Quantum Time is the Time it Takes for an Elementary Particle to Absorb a Quantum of Energy

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ABSTRACT

This paper is a continuation of a series of papers on the universe as the surface volume of a four dimensional, expanding hyperverse. We argue that the whole universe is undergoing a geometric mean expansion, and is larger than the observable hyperverse by a factor of $\left(\frac{R_H}{2l_p}\right)^4$, and its radius is larger by a factor of $\left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}$. The growth rate of the whole is actually accelerating, compared to the constant, 2c velocity we measure for the observable universe. We show that the ratio of the length of the small energy quantum (SEQ), to the small radius quantum (SRQ), values discussed at length in earlier hyperverse papers, is increasing at the same rate as the whole radius is increasing. We also show that, depending on the type of particle, the amount of time it takes for a particle to travel the distance of one SEQ length, approximately 10^{-23} seconds, matches the time it takes for the particle to absorb one SEQ of energy. The quantum of time is the time it takes for an elementary particle to absorb one SEQ quantum of energy. The unit of quantum time is not a constant, but increases in duration at the same rate as the increase in the velocity of the whole hyperverse, canceling it, giving us the constant, 2c radial expansion rate.

Significantly, our equation for the quantum of time, derived from the hyperverse model, using only the values of c, G, h-bar and the radius of the observable hyperverse, matches the quantized time interval calculated for the electron by Piero Caldirola, using classical electron theory. His 'chronon', and our quantum absorption time, are identical values. Equating the two quantum time equations produces the correct equation of electric charge, further supporting the validity of the hyperverse model and the unit of quantum time. We continue by showing that the relation between particle mass and quantum absorption time is governed by the time-energy uncertainty relationship, allowing easy calculation of the quantum time values for all elementary particles, and supporting the concept of the geometric mean expansion of space.

Subject headings: geometric mean expansion of space; quantum time, quantum gravity;chronon,matter absorbs space,2c expansion of space

1. Introduction

In a previous hyperverse paper [1] we showed that if we took the three dimensional volume of the observable universe, with a radius of about 46.25 billion light years, and wrapped it around to form the surface volume of a four dimensional hypersphere, that the radius of this 'observable hyperverse' would be 27.6 billion light years. Given the age of the universe as 13.8 billion years, we find a striking result: our observable hyperverse is expanding at exactly twice the speed of light.

Assuming this 2c radial expansion is meaningful, we developed models [2,3,4] for time, proposed that the universe is undergoing a geometric mean expansion that creates quanta, and showed that the Planck values represent the initial condition of the universe, preserved for us as the geometric means of expansion. We also developed the idea that particles of matter are not static entities, but are dynamic, created to conserve the continually increasing angular momentum of the universe. The universe must continually create matter by crushing and coalescing the quanta of space, and existing particles must continually accrete the quanta of space to conserve angular momentum, explaining why all particles of a kind are identical. The rate of the continual absorption of space by matter matches the force of gravity; gravity is the continuing process of creation and growth of elementary particles.

Despite the productiveness of the hyperverse model, there is a problem: the whole hyperverse is much larger than the observable hyperverse; the observable universe is just a small part of the surface of the whole. Given that the observable hyperverse and the whole hyperverse are both the same age, the expansion rate of the whole would be much greater than 2c. Furthermore, calculations show the expansion rate of the whole hyperverse is actually accelerating.

In this paper we will present a model of quantized time, link it precisely to quantum gravity by showing that the time it takes for an elementary particle to absorb one quantum of space is the unit of quantized time, and show that the increase in the duration of the quantum unit of time cancels the accelerating growth of the whole hyperverse, giving us the constant, 2c expansion that we actually experience. Additionally, we will show that our unit of quantized time, developed from the hyperverse concept and using only the constants of c, G, h-bar, and the radius of the observable hyperverse, matches the unit of quantized time developed by Piero Caldirola [6], termed the "chronon", using properties of the classical electron such as electron charge and the permittivity of free space. Significantly, combining the two quantum time equations gives us the accepted equation for the electron charge.

The primary contributions of this paper are:

1. We support the earlier claim that the energy and volume of the whole hyperverse is larger than the observable by a factor of $\left(\frac{R_H}{2l_p}\right)^4$, and its radius is larger by the cube root, or $\left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}$.

2. We show that the whole universe is not only larger than the observable, its expansion rate is greater, and in particular, it is accelerating. This is quite different from the constant, twice the speed of light expansion rate, we find with the observable hyperverse model.

3. From the geometric mean paper [3], we review that the small energy quantum, the SEQ, which is the geometric mean counterpart of the energy of the observable universe, increases in size as the universe expands. Also from [3] we argued there is a second, much smaller quantum, the small radius quantum, or SRQ, derived from the radius of the observable hyperverse, which shrinks with expansion. In this paper, we show that the ratio of the SEQ to the SRQ matches the ratio of the radial velocity of the whole to the observable hyperverse.

4. Similarly, the ratio of the time it takes an SEQ to make frame advances, relative to the SRQ frame advance time, increases at the same rate as the rate that the velocity of the whole is increasing relative to the observable hyperverse.

5. We propose that the frame advance time of the SEQ is the unit of quantum time.

6. This means that the basic unit of time is expanding at the same rate as the radial velocity of the whole; the faster the whole expands, the further the longer it takes for a unit of time to occur, resulting in mutual cancellation, and producing the constant 2c radial expansion.

7. We claim that the constant, 2c radial expansion rate is the result of the growth in the quantized time cancelling the accelerating expansion rate of the whole hyperverse.

8. Importantly, we show that the time for an elementary particle to absorb an SEQ equals the SEQ frame advance time. That is, particles of matter absorb one quanta of energy for every unit of quantized time.

9. This is the key relation between quantized time, quantized energy, and quantized gravity: a particle of matter absorbs one unit of energy in one unit of time.

10. We show that the quantized unit of time developed by Piero Caldirola matches the hyperverse quantum time unit, using very different equations and concepts. Combining the Caldirola and hyperverse equations gives us the correct equation for the electric charge.

11. The value of the quantum time of any elementary particle can be calculated simply by using the time-energy uncertainty relationship. That is, we show that the product of the particle's energy and its associated quantum time equals h-bar over two.

11. The two most critical claims in this paper are that quantum time is the time for a particle of matter to absorb a quantum of space, and secondly, the unit of quantum time lengthens as space expands, in a manner that cancels the radial acceleration of the whole hyperverse, giving us a constant 2c expansion rate.

2. The Whole Hyperverse

The whole universe is larger than the observable universe. In the Geometric Mean paper [1], equation (70), we gave a possible energy, and size, for the whole hyperverse. Using the geometric mean concept, we asked what the geometric mean counterpart of the energy of the small radius quantum, or SRQ, would be, and calculated a value, as shown in equation (1).

$$E_{whole} = \frac{(\text{initial energy})^2}{E_{SRQ}} = \frac{\left(\frac{\sqrt{\frac{c^5\hbar}{G}}}{2}\right)^2}{\frac{c\hbar}{R_H}\left(\frac{2l_p}{R_H}\right)^4} = \frac{R_H c^4}{4G}\left(\frac{R_H}{2l_p}\right)^4 = E_O\left(\frac{R_H}{2l_p}\right)^4 \tag{1}$$

E_{whole} is the energy of the whole hyperverse, E_{SRQ} is the energy of the small energy quantum, c is the speed of light, $\hbar$ is the reduced Planck constant, G is the gravitational constant, R_H is the fourth-dimensional radius of the observable hyperverse, and l_p is the Planck length.

We find that the geometric mean partner of the SRQ energy is an energy larger than that of the observable universe, by a factor of $\left(\frac{R_H}{2l_p}\right)^4$, or approximately 4.3×10^{243}. We will work with the idea that the energy of the whole hyperverse is this geometric mean partner of the small radius quantum energy:

$$E_{whole} = 3.449\,731\,845\,561\,096\,007\,9 \times 10^{313}\,\frac{\mathrm{m}^2}{\mathrm{s}^2}\,\mathrm{kg} \tag{2}$$

If we assume that the energy density of the whole universe is the same as it is within the observable universe, we can deduce that the whole hyperverse surface volume is larger by the factor of $\left(\frac{R_H}{2l_p}\right)^4$. That is, the volume of the whole universe is:

$$V_{whole} = V_H \times \left(\frac{R_H}{2l_p}\right)^4 \tag{3}$$

Using the equation for the surface volume of a 4D sphere, $2\pi^2 R^3$, we can calculate the radius, the fourth-dimensional radius or hyper-radius, of the whole hyperverse:

The volume of the whole hyperverse, V_{whole} or V_w, is:

$$V_{whole} = 2\pi^2 R_w^3 \tag{4}$$

where R_w is the fourth-dimensional radius of the whole hyperverse.

The volume of the observable hyperverse, V_H is:

$$V_H = 2\pi^2 R_H^3 \tag{5}$$

Combining the above equations, we find:

$$V_w = V_H \times \left(\frac{R_H}{2l_p}\right)^4 = 2\pi^2 R_H^3 \times \left(\frac{R_H}{2l_p}\right)^4 = 2\pi^2 R_w^3 \tag{6}$$

We get the radius of the whole hyperverse by solving this equation, for R_w:

$$2\pi^2 R_w^3 = 2\pi^2 R_H^3 \times \left(\frac{R_H}{2l_p}\right)^4 \tag{7}$$

$$R_w = \left(\frac{2\pi^2 R_H^3 \times \left(\frac{R_H}{2l_p}\right)^4}{2\pi^2}\right)^{\frac{1}{3}} = R_H \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}} = 4.281\,459\,115\,196\,810\,360\,1 \times 10^{107}\,\mathrm{m} \tag{8}$$

In summary, we make the claim that the whole volume, and whole energy, are larger than the observable by a factor of $\left(\frac{R_H}{2l_p}\right)^4$, and the radius of the whole is larger than the observable hyperverse radius by a factor of $\left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}$:

$$E_w = E_O \left(\frac{R_H}{2l_p}\right)^4 \tag{9}$$

$$R_w = R_H \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}} \tag{10}$$

3. Then and Now for the Whole Hyperverse: The Geometric Mean Expansion of the Whole Hyperverse

Let us look at what happens to the whole hyperverse with a doubling in its radius. "R_w now" represents the current radius of the whole hyperverse. "R_w then" represents the radius when the universe was half its current size. In other words, when the hyperverse radius, R_H, was half the current size.

$$\frac{R_w \text{ now}}{R_w \text{ then}} = \frac{R_H \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}}{\frac{R_H}{2} \left(\frac{\frac{R_H}{2}}{2l_p}\right)^{\frac{4}{3}}} = 4\sqrt[3]{2} = 5.039\,684\,199\,579\,492\,659\,1 \tag{11}$$

With a doubling of the radius of the observable hyperverse, the radius of the whole hyperverse increases by a factor of $4\sqrt[3]{2}$. Since, by definition, the observable radius doubles with a doubling, the radius of the whole increases faster than the radius of the observable by a factor of $2\sqrt[3]{2}$ with each doubling:

$$\frac{4\sqrt[3]{2}}{2} = 2\sqrt[3]{2} = 2.519\,842\,099\,789\,746\,329\,5 \tag{12}$$

The energy of the whole hyperverse, now to then, is:

$$\frac{E_w \text{ now}}{E_w \text{ then}} = \frac{\frac{R_H c^4}{4G}\left(\frac{R_H}{2l_p}\right)^4}{\frac{\frac{R_H}{2} c^4}{4G}\left(\frac{\frac{R_H}{2}}{2l_p}\right)^4} = 32 \tag{13}$$

The energy of the observable hyperverse doubles with a doubling of the radius:

$$\frac{E_O \text{ now}}{E_w \text{ then}} = \frac{\frac{R_H c^4}{4G}}{\frac{\frac{R_H}{2} c^4}{4G}} = 2 \tag{14}$$

The energy of the whole is increasing at a faster rate than the observable, by a comparative factor of $\frac{32}{2}$, or 16, and the radius by $2\sqrt[3]{2}$ or about 2.5198 times.

4. The 2c Expansion Rate of the Observable Universe

In [1] we asked: "If the universe is the surface volume of a 4D sphere, how large would a hyperverse be whose 3D surface volume matched the volume of our observable universe?" That is, we solve for the following equation:

$$2\pi^2 R_H^3 = \frac{4}{3}\pi r_o^3 \tag{15}$$

where r_o is the radius of the observable universe. Using the 46.25 billion light years for the radius of the observable universe, we find that the radius of the observable hyperverse would be 27.5866 billion light years:

$$R_H = (46.25)\sqrt[3]{\frac{2}{3\pi}} \approx 27.5866 \text{ billion light years} \tag{16}$$

Given the age of the universe is about 13.8 billion years old, we discover the striking result that the speed of radial expansion is twice the speed of light, or $2c$:

$$\frac{27.5866 \text{ billion light years}}{13.8 \text{ billion years}} = 1.999 \text{ light years per year } \Rightarrow 2c \tag{17}$$

The observable hyperverse is expanding at exactly twice the speed of light.

5. The Dilemma of 2c

The observable hyperverse is part of the whole hyperverse. As discussed above, the whole universe is larger than the observable, presumably by a factor of $\left(\frac{R_H}{2l_p}\right)^4$. If, for example, the whole hyperverse were only twice as large as the observable, the radius of the whole would be twice as big, and given the whole and observable universes are the same age, the radial expansion rate would be 4 times the speed of light, or $2 \times 2c$. If the whole were 10^{243} times larger, the expansion rate would be 10^{243} times the 2c expansion rate we calculate for the observable.

In a series of papers [1,2,3,4] we argued that 2c is the perfect expansion rate for the hyperverse, as it gives us our models for time, quanta, matter and gravity. But the whole is larger, and since the observable is simply a tiny portion of the whole, and the whole and observable are the same age, the whole must be expanding at 10^{243} times faster than the observable hyperverse; the whole must be expanding at $2c \times \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}$.

To state this more explicitly, if the whole radius is $R_H \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}$ and the age of the universe is $\frac{R_H}{2c}$, then the velocity of radial expansion would be the radial distance divided by the time:

$$\text{radial velocity} = \frac{\text{distance}}{\text{time}} = \frac{R_H \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}}{\frac{R_H}{2c}} = 2c \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}} \tag{18}$$

This presents a clear problem: how can we have two radial velocities for every point in space?

6. The Accelerating Expansion of the Whole

Additionally, our 2c radial expansion for the observable hyperverse is a constant velocity, but the whole is expanding at $2c \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}$. Notice that the whole hyperverse radial expansion rate contains the R_H term in the numerator, meaning the expansion rate of the whole is increasing with time; the growth of the whole hyperverse is accelerating. To us, there is no acceleration, as we appear to be expanding at the constant velocity of 2c.

Using the 'now to then' approach, we see that the whole radius is expanding by a factor of $2\sqrt[3]{2}$ with each doubling, matching the change in the radius of the whole, discussed above:

$$\frac{\text{radial expansion rate of whole NOW}}{\text{radial expansion rate of whole THEN}} = \frac{2c\left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}}{2c\left(\frac{\frac{R_H}{2}}{2l_p}\right)^{\frac{4}{3}}} = 2\sqrt[3]{2} \tag{19}$$

The radial expansion rate of the observable NOW to THEN is:

$$\frac{\text{radial expansion rate of observable NOW}}{\text{radial expansion rate of observable THEN}} = \frac{2c}{2c} = 1 \tag{20}$$

The relative expansion rate of the whole to the observable is $2\sqrt[3]{2}$:

$$\frac{\left(\frac{\text{radial expansion rate of whole NOW}}{\text{radial expansion rate of whole THEN}}\right)}{\left(\frac{\text{radial expansion rate of observable NOW}}{\text{radial expansion rate of observable THEN}}\right)} = 2\sqrt[3]{2} \tag{21}$$

So we have a problem of two velocities, and that the observable hyperverse is expanding at a constant rate of $2c$, but the whole is undergoing an accelerating expansion, at the vastly greater rate of $2c\left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}$.

7. Reviewing the SEQ and SRQ

In the Geometric Mean paper [1] we defined two quantum levels within the observable hyperverse, the small energy quantum, and the small radius quantum. The small energy quantum, or SEQ, is the geometric mean partner of the energy of the observable universe. We calculate the SEQ from this expression:

$$E_{SEQ} = \frac{E_{initial}^2}{E_O} = \frac{\left(\frac{\sqrt{\frac{c^5\hbar}{G}}}{2}\right)^2}{\frac{R_H c^4}{4G}} = \frac{c\hbar}{R_H} \tag{22}$$

$E_{initial}$ represents the initial energy of the universe, existing at the time the current, geometric mean expansion started. We derived and use the value of one-half the Planck energy.

The radius of this quantum, from [3] is:

$$R_{SEQ} = \left(R_H 4l_p^2\right)^{\frac{1}{3}} = R_H\left(\frac{2l_p}{R_H}\right)^{\frac{2}{3}} = 6.495\,953\,894\,227\,408\,611\,9 \times 10^{-15}\,\text{m} \tag{23}$$

This is similar to the Compton radius of elementary particles. We claimed in [3] that this quantum level is the quantum of our existence, the quantum of quantum mechanics.

The small radius quantum, or SRQ, is the geometric mean partner of the radius of the observable hyperverse, and is derived as:

$$R_{SRQ} = \frac{(2l_p)^2}{R_H} = \frac{4l_p^2}{R_H} = R_H \left(\frac{2l_p}{R_H}\right)^2 \tag{24}$$

The energy associated with it is:

$$E_{SRQ} = \frac{c\hbar}{R_H}\left(\frac{2l_p}{R_H}\right)^4 = 2.773\,577\,165\,630\,088\,315 \times 10^{-296}\,\frac{\mathrm{m}^2}{\mathrm{s}^2}\,\mathrm{kg} \tag{25}$$

This quantum level is much smaller than the SEQ.

We looked at how both the SEQ and SRQ change with time, using the 'now and then' comparison. We find with a doubling of the observable hyperverse radius, that the SEQ radius increases with expansion by a factor of $\sqrt[3]{2}$ with each doubling of the observable hyperverse radius.:

$$\frac{\text{SEQ radius NOW}}{\text{SEQ radius THEN}} = \frac{\left(R_H 4l_p^2\right)^{\frac{1}{3}}}{\left(\frac{R_H}{2}4l_p^2\right)^{\frac{1}{3}}} = \sqrt[3]{2} = 1.259\,921\,049\,894\,873\,164\,8 \tag{26}$$

The SRQ radius shrinks by one-half with every doubling of the observable hyperverse radius:

$$\frac{\text{SRQ radius NOW}}{\text{SRQ radius THEN}} = \frac{\frac{4l_p^2}{R_H}}{\frac{4l_p^2}{\frac{R_H}{2}}} = \frac{1}{2} \tag{27}$$

The relative size change of the SEQ radius to the SRQ radius is

$$\frac{\left(\frac{\text{SEQ radius NOW}}{\text{SEQ radius THEN}}\right)}{\left(\frac{\text{SRQ radius NOW}}{\text{SRQ radius THEN}}\right)} = \frac{\sqrt[3]{2}}{\frac{1}{2}} = 2\sqrt[3]{2} \tag{28}$$

With each doubling of the hyperverse, the SEQ radius increases in size, compared to the SRQ radius, by a factor of $2\sqrt[3]{2}$. Importantly, notice that this rate of relative change in the quantum levels' radii matches the rate of change of the radial velocity of the whole hyperverse relative to the observable hyperverse.

8. Reviewing the Ideal Particle

In [4] we introduced the concept of the 'ideal particle', a particle with the target values of mass and radius that appears to be what the expanding universe is trying to create. Actual particles are somewhat different, assumably due to electrical interactions. electrical interactions, in hyperverse theory, are believed to result for spin orientations [5]. These equations are derived from the geometric mean model and reflect the conservation of angular momentum. The three equations of the ideal particle are:

$$\text{particle radius:} \quad \left(\frac{16 l_p^4}{R_H}\right)^{\frac{1}{3}} = R_H \left(\frac{2 l_p}{R_H}\right)^{\frac{4}{3}} \tag{29}$$

$$\text{particle mass:} \quad \left(\frac{1}{4G}\frac{\hbar^2}{R_H}\right)^{\frac{1}{3}} = \left(\frac{R_H c^2}{4G}\right)\left(\frac{2 l_p}{R_H}\right)^{\frac{4}{3}} \tag{30}$$

$$\text{particle number:} \quad \left(\frac{R_H}{2 l_p}\right)^{\frac{4}{3}} \tag{31}$$

9. The SEQ Frame Advance

In the paper on time and the hyperverse [3], we discussed the concept of frame advances, in which the radial advance of the hyperverse can be described as occurring in incremental steps, or frames, each frame advance equal to the radius of either the SEQ or SRQ quantum level.

To calculate the number of frames at the SEQ level, we take the radius of the observable hyperverse, and divide it by the SEQ radius:

$$\frac{R_H}{R_{SEQ}} = \frac{R_H}{\left(R_H 4 l_p^2\right)^{\frac{1}{3}}} = \left(\frac{R_H}{2 l_p}\right)^{\frac{2}{3}} = 4.039\,394\,679\,712\,516\,885\,5 \times 10^{40} \tag{32}$$

The time for the hyperverse to make one SEQ frame advance is the age of the universe, divided by the number of SEQ frame advances:

$$\frac{\text{age of universe}}{\text{number of SEQ frame advances}} = \frac{\frac{R_H}{2c}}{\left(\frac{R_H}{2l_p}\right)^{\frac{2}{3}}} = \frac{\left(R_H 4l_p^2\right)^{\frac{1}{3}}}{2c} = \frac{\text{Radius of the SEQ}}{2c} \tag{33}$$

An SEQ frame advance currently takes about 10^{-23} seconds:

$$\frac{\left(R_H 4l_p^2\right)^{\frac{1}{3}}}{2c} = \frac{6.495\,953\,894\,227\,408\,611\,9 \times 10^{-15}\,\text{m}}{2\,(2.99792458 \times 10^{8}\,\text{m}\,\text{s}^{-1})} = 1.083\,408\,491\,588\,438\,928 \times 10^{-23}\,\text{s} \tag{34}$$

Notice that the hyperverse radius is in the numerator, so that the time for an SEQ to make a frame advance increases as the universe expands. Using the 'now and then' approach, we find that the time to make a frame advance increases at a rate of one-half the rate of the radial distance, from equation (26):

$$\frac{\text{time for SEQ to make a frame advance NOW}}{\text{time for SEQ to make a frame advance THEN}} = \frac{\frac{\left(R_H 4l_p^2\right)^{\frac{1}{3}}}{2c}}{\frac{\left(\frac{R_H}{2} 4l_p^2\right)^{\frac{1}{3}}}{2c}} = \sqrt[3]{2} \tag{35}$$

10. SRQ Frame Advances

We determine the number of frame advances at the SRQ level similarly, by dividing the observable hyperverse radius by the radius of the SRQ:

$$\frac{R_H}{R_{SRQ}} = \frac{R_H}{\frac{4l_p^2}{R_H}} = \left(\frac{R_H}{2l_p}\right)^2 = 6.590\,962\,905\,388\,697\,310\,3 \times 10^{121} \tag{36}$$

The time for the hyperverse to make one SRQ frame advance is the age of the universe divided by the number of SRQ frame advances:

$$\frac{\text{age of universe}}{\text{number of SRQ frame advances}} = \frac{\frac{R_H}{2c}}{\left(\frac{R_H}{2l_p}\right)^2} = \frac{\frac{4l_p^2}{R_H}}{2c} = \frac{\text{Radius of SRQ}}{2c} \tag{37}$$

Numerically, an SRQ frame advance takes about 6.6×10^{-105} seconds:

$$\frac{\frac{4l_p^2}{R_H}}{2c} = \frac{3.981\,166\,633\,261\,840\,704\,9 \times 10^{-96}\,\text{m}}{2\,(2.99792458 \times 10^8\,\text{m}\,\text{s}^{-1})} = 6.639\,871\,229\,285\,295\,604\,2 \times 10^{-105}\,\text{s} \quad (38)$$

This is the value we defined as 'small time' in [3].

11. The Acceleration of the Whole Hyperverse is Cancelled by the Increase in the Duration of the SEQ-Based Quantum of Time

We showed in equation (19) that with each doubling of the hyperverse radius, the whole radius is expanding faster than the observable radius by the factor of $2\sqrt[3]{2}$. And in equation (28) we showed that with each doubling of the observable hyperverse radius, that relative to the SRQ radius, the SEQ radius also increases by a factor of $2\sqrt[3]{2}$. Both the whole radius, and the SEQ unit of time, are increasing at the same rate.

Comparing the time for an SEQ frame advance against that of the SRQ, we find that the SEQ frame advance time increases at a rate of $\left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}$ relative to the SRQ:

$$\frac{\text{SEQ frame advance time}}{\text{SRQ frame advance time}} = \frac{\left(\frac{\left(R_H 4l_p^2\right)^{\frac{1}{3}}}{2c}\right)}{\left(\frac{\frac{4l_p^2}{R_H}}{2c}\right)} = \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}} \quad (39)$$

This equals the rate that the radial velocity of the whole increases, relative to the observable hyperverse:

$$\frac{\text{radial velocity of the whole hyperverse}}{\text{radial velocity of the observable hyperverse}} = \frac{2c\left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}}}{2c} = \left(\frac{R_H}{2l_p}\right)^{\frac{4}{3}} \quad (40)$$

Here is the key point: both the radial velocity of the whole hyperverse, relative to the observable, and the frame advance time of an SEQ, relative to the frame advance time of the SRQ, are increasing at the same rate. Their identical rates cancel, leaving us with the constant expansion velocity of 2c.

We are accustomed to thinking of time as a constant, but we see that in the accelerating, whole hyperverse, the SEQ frame advance time increases with expansion.

We can express the frame advance time in terms of time. Using the relation that the age of the universe is $\frac{R_H}{2c}$:

$$\text{Let T = the age of the universe, so that } T = \frac{R_H}{2c} \tag{41}$$

and rearrange:

$$R_H = T \times 2c \tag{42}$$

we can restate equation (33), replacing the R_H term with $T \times 2c$:

$$\text{SEQ frame advance time} = \left(\frac{\left(T \times 2c \times 4l_p^2\right)^{\frac{1}{3}}}{2c} \right) = \sqrt[3]{T\frac{G\hbar}{c^5}} = \left(Tt_P^2\right)^{\frac{1}{3}} \tag{43}$$

This value is based on the ideal particle mass and radius, and would vary according to the structure of the specific particle. Thus we could see this as the "ideal quantum absorption time".

12. The Time it Takes for a Particle to Absorb a Quantum of Energy is the SEQ Frame Advance Time

We discussed a model of particle creation in [4], claiming that particles of matter exist because the expanding universe is crushing and coalescing the quanta of space to conserve the continually increasing angular momentum.

The energy of the ideal particle is:

$$\text{energy of the ideal particle} = \left(\frac{1}{4G}c^6\frac{\hbar^2}{R_H}\right)^{\frac{1}{3}} \tag{44}$$

The number of SEQ in a particle is the particle mass divided by the energy of an SEQ:

$$\text{The number of SEQ within the ideal particle} = \frac{\left(\frac{1}{4G}c^6\frac{\hbar^2}{R_H}\right)^{\frac{1}{3}}}{\frac{c\hbar}{R_H}} = \left(\frac{R_H}{2l_p}\right)^{\frac{2}{3}} \tag{45}$$

From equation (32), notice that this value matches the number of SEQ frame advances, suggesting a particle of matter absorbs one SEQ per SEQ frame advance.

We can calculate the rate at which SEQ are absorbed by a particle by dividing the total time, by the number of SEQ in a particle:

$$\frac{\text{age of universe}}{\text{number of SEQ in a particle}} = \frac{\frac{R_H}{2c}}{\left(\frac{R_H}{2l_p}\right)^{\frac{2}{3}}} = \frac{\sqrt[3]{R_H 4l_p^2}}{2c} = \frac{\text{Radius of the SEQ}}{2c} \tag{46}$$

The time it takes for an ideal particle to absorb an SEQ is about 10^{-23} seconds:

$$\frac{\sqrt[3]{R_H 4l_p^2}}{2c} = \frac{6.495\,953\,894\,227\,408\,611\,9 \times 10^{-15}\,\mathrm{m}}{2\,(2.99792458 \times 10^{8}\,\mathrm{m\,s^{-1}})} = 1.083\,408\,491\,588\,438\,928 \times 10^{-23}\,\mathrm{s} \tag{47}$$

13. The Relation to Piero Caldirola's "Chronon"

Piero Caldirola produced an equation for the unit of quantum time, for the classical electron. In the paper by Farias and Recami [6], equation 13 gives Caldirola's value of quantum time, which he termed the "chronon":

$$\text{Caldirola's quantum time} = \frac{2}{3}\frac{\frac{1}{4\pi\epsilon_0}e^2}{mc^3} = \frac{e^2}{6\pi c^3 m\epsilon_0} = 6.266\,420\,091\,262\,249\,288\,4 \times 10^{-24}\,\mathrm{s} \tag{48}$$

e represents the electron charge, and ϵ_0 is the permittivity of free space.

The unit of quantum time produced by the hyperverse model, based on the ideal particle, is:

$$\text{Hyperverse quantum time} = \frac{\left(R_H 4l_p^2\right)^{\frac{1}{3}}}{2c} = 1.083\,408\,491\,588\,438\,928 \times 10^{-23}\,\mathrm{s} \tag{49}$$

They are close, off by a factor of about 1.7289. Caldirola determined quantum time for the classical electron, whereas the hyperverse unit is for on the ideal particle.

Let us:

1. insert ideal particle mass into Caldirola equation.

2. convert from classical to Compton radii by use of the fine structure constant, α.

3. modify the fraction in the Caldirola equation, changing it from 2/3 to 1/2.

When we do this, we find that the modified Caldirola equation gives the same value for quantum time as does the hyperverse model, for the ideal particle:

$$\text{modified Caldirola} = \frac{1}{2}\frac{\frac{1}{4\pi\epsilon_0}e^2}{\alpha mc^3} = \frac{e^2}{8\pi c^3 m\alpha\epsilon_0} = 1.083\,406\,909\,226\,670\,033\,1 \times 10^{-23}\,\mathrm{s} \tag{50}$$

So we have the identity:

$$\frac{1}{2}\frac{\frac{1}{4\pi\epsilon_0}e^2}{\alpha mc^3} = \frac{\left(R_H 4l_p^2\right)^{\frac{1}{3}}}{2c} \tag{51}$$

Let us insert the ideal particle mass, $\left(\frac{1}{4G}\frac{\hbar^2}{R_H}\right)^{\frac{1}{3}}$, rearrange, and solve for the electric charge:

$$e = \sqrt{4\pi c\alpha\epsilon_0\hbar} \tag{52}$$

We find the value matches the CODATA value for the electron charge [7].

We can also compare the quantum unit of time of an electron, calculated by both the modified Caldirola equation and the hyperverse equation:

$$\text{electron in modified Caldirola equation: } t = \frac{1}{2}\frac{\frac{1}{4\pi\epsilon_0}e^2}{\alpha m_{electron}c^3} = 6.440\,438\,533\,690\,713\,174\,5\times10^{-22}\,\mathrm{s} \tag{53}$$

Using the hyperverse equation with the Compton radius of the electron, we find the same time interval:

$$\frac{\text{Compton radius of electron}}{2c} = \frac{\frac{\hbar}{m_{electron}c}}{2c} = \frac{\hbar}{2m_{electron}c^2} = \frac{\hbar}{2E_{electron}} = 6.440\,438\,816\,915\,123\,747\times10^{-22}\,\mathrm{s} \tag{54}$$

We find the remarkable result that the modified Cardirola equation gives the same value for the quantum of time as does the hyperverse model. And equating them gives the correct equation for the electron charge, supporting the validity of the equations.

14. The Quantum Time and Energy of a Particle Fit the Time-Energy Uncertainty Relation

We have claimed that quantum time is both the frame advance time of the particle, and the time it takes a particle to absorb a quantum of space. From equation (54), notice that this expression

$$t_{absorb} = \frac{\hbar}{2} \times \frac{1}{E_{particle}} \tag{55}$$

is a time-energy uncertainty relationship:

$$\frac{\hbar}{2} = t_{absorb} \times E_{particle} \tag{56}$$

We used time-energy uncertainty in [3] to argue that the universe is undergoing a geometric mean expansion, and here, we find further support for that claim. Since we are dealing with the quantum levels themselves, we have no need of delta values.

15. The Quantum Unit of Time for Elementary Particles

We can use this relationship to calculate the quantum unit of time for other particles. The following table gives the quantum time values for the elementary particles; that is, the time it takes for each particle type to absorb one SEQ.

particle	energy	time
ideal particle	$4.866\,924 \times 10^{-12}$ J	$1.083\,407 \times 10^{-23}$ s
electron	$8.187\,10565 \times 10^{-14}$ J	$6.440\,440 \times 10^{-22}$ s
muon	$1.692\,833\,774 \times 10^{-11}$ J	$3.114\,812 \times 10^{-24}$ s
tau	$2.846\,78 \times 10^{-10}$ J	$1.852\,219 \times 10^{-25}$ s
up quark	$3.685\,009 \times 10^{-13}$ J	$1.430\,894 \times 10^{-22}$ s
charm	$2.042\,776 \times 10^{-10}$ J	$2.581\,222 \times 10^{-25}$ s
top	$2.777\,214\,183\,822 \times 10^{-8}$ J	$1.898\,614 \times 10^{-27}$ s
down quark	$7.690\,451\,184 \times 10^{-13}$ J	$6.856\,371 \times 10^{-23}$ s
strange	$1.522\,068\,463\,5 \times 10^{-11}$ J	$3.464\,272 \times 10^{-24}$ s
bottom	$6.697\,101\,239\,4 \times 10^{-10}$ J	$7.873\,345 \times 10^{-26}$ s
electron neutrino	$3.524\,790\,126 \times 10^{-19}$ J	$1.495\,936 \times 10^{-16}$ s
muon neutrino	$2.723\,701\,461 \times 10^{-14}$ J	$1.935\,917 \times 10^{-21}$ s
tau neutrino	$2.483\,374\,861\,5 \times 10^{-12}$ J	$2.123\,263 \times 10^{-23}$ s

Table 1. The SEQ absorption times for the elementary particles.

16. Relating Matter, Gravity and Time

From the above equations, we can state that a particle of matter absorbs one SEQ with each SEQ frame advance. Thus, the time it takes for a particle to absorb an SEQ is the SEQ frame advance time, about 10^{-23} seconds, depending on the particle.

We are made of elementary particles and atoms; our time is atomic time. The model says that a particle of matter is altered with every SEQ frame advance; that matter is changed in quantized increments by the absorption of a quantum of energy with the passage of each unit of quantized time.

We will propose that it is the absorption of a quantum of energy, by an elementary particle, in this unit of quantized time, that forms the foundation of quantum time and quantum gravity. Gravity is the absorption of quantized energy by matter. The time it takes to absorb a quantum of energy matches the frame advance rate of the SEQ, and gives us our unit of quantized time. We claim that the quantum unit of time is the time it takes for a particle of matter to absorb a quantum of energy.

Additionally, the length of a unit of quantum time is not a constant, but expands in duration with the expansion of the universe. This growth in the duration of the unit of quantum time is what gives us the constant, 2c, radial expansion of the hyperverse.

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