_\theta^2 &= \langle \frac{\partial}{\partial \theta}, \frac{\partial}{\partial \theta} \rangle = (\frac{\partial x}{\partial \theta})^2 + (\frac{\partial y}{\partial \theta})^2 + (\frac{\partial z}{\partial \theta})^2 + (\frac{\partial w}{\partial \theta})^2 = -\mathbf{1} R^2 sinh^2\chi \\
h_\phi^2 &= \langle \frac{\partial}{\partial \phi}, \frac{\partial}{\partial \phi} \rangle = (\frac{\partial x}{\partial \phi})^2 + (\frac{\partial y}{\partial \phi})^2 + (\frac{\partial z}{\partial \phi})^2 + (\frac{\partial w}{\partial \phi})^2 = -\mathbf{1} R^2 sinh^2\chi sin^2\theta
\end{aligned}
$$

$d\sigma^2 = R^2[d\chi^2 + sinh^2\chi(d\theta^2 + sin^2\theta d\phi^2)]$ is the metric on the hyperboloid. The metric $ds^2 = dR^2 - R^2[d\chi^2 + sinh^2\chi(d\theta^2 + sin^2\theta d\phi^2)]$ describes a four dimensional flat space. It is similar to the Robertson-Walker metric $ds^2 = dt^2 - a^2[d\chi^2 + sinh^2\chi(d\theta^2 + sin^2\theta d\phi^2)]$ which describes a curved four dimensional space-time. The difference is dR is replaced by dt and R by the scale factor a.

In curved space-time light follows a path that minimizes its travel time. Suppose a (virtual) photon is following a path

$$
\frac{d\gamma}{ds} = \frac{dt}{ds}\partial_t + \frac{d\chi}{ds}\partial_\chi + \frac{d\theta}{ds}\partial_\theta + \frac{d\phi}{ds}\partial_\phi
$$

Then, letting $\langle *, * \rangle$ denote an inner product

$$
0 = \left\langle \frac{d\gamma}{ds}, \frac{d\gamma}{ds} \right\rangle = \frac{dt^2}{ds^2}\langle \partial_t, \partial_t \rangle + \frac{d\chi^2}{ds^2}\langle \partial_\chi, \partial_\chi \rangle + \frac{d\theta^2}{ds^2}\langle \partial_\theta, \partial_\theta \rangle + \frac{d\phi^2}{ds^2}\langle \partial_\phi, \partial_\phi \rangle
$$

$$
0 = \frac{dt^2}{ds^2} - \frac{d\chi^2}{ds^2}a^2 - \frac{d\theta^2}{ds^2}a^2 sinh^2\chi - \frac{d\phi^2}{ds^2}a^2 \sinh^2\chi sin^2\theta
$$

describes the path of a photon in curved space-time. Notice that $\frac{dt}{ds} > 0$ and $\frac{dt}{ds} < 0$ can both be solutions.

Consider a Universe of negative curvature with zero mass-energy density and zero pressure. Then

$$0 = \frac{-1}{a^2} + \left(\frac{\dot{a}}{a}\right)^2 \quad (1)$$

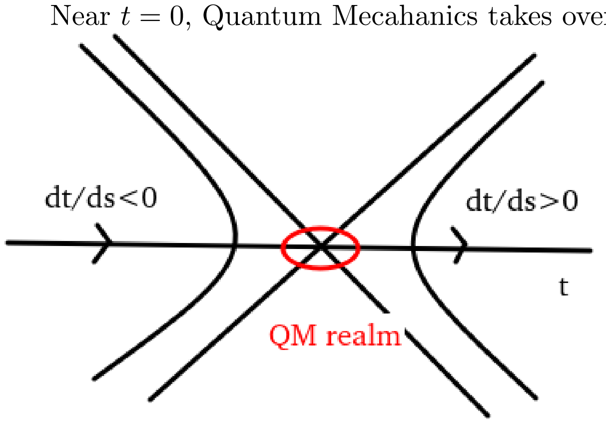
$$0 = -2\frac{\ddot{a}}{a} + \frac{1}{a^2} - \left(\frac{\dot{a}}{a}\right)^2 \quad (2)$$

$$0 = -2\frac{\ddot{a}}{a} \quad (3)$$

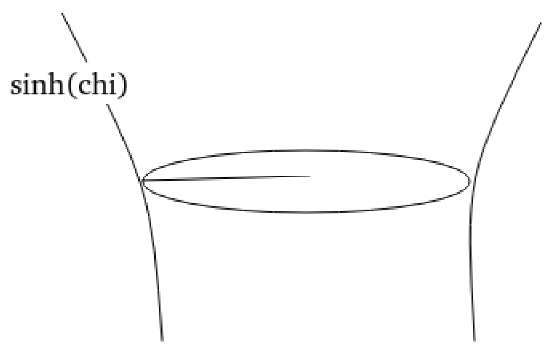
Then we have a Universe where $\dot{a} = 1$ and $\ddot{a} = 0$. The R-W metric for such a Universe is $ds^2 = dt^2 - a^2(d\chi^2 + sinh^2\chi(d\theta^2 + sin^2\theta d\phi^2)$. In such an empty Universe it does not matter whether it expands or contracts (both $\dot{a} = \pm 1$ satisfy the above equations). So, we postulate a contracting w.r.t. t empty open Universe ($k = -1$) with the time interval $t \in (-\infty, 0)$ and time moving backwards w.r.t s ($\frac{dt}{ds} < 0$ and $\frac{da}{dt}\frac{dt}{ds} = \frac{da}{ds} > 0$).

Recall in Hawking's work his example of the zero point of time being like the North Pole. Once you reach the North Pole you cannot go further north. However, if you continue traveling along the same meridian you start going south. That is what we are suggesting here. The parameter s increases in the direction away from $t = 0$. We can think of that parameter as always pointing south similar to the azimuth in spherical coordinates. $dt/ds < 0$ represents going north and $dt/ds > 0$ represents going south.

Near $t = 0$, Quantum Mecahanics takes over so as $\Delta t \to 0$, $\Delta E \to \infty$.



So, the mass-energy of the Universe came into existence when the antecedent contracting empty Universe collided with $t = 0$. It seems clear that dt/ds had to reverse sign after t "passes through" zero*. However, we cannot say exactly what happened near $t = 0$ nor even that $t = 0$ existed.



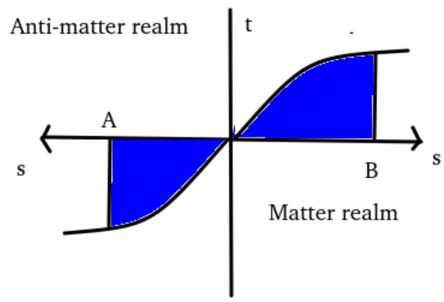
The strong negative curvature near $t = 0$ acted like a gravitational field** allowing virtual particles to borrow from that field to repay their energy debt. This resulted in a net energy of zero. Virtual particles became real (positive energy) but are in a gravitational energy well of equal but negative energy.*** As we saw in *The Hubble Parameter*, $H \to 0$ as $\eta \to \infty$. This suggests that the remaining gravitational binding energy, which never totally vanishes must approximately equal the remaining positive energy (mass and associated motions). As in *The Hubble Parameter* $\rho \propto a^{-3}$.**** Gravitational binding energy between two bodies $\propto r^{-1}$ but if the gravitational binding energy for the whole Universe $\propto a^{-3}$ then the total energy of the Universe is close to zero.

*Time reversal w.r.t. s affected the distribution of matter vs anti-matter. We shall use dt/ds as a proxy for particle energy. First anti-matter was produced as the universe contracted. When dt/ds reversed sign, matter was produced with $E \propto \frac{dt}{ds}$ which resulted in mutual annihilation which liberated a lot of energy leading to the production of more matter, gravity, and more matter.

The two realms are separated by the geodesic equation(s):

$$0 = \frac{d^2t}{ds^2} + \frac{d\chi^2}{ds^2}\dot{a}a + \frac{d\theta^2}{ds^2}\dot{a}asinh^2\chi + \frac{d\phi^2}{ds^2}\dot{a}asinh^2\chi sin^2\theta$$

with $\dot{a} < 0$ for the anti-matter realm and $\dot{a} > 0$ for the matter realm.



The anti-matter realm has $\frac{dt}{ds} < 0$ and $\frac{d^2t}{ds^2} > 0$ (decreasing concave up) while the matter realm has the reverse: $\frac{dt}{ds} > 0$ and $\frac{d^2t}{ds^2} < 0$ (increasing concave down). Note the opposing directions of s. $|t| \downarrow 0$ as $s \downarrow 0$ in both cases and the two curves are symmetric. To account for the matter-antimatter assymetry observed in Nature we propose the particle production interval was longer in the matter realm. As mutual annihilation proceeds, a remainder of energy

$$\int_0^B \left| \frac{dt}{ds} \right|_{\dot{a}>0} ds - \int_0^A \left| \frac{dt}{ds} \right|_{\dot{a}<0} ds > 0$$

remains in the matter realm which, through gravity, contributes to more particle production in the matter realm.
**Suppose a (virtual) photon is following a path

$$\frac{d\gamma}{ds} = \frac{dt}{ds}\partial_t + \frac{d\chi}{ds}\partial_\chi + \frac{d\theta}{ds}\partial_\theta + \frac{d\phi}{ds}\partial_\phi$$

Then, as we saw previously,

$$0 = \frac{dt^2}{ds^2} - \frac{d\chi^2}{ds^2}a^2 - \frac{d\theta^2}{ds^2}a^2 sinh^2\chi - \frac{d\phi^2}{ds^2}a^2 \sinh^2 \chi sin^2\theta$$

describes the path of a photon in curved space-time.
Recalling the geodesic equation

$$0 = \frac{d^2t}{ds^2} + \frac{d\chi^2}{ds^2}\dot{a}a + \frac{d\theta^2}{ds^2}\dot{a}asinh^2\chi + \frac{d\phi^2}{ds^2}\dot{a}asinh^2\chi sin^2\theta$$

We can subtract the one equation from the other and get

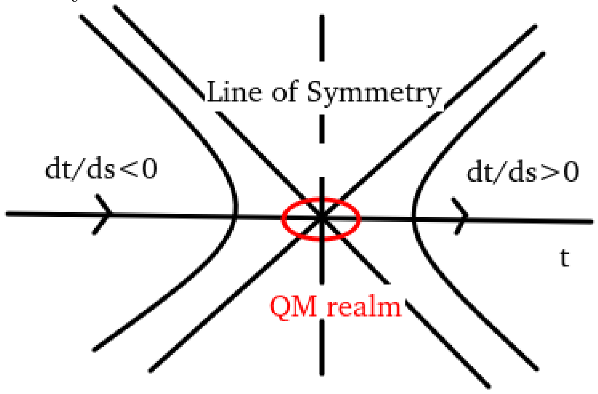
$$\frac{d^2t}{ds^2} - \frac{dt^2}{ds^2} + a(\dot{a} + a)(\frac{d\chi^2}{ds^2} + \frac{d\theta^2}{ds^2}sinh^2\chi + \frac{d\phi^2}{ds^2}\sinh^2\chi sin^2\theta) = 0$$

which describes the equivalent of a gravitational field in a contracting empty universe ($\dot{a} < 0$). For $\chi \equiv 0$, $t = -ln(1+s)$. We interpret $E = \frac{dt}{ds}$ to be the energy of a test particle in such a field. We can also add the equations and get

$$\frac{d^2t}{ds^2} + \frac{dt^2}{ds^2} + a(\dot{a} - a)(\frac{d\chi^2}{ds^2} + \frac{d\theta^2}{ds^2} sinh^2\chi + \frac{d\phi^2}{ds^2} \sinh^2\chi sin^2\theta) = 0$$

For $\chi \equiv 0$, $t = ln(1+s)$.
***This solves Hawking's chicken and egg problem. Negative curvature (a chicken) produced real particles (eggs) which produced gravity (more chickens) that produced more particles (eggs).
****Radiant energy, whose wavelength expands with the Universe, has $\rho_e \propto a^{-4}$ so we neglect it in the long term as $a \to \infty$.

The matter-energy of the universe comes into existence in what we specify by the QM realm. In the Heisenberg relation $\Delta t \Delta E \geq \frac{\hbar}{2\pi}$. It should perhaps be noted that the two sheets as discussed above are reflected copies of the same thing, one in which $dt/ds < 0$ (contracting phase) and the other in which $dt/ds > 0$ (expanding phase). As such, this as a type of bounce theory.



Reflecting through the line of symmetry, the direction of time goes to the right in the contracting phase but reverses and goes to the left in the expanding phase. This allows for CPT symmetry between the two halves.

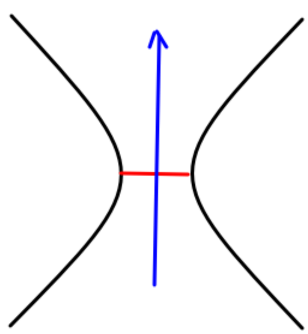
After developing this theory independently, the following quote was found at $https://www.physicsoftheuniverse.com/scientists_sakharov.html$

> After 1965, Sakharov returned to fundamental science and began working on particle physics and cosmology, particularly the

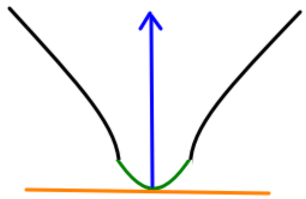
search for an explanation for the ”baryon asymmetry” of the universe (the huge preponderance of matter, as opposed to antimatter, in the known universe). He was the first scientist to introduce the concept of two universes called “sheets”, which may have been linked at the time of the Big Bang. The “other” universe would exhibit complete “CPT symmetry” (the inversion of charge, parity and time), having an opposite arrow of time and being mainly populated by antimatter. Sakharov called the singularities, where these two sheets could theoretically interact without being separated by space-time, a “collapse” and an “anticollapse”, similar to the black hole and white hole of wormhole theory. He also proposed the idea of induced gravity (or emergent gravity) as an alternative theory of quantum gravity.

Hawking Vs Sakharov

As quoted above, Sakharov viewed the Universe as emerging from a wormhole where time is running backwards in the contracting part and forward in the expanding part. (Blue arrow in the folowing diagram). There is a coordinate singularity between the two (red line) being the big Bang. This would imply time is potentially eternal in both direction. That is $t \in (-\infty, \infty)$



Hawking took this picture and removed the lower half and replaced it with a cup (green) where time merges into space at $t \approx 0$ and the cup is tangent to 4-dimensional space $\mathbf{R}^4$ (orange in next figure).



Hawking called this the No boundary Proposal because there is no boundary at $t = 0$ since it does not exist.

Conclusion

Our current open expanding Universe which is dominated by matter is a reflection of a contracting open Universe dominated by anti-matter in its later stage.

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