The Complex Universe

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In this paper, it is proposed that to fully understand the Cosmology of the Universe, we need to consider the FRW metric to measure the Universe in our past light cone and the internal Schwarzschild metric to accurately predict the scale factor. The unknowns in the internal Schwarzschild metric are solved for using cosmological data and it is shown that the predictions it gives match observations without the need for a cosmological constant. The entire Schwarzschild metric in Kruskal-Sezekeres coordinates is examined and we see that it describes two CPT symmetric Universes moving in opposite directions in the time dimension. One Universe contains matter while the other contains antimatter. It is then shown that due to the sign of the angular term in the internal Schwarzschild metric, the time dimension is complex-valued which allows the Universes to, in a sense, bounce off each other at the Big Bang due to particle annihilation and reproduction, after which both Universes expand away from one another. At the singularity, the geodesics reverse their direction in time and begin to re-collapse toward each other. This creates a discontinuity in the geodesics at the singularity, giving rise to the singular nature of the coordinates at that point in time. Finally, we look at the external solution and find that gravitational event horizons cannot be formed or reached until the end of the re-collapse. We find that all the gravitational event horizons in the Universe represent the same point which is the annihilation event at the end of re-collapse.

Keywords: Cosmology; General Relativity; Schwarzschild; Dark Energy; Black Holes
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I. INTRODUCTION AND MOTIVATION

Let us consider a 2D shell of gas spherically symmetrically distributed in space. This shell will collapse according to the Schwarzschild metric where the entire shell falls toward its own center. This metric is a vacuum solution because there is no matter at smaller radii, the gas exists effectively at a specific radius at any given time.

Now suppose we have an observer in the gas. The observer is a 2D creature that can only see along the surface of the shell. For the sake of the example, let us say that the observer on the shell expects to see the matter around her to slowly start to pull together over time due to gravitational attraction. However, over time, the observer would find that the matter is collapsing more quickly than expected because it is not taking into account the additional collapse that comes from the fact that the entire shell is falling in the external Schwarzschild spacetime.

As will be shown, this is an analog to the 4D Cosmology of our Universe. In the Cosmological case, we can imagine that the matter and energy in the Universe is isotropically distributed throughout infinite space (3D space in this case), but exists only at the present time (time is the radius in this case). Another way to say this is that matter and energy in the past and future has no gravitational effects on the present. The curvature of the present spacetime can be understood completely using present data. As will be demonstrated, that 3D space is falling in the *internal* Schwarzschild spacetime. The acceleration in time of the 3D space is what gives us the scale factor that predicts an accelerated expansion without the need for a cosmological constant.

When carefully examining the internal Schwarzschild metric, we will find that the radius of the angular term is actually imaginary. From this it will be shown that at the Big Bang, the Universe is at the event horizon of the Schwarzschild metric where the imaginary radius of the Universe is maximum and the real radius is zero. As time passes, the imaginary radius transitions to the real radius, which we see as the Universe expanding.

What we end up with is a Universe modelled as an infinite collection of uniformly distributed particles where each particle creates a dimple in the surrounding spacetime. The FRW metric tells us the mass distribution of the particles, the external Schwarzschild metric describes the spacetime surrounding each particle. As we will see, these can be thought of as 'real' metrics. The internal Schwarzschild metric describes how the distance between the dimples changes over time. This metric can be thought of as the 'imaginary' metric.

Next, we will examine the Schwarzschild metric in detail.

II. THE SCHWARZSCHILD METRIC

The Schwarzschild metric is the simplest non-trivial solution to Einstein's field equations. It is a vacuum solution for the spacetime around a spherically-symmetric distribution of energy. The general form of the metric can be expressed as:

$$d\tau^2 = -\frac{u-r}{r}dt^2 + \frac{r}{u-r}dr^2 - r^2 d\Omega^2 \qquad (1)$$

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Depending on the ratio $\frac{u}{r}$, we get three distinct descriptions of spacetime:

1. $u = 0$: This gives us the flat Minkowski metric of Special Relativity.

2. $\frac{u}{r} < 1$: This describes the metric for an eternally spherically-symmetric vacuum centered in space. This metric is also used to describe the vacuum outside a spherically symmetric object occupying a finite amount of space (like a star or planet).

3. $\frac{u}{r} \geq 1$: This describes the metric for a spherically symmetric vacuum centered on a point in time. Analogous to the second case, this metric should also describe a vacuum of time outside a spherically-symmetric object spanning infinite space. The center of the metric is everywhere in space, but at a single point in time (just like one could say that the vacuum described in the second case is centered at all times on a single point in space).

An important observation is that the internal metric describes a vacuum solution to the field equations. But the Universe is clearly filled with energy, so how can this solution apply? In order to satisfy the requirements of the metric, the Universe must be "a spherically-symmetric energy distribution occupying an infinite amount of space for a finite amount of time". For this metric to be a cosmological description, it must be that Universe only truly exists in the present and in a very real sense moves into the future. The surrounding vacuum is the future, and the Universe is freefalling through time toward the temporal center of the metric.

Time being the radial dimension of the metric combined with the fact that the solution is a vacuum solution gives a mathematical justification for our intuitive notions of past, present, and future. The in-homogeneity along the radial direction gives us an arrow of time that distinguishes the 'past' and 'future' analogous to the way the external solution gives us an absolute distinction between 'up' and 'down'. And the vacuum as described above gives us a boundary between them, that boundary being the 'present' time.

Observation has shown that the Universe is:

- Spherically Symmetric
- Homogeneous in space
- In-homogeneous across time

We will also make one further assumption in this paper:

- The Universe only ever occupies a single instant of Cosmic time and moves from one moment of cosmic time to the next where the time measured by observers between cosmic times depends on their respective motions.

Relativity of simultaneity does not prohibit the idea of the energy existing at a specific Cosmological time because of the nature of the metric. In Cosmology, we can determine absolute motion and absolute simultaneity because we have the Cosmic Microwave Background. For example, consider two events that are causally disconnected. If observers at each event see the CMB temperature to be uniform in all directions (the observers are co-moving), then if both observers measure the CMB to have the same temperature at both events, then we know the events are absolutely simultaneous, even if a third observer in motion sees them as non-simultaneous. Any observer in motion through space, inertial or otherwise, will see a dipole on the CMB, and that dipole will provide all the info about the state of motion of the observer. Therefore, we can define past, present, future, and motion in an absolute sense. To put it another way, the fact that cosmological time is finite into both the past and future allows us to specify the distance of any event from either the beginning or end of time absolutely.

Let us call events the same distance away from us in time celestial spheres. We can classify these spheres into three types:

1. **Dynamic Spheres** – These are the spheres that galaxies reside on. Objects on these spheres maintain a constant coordinate distance from us and move forward in time. We are able to move toward or away from objects on these spheres by moving through space. If we fix our sights on a particular galaxy, the light we see from that galaxy is being emitted later in time as we ourselves move through time.

2. **Static Spheres** – These are spheres fixed in time. The Cosmic Microwave Background is the most obvious example of these spheres. Light from the CMB sphere is always emitted from the same cosmological time, but as we ourselves move through time, we see light from that time emitted from farther and farther away from us in space, giving the impression that the CMB sphere is growing. We cannot move toward or away from any objects on this sphere because it is frozen in time.

3. **The Dark Sphere** – The Dark Sphere is the Big Bang and lies beyond the CMB. It is in principle unobservable for two reasons. First, the CMB is opaque so that any light from the Big Bang cannot penetrate it. Second, even if the CMB was not blocking our view, any light from that sphere would be infinitely redshifted in the frame of all future observers since the scale factor on that sphere is zero.

These spheres are shown in terms of the internal Schwarzschild metric in Figure 1. Figure 1 shows the Schwarzschild coordinates of the internal metric plotted on the Kruskal-Szekeres coordinate plane [1]. In these coordinates, space is the 't' coordinate emanating from the

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center of the diagram (Big Bang) and time is the 'r' coordinate depicted as hyperbolas (time is flowing forward as r goes toward zero). The upper right quadrant of this diagram represents a single fixed direction ($\theta = const$, $\phi = const$). So each bold line representing a sphere would be a point on each sphere over time. Note that light on this diagram travels on 45-degree lines.

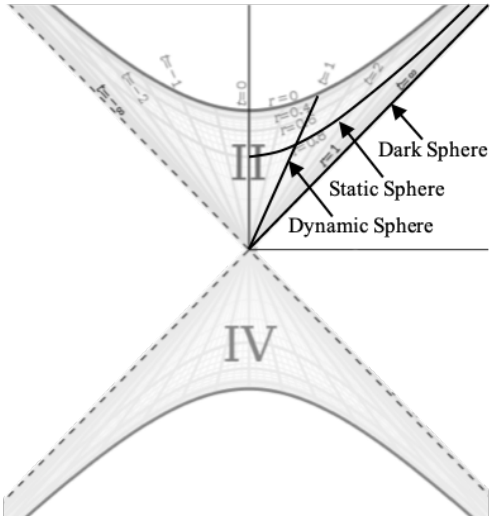

FIG. 1. Celestial Sphere Types on Kruskal-Szekeres Coordinate Chart

III. THE SCALE FACTOR

Expressions for the proper time interval along lines of constant t and Ω and the proper distance interval along hyperbolas of constant r and Ω from Equation 1 are:

$$\frac{ds}{dt} = \pm\sqrt{\frac{u-r}{r}} = \pm a \tag{2}$$

$$\frac{d\tau}{dr} = \pm\sqrt{\frac{r}{u-r}} = \pm\frac{1}{a} \tag{3}$$

And the coordinate speed of light is given by:

$$\left(\frac{dt}{dr}\right)_{light} = \pm\frac{r}{u-r} = \pm\frac{1}{a^2} \tag{4}$$

Where a is the scale factor. First we should notice that none of the three equations depend on the t coordinate. This is good because the t coordinate marks the position of other galaxies relative to ours. Since all galaxies are freefalling in time inertially, the particular position of any one galaxy should not matter. The proper temporal velocity, proper distance, and coordinate speed of light only depend on the cosmological time r.

A plot of the scale factor vs. r (with $u = 1$) is given in Figure 2 below:

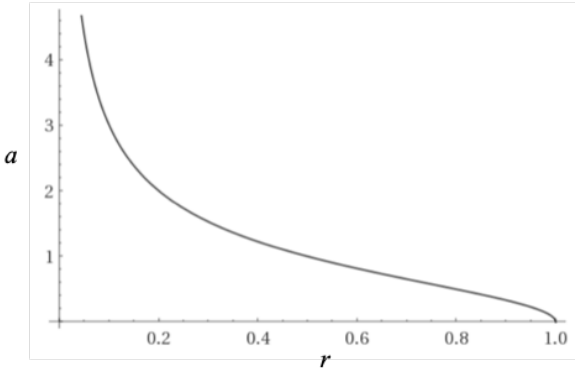

FIG. 2. Scale Factor vs. r for $u = 1$

IV. THE CO-MOVING OBSERVER

Let us take the center of our galaxy as the origin of an inertial reference frame. We can draw a line through the center of the reference frame that extends infinitely in both directions radially outward. This line will correspond to fixed angular coordinates (θ,ϕ). There are infinitely many such lines, but since we have an isotropic, spherically symmetric Universe, we only need to analyze this model along one of these lines, and the result will be the same for any line.

The radial distance in this frame is kind of a compound dimension. It is a distance in space as well as a distance in time. The farther away a galaxy is from us, the farther back in time the light we currently receive from it was emitted. Fortunately the $u/r \geq 1$ spacetime of the Schwarzschild solution plotted in Kruskal-Szekeres coordinates provides us with a method to understand this radial direction. Figure 1 showed the $u/r \geq 1$ solution on a Kruskal-Szekeres coordinate chart where, in this model, the hyperbolas of constant r represent spacelike slices of constant cosmological time and the rays of t represent spatial distances. We will focus on the upper half where the half represents an observer pointed in a particular direction and the positive t's represent the coordinate distance from the observer in that particular direction while the negative t's represent coordinate distance in the opposite direction.

We must determine the paths of co-moving observers ($dt = d\Omega = 0$) in the spacetime. For this we need the geodesic equations for the internal Schwarzschild metric [2] given in Equation 1. In these equations u represents a time constant (in Figure 1, the value of u is 1). The following equations are the geodesic equations for t and r ($0 \leq r \leq u$) for $d\Omega = 0$:

$$\frac{d^2t}{d\tau^2} = \frac{u}{r(u-r)}\frac{dr}{d\tau}\frac{dt}{d\tau} = \frac{a^2+1}{a^2 r}\frac{dr}{d\tau}\frac{dt}{d\tau} \tag{5}$$

$$\frac{d^2r}{d\tau^2} = \frac{u}{2r^2} = \frac{a^2+1}{2r} \tag{6}$$

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Looking at points $0 < r < u$, then by inspection of Equation 5 it is clear that an inertial observer at rest at t will remain at rest at t ($\frac{d^2t}{d\tau^2} = 0$ if $\frac{dt}{d\tau} = 0$). Also, we see that if an observer is moving inertially with some initial $\frac{dt}{d\tau}$, then if $\frac{dr}{d\tau} < 0$, the coordinate speed of the observer will be reduced over time (the coordinates are expanding beneath her) and if $\frac{dr}{d\tau} > 0$, the coordinate speed will be increased over time (the coordinates are collapsing beneath her).

V. CALCULATION OF COSMOLOGICAL PARAMETERS

In order to compare this model to cosmological data, we must solve for u and find our current position in time (r_0) in the model. Reference [3] gives us transition redshift values ranging from $z_t = 0.337$ to $z_t = 0.89$, depending on the model used. We can use the expression for the scale factor in Equation 2 to get the expression for cosmological redshift from some emitter at r measured by an observer at r_0 [2]:

$$1 + z = \frac{a_0}{a} = \sqrt{\frac{r(u - r_0)}{r_0(u - r)}} \tag{7}$$

Furthermore, the decelration parameter is given by:

$$q = \frac{\ddot{a}a}{\dot{a}^2} = \frac{4r}{u} - 3 \tag{8}$$

By setting Equation 8 equal to zero, we find that the scale factor at the transition from decelerating to accelerating expansion a_t is:

$$a_t = \sqrt{\frac{4}{3} - 1} = \frac{1}{\sqrt{3}} \tag{9}$$

Using Equations 7, 9, and the transition redshift estimate, we can get an expression for the present scale factor:

$$a_0 = a_t(1 + z_t) = \frac{1 + z_t}{\sqrt{3}} \tag{10}$$

Next, we find expressions for u and our current radius r_0 by noting that the Universe has been found to be roughly 13.8 billion years old. Therefore, we can set $\alpha_{r_0} \equiv u - r_0 = 13.8$ and use Equations 2 and 10 to obtain the following for u and r_0:

$$r_0 = \frac{u - r_0}{a_0^2} = \frac{\alpha_{r_0}}{a_0^2} = \frac{3\alpha_{r_0}}{(1 + z_t)^2} \tag{11}$$

$$u = r_0 + \alpha_{r_0} = \alpha_{r_0}\left(\frac{3}{(1 + z_t)^2} + 1\right) \tag{12}$$

Next we compute the CMB scale factor (a_{CMB}) and coordinate time (r_{CMB}) in this model where the redshift of the CMB (z_{CMB}) is currently measured to be 1100:

$$a_{CMB} = \frac{a_0}{1 + z_{CMB}} \tag{13}$$

$$r_{CMB} = \frac{u}{1 + a_{CMB}^2} \tag{14}$$

We can next derive the Hubble parameter equation using the scale factor. The Hubble parameter is given by (in units of $(Gy)^{-1}$):

$$H = \frac{\dot{a}}{a} = \frac{u}{2r(u - r)} \tag{15}$$

Table I below gives the values of u, r_0, H_0, a_0, q_0, a_{CMB}, r_{CMB}, and q_{CMB} given the upper and lower bounds of z_t from [3] as well as the average of the upper and lower bound values and assuming $\alpha_{r_0} = 13.8$. All times are in Gy and H_0 is in $(km/s)/Mpc$.

z_t	α_{r_0}	u	r_0	H_0	a_0	q_0	a_{CMB}	r_{CMB}	q_{CMB}
0.337	13.8	37.0	23.2	56.6	0.77	-0.49	0.0007	36.95	0.99
0.614	13.8	29.7	15.9	66.2	0.93	-0.86	0.0008	29.65	0.99
0.89	13.8	25.4	11.6	77.6	1.09	-1.17	0.0010	25.35	0.99

TABLE I. Limiting Cosmological Parameter Values Based on z_t Measurement and a 13.8 Gy Age of the Universe

From the results in Table I, we see that the true transition redshift is likely between 0.614 and 0.89 given the fact that the current value of the Hubble constant is known to be in that range. Thus, more accurate measurements of the transition redshift are needed to increase the confidence of this model, though we do see that it is able to reproduce measured results.

Table II has the proper times from $r = u$ to the current time as well as the CMB for stationary, inertial observers ($dt = rd\Omega = 0$) by integrating Equation 1. The column τ_{tot} gives the time from $r = u$ to $r = 0$. The expression for τ_{tot} turns out to be quite simple:

$$\tau_{tot} = \frac{\pi}{2}u \tag{16}$$

In Table II below, the column τ_{remain} gives the time between $r = r_0$ and $r = 0$.

z_t	α_{r_0}	τ_0	τ_{tot}	τ_{remain}	τ_{CMB}
0.337	13.8	42.2	58.1	15.9	8.6
0.614	13.8	37.1	46.7	9.6	2.4
0.89	13.8	33.7	39.9	6.2	2.3

TABLE II. Limiting Proper Times Based on z_t Measurements and an age of 13.8 Gy for the Universe (Time is in Gy)

Note that while the coordinate times for the current age of the Universe ($u - r_0$) are close to current estimates (for high z_t), the proper time τ_0 is actually much larger. And even though we are presently only about halfway through the "coordinate life" of the Universe (according to Table I), the amount of proper time remaining is actually much less than the amount of proper time that has already passed (according to Table II).

Next we would like to use the u and r_0 values found to create an envelope on a Hubble diagram to compare to

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measured supernova and quasar data. First we need to find r as a function of redshift. We can do this by solving for r in Equation 7:

$$r = \frac{u(1+z)^2}{a_0^2 + (1+z)^2} \tag{17}$$

We can derive the expression for t vs. r along a null geodesic where the geodesic ends at the current time r_0 and $t = 0$ by setting $d\tau = rd\Omega = 0$ in Equation 1 and integrating:

$$t = \int_{r_0}^{r} \frac{r}{u-r} dr = u \ln\left(\frac{u-r_0}{u-r}\right) + r_0 - r \tag{18}$$

Next we substitute Equation 17 into Equation 18 to get coordinate distance in terms of redshift:

$$t = r_0 + u\left[\ln\left(\frac{a_0^2 + (1+z)^2}{1+a_0^2}\right) - \frac{(1+z)^2}{a_0^2 + (1+z)^2}\right] \tag{19}$$

We need to convert the distance from Equation 19 to the distance modulus, μ, which is defined as:

$$\mu = 5\log_{10}\left(\frac{D_L}{10}\right) \tag{20}$$

Where D_L in Equation 20 is the luminosity distance. Luminosity distance is inversely proportional to brightness via the relationship:

$$B \propto \frac{1}{D_L^2} \tag{21}$$

The brightness is affected by two things. First, the spatial expansion will effectively increase the distance between two objects at fixed co-moving distance from each other. This will reduce the brightness by a factor of $(1+z)^2$ (because the distance in Equation 21 is squared). But there is also a brightening effect caused by the acceleration in the time dimension. We define $V \equiv \frac{d\tau}{dr} = \frac{1}{a}$ as the temporal velocity of the inertial observer at some r and the speed of light at that r as $V_c \equiv \frac{dt}{dr} = \frac{1}{a^2}$. The ratio of these velocities gives us:

$$\frac{V_c}{V} = \frac{dt}{dr}\frac{dr}{d\tau} = \frac{dt}{d\tau} = \frac{a}{a^2} = \frac{1}{a} \tag{22}$$

Equation 22 tells us how far a photon travels over a given period of time measured by the inertial observer's clock. So we see that as light travels from the emitter to the receiver, this speed decreases. This decrease in the speed from emitter to receiver will result in an increased photon density at the receiver relative to the emitter, increasing the brightness. Therefore, this effect will increase the brightness by a factor of:

$$\frac{a_0}{a} = 1 + z \tag{23}$$

Taking these brightness effects into account, the total brightness will be reduced by an overall factor of $1 + z$ relative to the case of an emitter and receiver at rest relative to each other in flat spacetime. Equation 21 in terms of co-moving distance t and redshift z becomes:

$$B \propto \frac{1+z}{(t(1+z))^2} \rightarrow B \propto \frac{1}{t^2(1+z)} \tag{24}$$

Giving the luminosity distance as a function of co-moving distance t and redshift z:

$$D_L = t\sqrt{1+z} \tag{25}$$

Which gives us the final expression for the distance modulus as a function of co-moving distance and redshift:

$$\mu = 5\log_{10}\left(\frac{t\sqrt{1+z}}{10}\right) \tag{26}$$

A plot of distance modulus vs. redshift is shown in Figure 3 below plotted over data obtained from the Supernova Cosmology Project [4]. Curves calculated from all three values of z_t in Table I are plotted, giving an envelope for the model's prediction of the true Hubble diagram.

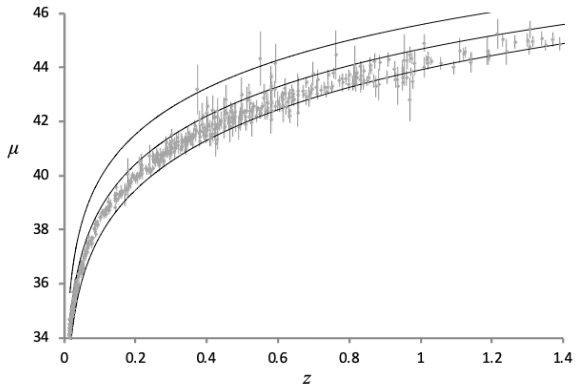

FIG. 3. Distance Modulus vs. Redshift Plotted with Supernova Measurements

Note that the middle curve corresponds to $z_t = 0.614$ and the lower curve corresponds to $z_t = 0.89$. The supernova data is better fit by a curve between these values. The curve halfway between (with $z_t = 0.75$) gives us $H_0 = 71.6$, $a_0 = 1.0$, $q_0 = -1.0$, $u = 27.3$, and $r_0 = 13.5$.

In [5], the authors analyze a large sample of quasar data to obtain distance moduli at higher redshifts than is possible with supernova data. Figure 4 shows the same predicted envelope from Figure 3 for the Hubble diagram plotted out to higher redshifts with the quasar data from [5] also shown with error bars. The black diamonds in the figure are the 18 high-luminosity XMM-Newton quasar points described in [5].

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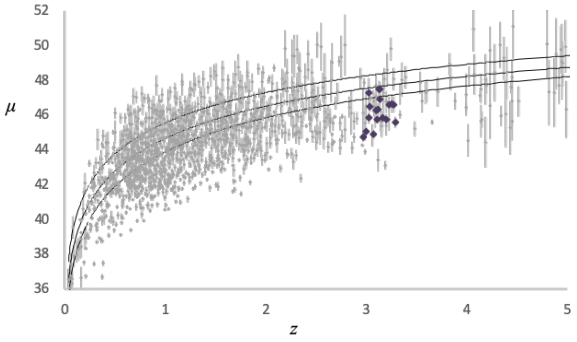

FIG. 4. Distance Modulus vs. Redshift Plotted with Quasar Measurements

Finally, by subtracting r_0 from Equation 17 we can calculate the lookback time for a given redshift. Figure 5 shows the lookback time vs. redshift for the three transition redshifts.

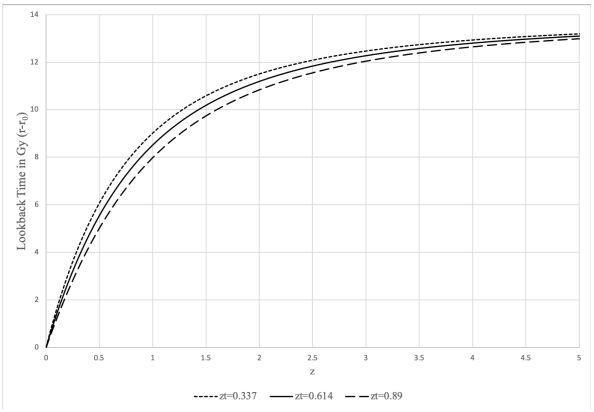

FIG. 5. Lookback Time vs. Redshift

VI. THE ANTIMATTER UNIVERSE

Figure 6 shows the full Schwarzschild metric in Kruskal-Sezekeres coordinates. The diagram can be split in two along the diagonal where in the top right half, forward time points up while in the bottom right half, forward in time points down. Left and right are also swapped when looking at the upper and lower halves.

We can therefore conjecture that the diagram is describing both a matter Universe expanding up from the center and an antimatter Universe expanding down from the center, each one moving toward a singularity. The reason we expect an antimatter Universe is because the directions of both time and space are reversed relative to each other and therefore, we expect the particles of the second Universe to have opposite charges relative to the first. Thus, the pair of Universes (or 'Duoverse') satisfies CPT symmetry and the Kruskal coordinates T and X represent cardinal directions of space and time.

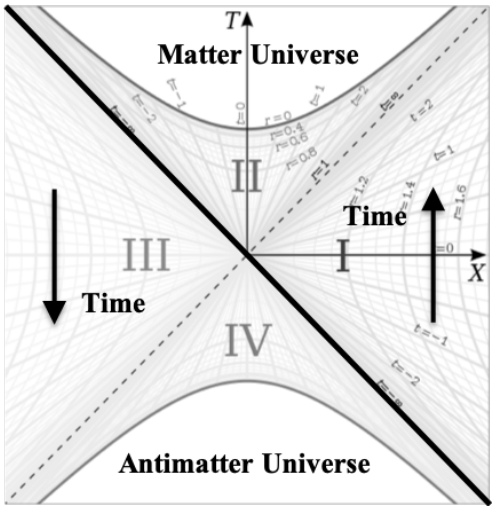

FIG. 6. Matter and Antimatter Universes

VII. COMPLEX COSMOLOGICAL TIME

Notice that the dr and $rd\Omega$ terms in Equation 1 have opposite signs. As is the case in the external Schwarzschild and FRW metrics, we would expect the angular and pure radius terms to have the same sign. We can remedy this by changing Equation 1 to:

$$d\tau^2 = -\frac{u-r}{r}dt^2 + \frac{r}{u-r}dr^2 + (ir)^2\, d\Omega^2 \tag{27}$$

Making the radius in the angular term imaginary gives us the expected form of the metric. This can be understood by imagining what a co-moving observer sees as time passes.

Imagine an inertial observer at $r = u$ and $t = 0$. The radius of the Universe is completely imaginary at this time. Then, as time passes, the observer sees space expand around them with the surface $r = u$ now becoming visible (ignoring redshift for the sake of this example) with an increasing radius over time. We can interpret this as a real radius increasing while the imaginary radius decreases.

Looking at Figure 6, let us imagine a complex plane perpendicular to the page whose real axis is coincident with the T axis of Figure 6. Setting $u = 1$, in Kruskal coordinates the relationship between T and r along $t = 0$ is:

$$T = \pm\sqrt{(1-r)e^r} \tag{28}$$

$$r = 1 + W_0\left(-\frac{T^2}{e}\right) \tag{29}$$

Where W_0 is the Lambert W function. Therefore, we can plot the relationship between T and ir on the aforementioned complex plane in Figure 7 for both the matter and antimatter Universes:

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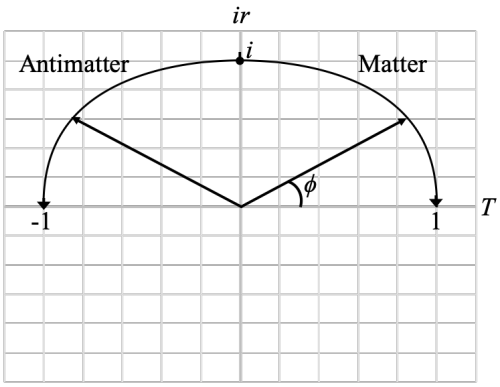

FIG. 7. Imaginary Radius to Real Radius for the Matter (Right) and Antimatter (Left) Universes

In Figure 7, we see two oblong curves, the right one for the matter Universe and the left one for the antimatter Universe with a vector whose projections give the magnitudes of the real and imaginary radii at a given time. The two Universes are coincident at i, representing the event horizon/Big Bang era (in the rest of this paper, the Big Bang will be referred to as Annihilation). Here, we can say the matter and antimatter Universes have annihilated with each other and new pairs of matter and antimatter are created from the annihilation, creating the two Universes travelling in opposite directions of time. Over time, the imaginary radii of the Universes decrease while the real radii increase up to the singularity, where the imaginary radii are zero and the real radii are 1.

The antimatter Universe moves in the opposite direction of time relative to the matter Universe, and so we expect their vectors on this plane to rotate in opposite directions as shown.

But looking at Figure 7, one can't help but be tempted to complete the curves by mirroring them in the real axis. Doing so would indicate that right as the Universes reach maximum expansion, the geodesics reverse in time and the Universes begin to re-collapse toward each other. This creates a discontinuity in the geodesics, resulting in the singular nature of $r = 0$, which we will dissect further in the next section.

VIII. NEWTONIAN ANALOG

This entire system is the temporal equivalent of two masses initially moving apart from one another until they reach a maximum separation distance u. At that point they will start falling toward each other again due to mutual gravitational attraction. When they meet at their common center, they annihilate, creating new pairs of matter/antimatter particles and begin moving away from each other again, as if they've bounced off each other. It is equivalent to the exchange of potential and kinetic Energy, but in the time dimension. Looking at the equation $E^2 = m^2 + p^2$, we can say that this process conserves E by converting p into m during expansion (cosmological redshift is a consequence of the loss of momentum) and vice versa during the collapse.

Now consider the Newtonian example of a ball in a gravitational field rising to a maximum height h and then falling back to the ground. $\frac{dh}{dt}$ will be positive on the way up, negative on the way down and zero at max height. But this also means that $\frac{dt}{dh}$ will be infinite at the maximum height because $dh = 0$ there. We might think that when comparing this to the present case, $t \to \tau$ and $h \to r$, but this is incorrect. We know that r is our time coordinate and τ is the distance along the geodesic, so $h \to \tau$ and $t \to r$. So from Equation 3, we see that, just like in the Newtonian example, $\frac{d\tau}{dr} = 0$ and $\frac{dr}{d\tau} = \infty$ at the singularity because in this case $d\tau = 0$ at the turnaround.

When the Newtonian ball falls back to the ground, if the ball and ground were perfectly rigid and the collision perfectly elastic, there would be an infinite impulse during the collision where the ball would shatter and the fragments would once again start rising up into the air. This is analogous to the matter and antimatter Universes annihilating after the collapse and then re-expanding.

IX. THE NATURE OF EXPANSION

From Equation 4 we can calculate the angle of the cosmological light cone as $\theta = \arctan \frac{1}{a^2}$. At the beginning, when $\theta = \frac{\pi}{2}$, the speed of light is infinite which means all fractions of the speed of light are infinite, and that manifests itself as space having zero size. As time progresses, the light cone closes. The closing of the light cone manifests as an expansion of space since this means the cosmological speed of light is getting smaller, so all fractions of it also get proportionally smaller. The cosmological redshift and dimming come from the fact that the present Universe is accelerating away from past events through time. So if you set off to another galaxy at some time with a constant velocity, over time that velocity will effectively slow as the light cone closes even though no forces have acted on the observer. Since the observer does not feel any change in their velocity, they will describe this as an expansion of space since it will take them longer to reach their destination. As θ goes to zero, the light cone closes completely meaning nothing can move in space, manifesting itself as an infinite scale factor. The Universe has lost all momentum and the momentum has been converted into inertia and this increase in inertia manifests as spatial expansion.

X. THE MANY WORLDS

To this point we have described the spacetime dynamically, but there is still an open issue regarding the angle in the internal Schwarzschild metric at which a given

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event takes place. As we will see, the answer to this question is that it depends on from which location it is being measured from.

Let's consider the Universe at $r = 0$, the singularity. Imagine a 3D flat space where every point in this space is an observer in the Universe at $r = 0$. If we pick out one such observer, when they look out at the Universe (we will ignore the redshift for this argument and assume the entire past light cone for the observer is visible), this observer will see the Universe much like we see it today: a dense plasma at the farthest distance followed by stars and galaxies with decreasing densities as the radius gets smaller. A 2D representation of this is shown in Figure 8 below where the observer is at the center of the circle.

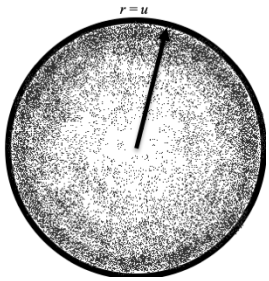

FIG. 8. Observable Universe at $r = 0$

So each observer in the 3D flat space has a sphere like this mapped to it. We will refer to these spheres as observable Universes. But the radius of the sphere is not in the 3D space but is instead the 4th dimension. There is also an antimatter sphere at each point that intersects the matter radius at the $r = 0$ points and extend into the negative direction of this 4th dimension. This is a static picture, but dynamically, we can imagine the spheres growing out from the $r = 0$ points in the 3D space as time progresses. Thus, the r in Figure 8 is the real radius from Figure 7 which grows as the imaginary radius becomes real. So this model can be said to have 3 flat dimensions of space and 3 spherical dimensions of time (though the 3 dimensions of space and two angular dimensions of time are dependant, so this can still be reduced to a 4D spacetime). Furthermore, all light beams in a given observable Universe converge at the center of the time sphere, meaning that every point in the 3D space has null geodesics converging to them from all directions as the geodesics approach $r = 0$, which satisfies the singularity theorem. We would normally imagine light converging to the center of a volume, but that is not the case here. In this scenario, every single point in the volume has its own set of geodesics converging to it from all directions.

Let us consider our current position in the Universe where we sit at some $r = r_0$. Imagine we send out light from our current location in all directions. Assuming none of the light is absorbed in transit, the light will reach a spherical surface around us in the 3D space as the light beams reach $r = 0$. Therefore, the angle at which we reside in the internal Schwarzschild metric depends on which observable Universe we are measuring our position from because we will be visible to all the observable Universes that lie on that aforementioned 2D shell in the 3D space. Each of those observable Universes see us from a different direction, and the direction from which a given observable Universe sees us determines our angle in the internal Schwarzschild metric. Another way to put it is that each of the infinite observable Universes at $r = 0$ corresponds to a unique infinite set of null geodesics (one geodesic for each direction) that converge at a given observable Universe's t at $r = 0$.

These quasi 3+3 dimensional matter and antimatter Universes contain all the events for a single expansion from beginning to end (these dimensions are smooth and continuous). However, the matter and antimatter Universes then re-collapse and eventually result in new expansions. Therefore, we can think of each successive expansion and contraction of the Universes as happening along another dimension which is discrete. This dimension essentially labels the different countably infinite random Universes.

Since each Duoverse begins with annihilation, this means each Duoverse begins with a random configuration after annihilation. Therefore, there is no cause and effect relationship between Duoverses from cycle to cycle. This means the cycles cannot be ordered sequentially because there is no way to know which cycle preceded or will follow the current cycle. If we cannot order the cycles in a sequence, then we can think of them all as being parallel to each other. While events within a cycle can have cause and effect relationships (i.e. the events 'happen' at given times), the various cycles themselves do not 'happen', they just exist along side all other cycles. Thus we can think of the annihilation events as being *a single* event from which infinite Duoverses emerge and to which they return. This implies that finding ourselves in a particular Duoverse is completely probabilistic where the probability that we find ourselves in a Duoverse with a particular configuration depends on how likely that configuration is across all possible configurations (where many configurations are similar enough to be effectively indistinguishable from each other). This gives us the many worlds that have been invoked to explain quantum probability in the Everett many worlds interpretation of QM.

XI. THE CHARGE AND SPIN HYPOTHESIS

Given that the matter and antimatter Universes are moving in opposite directions in time, we can hypothesize that the electric charge of a particle is related to the orientation of the particle's velocity vector in time. The sign of the charges of matter particles would indicate that the temporal velocities of these particles are oriented parallel to the time radius of the matter Universe. The antimatter particles have opposite sign and so their vectors are oriented anti-parallel to the time radius of the

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matter Universe (or parallel to the time radius of the antimatter Universe). This could be perhaps understood as differences in the directions of group and phase velocities of the wave function in time:

1. *Matter particles in matter Universe*: Group and phase velocities pointed in the same direction toward positive time.
2. *Antiparticles in matter Universe*: Group velocity pointed in positive time direction, phase velocity pointed in negative time direction.
3. *Antimatter particles in antimatter Universe*: Group and phase velocities pointed in the same direction toward negative time.
4. *Matter particles in antimatter Universe*: Group velocity pointed in negative time direction, phase velocity pointed in positive time direction.

Consider the turnaround point at the singularity as the Universe transitions from expansion to collapse. On the way into the singularity, the phase and group velocity vectors of matter particles are pointing toward the singularity. At the singularity, the velocity vectors disappear because of the turnaround and all matter becomes instantaneously chargeless. Photons also converge at every point in space at the singularity as discussed in the previous section. Once the collapse starts, the photons reemerge from every point in space and the matter group and phase velocity vectors are pointed away from the singularity, flipping the charges of all charged particles. Therefore, relative to the expanding Universe, the collapsing Universe is an antimatter Universe moving backwards in time (and this is mirrored in the other antimatter Universe).

We can extend this hypothesis further by considering the spin of Fermions. Fermions can be measured to be spin up or spin down. We could interpret the spin to be a physical spin about the time radius with, for instance, spin up indicating the spin vector is parallel to the time radius of the matter Universe, and spin down indicating the spin vector is anti-parallel to the time radius of the matter Universe. Treating Quantum spin as a rotation about the time axis could be seen as a necessary consequence of relativity: if space and time are equivalent, then the possibility of rotations about an axis in space implies that it is also possible to rotate about an axis of time.

More generally, we can posit that the imaginary parts of the quantum wave functions are vibrations of the wave function along the radial time dimension.

XII. RELATIONSHIP TO THE EXTERNAL SCHWARZSCHILD SOLUTION

Figure 9 shows the full Schwarzschild metric with corresponding worldlines in both the external and internal solutions for the matter and antimatter Universes.

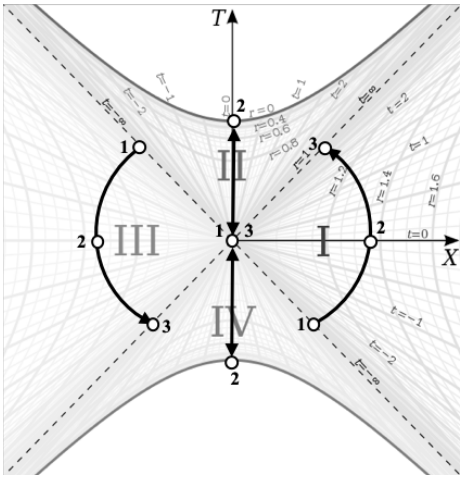

FIG. 9. Universe Pair Production and Annihilation at the Event Horizon

- At points 1, the event horizon/Annihilation, matter and antimatter pairs are produced as their respective Universes begin moving through opposite directions in time.
- At points 2, the Universes reach 'maximum height', where they turn around and begin collapsing toward each other.
- At points 3, the Universes meet again at the event horizon and annihilate each other, restarting the process at point 1.

The back-and-forth lines on the T axis are actually the rotations from Figure 7 (extended to the bottom half of the plane) as seen by looking straight down the imaginary axis.

For matter that is currently falling to become black holes, we know that it takes a finite proper time in the falling matter's frame to reach the horizon. But looking at Figure 9, we see that in the expansion phase it would be impossible to reach the event horizon since $t < 0$ in that phase and no worldline can reach the horizon at $t < 0$ without moving faster than light. Therefore, we conclude that the black hole will never form because the matter will not reach the event horizon radius until the entire Universe has re-collapsed to the Annihilation event, at which point all matter in both Universes will meet at the event horizon and annihilate.

So in a sense, the whole Universe will 'fall into a black hole', where once the matter in it reaches the Annihilation event after the Universe collapses (which corresponds to the event horizon), it re-emerges into a new expanding spacetime that is the next cycle of the expanding Universe (i.e. its geodesic enters the black hole region of the spacetime in Figure 9). All gravitational event horizons are surfaces of future time that all matter will fall to at the end of re-collapse as it is destroyed and remade in an effectively new, expanding Universe.

[1] Figures 1, 6, and 9 are modifications of: 'Kruskal diagram of Schwarzschild chart' by Dr Greg. Licensed under CC BY-SA 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Kruskal_diagram_of_Schwarzschild_chart.svg#/media/File:Kruskal_diagram_of_Schwarzschild_chart.svg.

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