COSMOS

Two Evolutionary Models

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1 INTRODUCTION

This essay introduces two new cosmological models for investigating the evolutionary dynamics of the Universe. The starting point is that there are three possible ways to model the evolution of the Universe. The first is based on spacetime, the second on time, and the third on space. The standard approach in cosmology is based on General Relativity and uses spacetime. However, it is also possible to analyze the expansion in terms of time or space individually. And these latter two approaches form the basis of the two cosmological models that this essay introduces. The purpose is to simplify things and make the analysis more accessible to the general public.

The approach taken in this essay also differs from standard cosmology in that it is based entirely on just high-school-level math. The approach is informed by the fact that cosmology can also be approached without studying General Relativity first. But the assumption is that everything in this essay is also compatible with General Relativity. General Relativity provides the underlying physics along with the standard cosmological ΛCDM model. The purpose is not to start a revolution in cosmology, but to provide an alternative approach to studying the way that the Universe evolves.

This approach is based on the insight provided by Marina Cortes and Andrew Liddle (Cortes & Liddle 2026: 21):

> It is perfectly possible to discuss cosmology without having already learned general relativity. In fact, the most crucial equation, the Friedmann equation, which describes the expansion of the Universe, turns out to be the same when derived from Newton's theory of gravity as it is when derived from the equations of general relativity.

In this essay, as we build the two new models of the Universe, we will not use the Friedmann equation or the standard equations of cosmology. Instead, we will use equations that are derived from the dimensions of the gravitational constant (G) and that are also related to the equations of gravitational acceleration (g) and escape velocity.

The GEM model, which is intended as a general model, is more focused on the spatial and radial expansion of the Universe. Its basic equation can be written in the following simple form for a flat Universe (other forms will be introduced later in the essay):

[E0] $$R=(2*G*M*t^2)^{(1/3)}$$

And the two basic equations of the TEM model, which is focused on the temporal expansion of the Universe, are the following equations.

The first equation gives the expansion time of the physical Universe:

[E1] $$t=\left(\frac{R^3}{(2*G*M)}\right)^{(1/2)}$$

The second equation gives the look-back time of the visible Universe:

[E2] $$\tau=\left(\frac{R^3}{(G*M)}\right)^{(1/2)}$$

These three equations are the fundamental equations behind the two cosmological models introduced in this essay.

It is also worth pointing out that this essay does not use the scale factor a(t) used by professional cosmologists. Instead, the equations use the standard SI unit values of meters (length), seconds (time), and kilograms (mass). This will make the model easier to understand and also more accessible to the general public. Everyone who can understand high-school-level math and do a little algebra is able to understand the two models.

The two models are thus not based directly on General Relativity or the Friedmann equation, but if given the values for mass and expansion distance that are in line with the standard model of cosmology accepted today, equation E1 will give us the value for the expansion time (t) that is in the right ballpark. Similarly, equation E0 gives us estimates of the expansion distance R in meters for today's Universe that are in the right ballpark.

So it seems that the two models give us reasonable estimates for the values of the parameters, so that they are useful. They are not intended as substitutes for General Relativity, the Friedmann Equation, or the standard model of cosmology, but as useful complements, with which to think about the evolving Universe in terms of time and radial distance.

The TEM model introduced in this essay differs from the standard approach by studying the temporal expansion of the Universe. The evolution is described by the expansion time (t) and the expansion distance expressed as time, which also takes the value of the expansion time (t). The model also introduces a second time variable, which is the "look-back time" (τ), and that is indicated by the Greek letter tau. Equations E1 and E2 will give the values of these variables.

The difference between these time concepts will be explained later in the essay. Right now, it is important to point out that both Edward Milne and Paul Dirac contemplated a dual theory of time (See Davies 1995: 140-145). These models are not important per se, but the important point is that it is possible to think of the model of the Universe as having two different time scales. In the model introduced in this essay, there is the expansion time (t) related to the physical expansion of the Universe, and the look-back time (τ) related to the expansion of the observable Universe. These two different time scales allow us to study the evolution of the Universe just in terms of time. Both times refer to the same mass (M) and physical radius (R) of the Universe.

The essay includes several sections. The second section introduces the major assumptions behind the essay, and especially the TEM model. The third section includes a discussion of the concept of time. After these introductory sections, there is section 4, which introduces the TEM model that models the evolution of the Universe in terms of time. The basic equations related to this model are introduced in section 5. The general GEM model that is focused on the radial expansion of the Universe is the topic of section 6. Section 7 provides the general conclusions of the essay.

2 BASIC ASSUMPTIONS

In this part of the essay, we will focus on the underlying assumptions behind the two cosmological models introduced in this essay. These assumptions are especially relevant to the TEM model, which deals with the temporal Universe. We will also use some ideas introduced by Roberto Mangabeira Unger & Lee Smolin in their book *The Singular Universe and the Reality of Time* (Unger & Smolin 2015). We will especially take note of their assumptions about the single Universe, the relevancy of time, and the fact that cosmological models should be based on observable and testable assumptions as far as possible.

Our starting point is the idea that our basic assumptions behind our models should be as simple as possible. These simple assumptions should fit observational data as much as possible. Only after building these simple baseline assumptions should more elaborate models be introduced. The baseline assumptions should be the starting point on which to build models that also introduce unobservable phenomena and features. This requirement that we build baseline assumptions and models first will delimit our models and theories, but they will lead us toward science that is based on observation and which is refutable.

So we will build a model of the Universe that is as simple as possible. Our real Universe might not be as simple as this, but this is the starting point of the discussion. This simple baseline set of assumptions is especially relevant to the TEM model introduced in this essay.

And the simple baseline assumptions of our model are:

1) There is a single Universe. This Universe started to expand in the Big Bang and has been expanding ever since then.

2) The Universe can be looked at from two points of view. First, there is the physical Universe that is not fully observable, and secondly, there is the

observable Universe that is fully observable, but that gives us a view of the past of the Universe.

3) The Universe is homogeneous and isotropic, so that the large-scale Universe has a smooth mass distribution on average.

4) The topology of this Universe is spherical. We are at the center of our *temporal* Universe.

5) The geometry inside this spherical temporal Universe is flat.

6) There is also temporal homogeneity because of the homogeneity of mass distribution. This means that it is possible to think of a Universal or Cosmic time, so that all clocks tick at the same rate when considering simultaneous reality.

7) The known laws of physics are invariant with respect to time.

Let's look at these assumptions in greater detail. The first assumption is that there exists a single Universe. This Universe is all there is, and we should build our baseline models with this assumption in mind.

Secondly, and this applies especially to the temporal TEM model, the observable Universe stretches back in time towards the Big Bang. But there is also the physical Universe that is not observable, but which exists simultaneously in cosmic time.

Standard cosmological models are confusing in this respect. On the one hand, they tell us that when we look at the Universe with our telescopes, what we see is the past of the Universe. So we are looking back in time towards the Big Bang. On the other hand, we are told that the visible Universe includes basically the Hubble sphere, and that the rest of the Universe is unobservable. But how can both of these views be held at the same time?

The TEM model, which is based on the view that the basic dimensions of the Universe are temporal, solves this problem. This will become apparent as we look at the TEM model in more detail.

Assumptions 3) and 6) tell us that the Universe is homogeneous and isotropic with respect to the global mass distribution and time. Since the mass of the Universe is evenly distributed on average, this means that clocks will also tick at the same rate on average given the time of expansion. So it becomes possible to calculate the average expansion time or the age of the cosmos.

We will also assume that this Universe is spherical. But notice that we are talking about the temporal Universe. We are not making assumptions about the topology of the physical Universe in meters, but about the temporal Universe in seconds. We are at the center of our temporal Universe. Whenever we look into space with our telescopes, we are looking back in time from our point of view.

Observations about the visible Universe show that the large-scale geometry of the Universe is flat. There is no curvature. We will keep this assumption.

We also assume that the known laws of physics do not change in time but are invariant. Unger & Smolin (2015) argue that the laws are mutable, but our simplest possible baseline model of the Universe holds that the laws do not change in time. That is, when we look back at the Universe in time, we should be able to explain the workings of the Universe with the same laws that we use to explain it today.

So, these are the assumptions with which we will build our simplest possible baseline model of the Universe. This essay introduces actually two simple models of the Universe, the TEM and GEM models, but the above assumptions are especially relevant for the TEM model.

3 TIME

There is no single agreed-upon definition or theory of time. But in this part of the essay, we will consider those aspects of time that are relevant to the argument of the essay. First, it can be noted that time has a speed, magnitude, and order. And time refers to change, which is relative, and which can be unified with space into spacetime.

It was Aristotle who defined time as referring to change. We will also define time as a measure of change. But it is a very special type of change. If you look at equations E1 and E2, you will notice that they involve a constant G and three variables: R, t or τ, and M. We can be interested in knowing how each of these components changes. But R and M refer to real physical variables, while time measures the rate of change at which these variables are changing.

Time itself is not a physical process, but the measure of the speed, magnitude, and order of physical change. But this change is relative, meaning that time does not change at a constant rate everywhere. As Einstein showed, time dilates, or slows down, when moving at high velocities or near concentrations of mass.

Einstein's special theory of relativity was published in 1905, and in 1908, Hermann Minkowski unified space and time into the concept of spacetime. And based on the concept of spacetime, Einstein finally published his general theory of relativity in 1915, which deals with gravity and the curvature of spacetime.

Einstein’s theories of relativity changed the way we think about time. Time does not have a fixed speed everywhere in the Universe. The ticking of clocks depends on how you move and in what kind of gravitational field you are in. This means that different observers have different measures of the magnitudes or the durations of time intervals. Also, different observers do not necessarily agree on the order in which events take place.

Then there is the difference between physical and mental time. Kenneth Denbigh (Denbigh 1981: 51-52) discusses how, in the case of physical time, it is good to talk about time with words like earlier than, simultaneous with, and later than. And in the case of mental mind-dependent time, one may talk about the past, present, and future.

Philosophers and physicists talk about eternalism and presentism when talking about time (Buonomano 2018: 11-14). Presentism is the view that only the present is real, while eternalism holds that the past, present, and future are equally real. Many think that the physical Universe is a "block universe" defined by eternalism, while mental time is better described with presentism.

But our model of the temporal expansion dynamics of the Universe leads us to the view that it is presentism that best describes the Universe as a whole. And it can be argued that the past, present, and future all come together in the minds of different observers. The past and future times are not present or real anymore, but with memory and imagination, these different temporal moments can be brought into the conscious awareness of different persons.

In this essay, however, we are more interested in the way in which the Universe changes as a whole, so the point of view is physical, not mental. And we are also interested in knowing how the Universe evolves in time.

John Wheeler used to think of space and time, or spacetime, in terms of meters alone. In his book "*A Journey into Gravity and Spacetime*" (Wheeler 1990), Wheeler discusses how time and even mass can both be described in terms of space, or meters. And in this essay, we will do the opposite: we will discuss the physical Universe in terms of two time components: the expansion time in seconds, and the expansion distance in terms of seconds.

This allows us to use the standard Pythagorean theorem when discussing the temporal intervals between any two events. The spacetime interval, as defined by Minkowski, takes the square of the distance in meters and subtracts the square of time in seconds multiplied by the square of the speed of light from that, in order to calculate the proper spacetime interval. But since we are dealing with only one kind of dimension, that is time, we can use the Pythagorean theorem to define the magnitudes of temporal distances.

A temporal distance for the look-back time (equation E2) is defined as:

[E3] $$\tau^2 = t_t^2 + t_d^2$$

The total temporal distance of the look-back time τ is related to the sum of the square of the expansion time t_t and the expansion distance expressed in terms of time t_d. And as will be seen later in the essay, these two components of the temporal distance have the same values.

So, we will not be discussing or using the Minkowskian 4-dimensional spacetime in this essay. The argument is not that the concept of spacetime is not valid or useful, but that our point of view is different because we are dealing with temporal change (the TEM model).

We will also not be discussing the relativistic theories of Einstein in this essay. We, of course, are interested in the stretching of space and time, but we are not dealing with the curvature of space or spacetime, but in the general evolution of the Universe in temporal terms. The argument is not that the relativistic theories are not valid, but that our point of view is different because we are dealing with the temporal change of the whole Universe (the TEM model).

Both space and time do stretch and dilate as relativity describes, and the physical space of the Universe is expanding. We are not living in a static Universe. But we will be analyzing this expansion primarily in terms of time alone with the TEM model.

So to sum things up: time refers to the processes of physical change, and it can be measured in terms of speed, magnitude (temporal intervals), and order of events. Time is mathematically the fourth dimension of spacetime along with three spatial dimensions, but it can also be treated as a simple measure of change.

And in this essay, we will do just that. Notice that the look-back time τ can be calculated in two ways. Either one can use equation E2 or E3. The resulting look-back time is the same. This is an important result, and it will be explained in more detail later in the essay. At the moment, it is important just to notice that equations E1 and E2 are related via equation E3. Equation E1 gives us the expansion time t of the Universe. It is also the expansion distance as expressed in seconds. And the look-back time can be calculated either with equation E2 or equation E3.

Time t is thus related to the size of the physical Universe, while time τ is related to the look-back distance or view that a particular observer at a particular location in time t has. The look-back time is thus related to the visible Universe that any observer can observe with telescopes from a particular location at a particular time.

But the whole physical Universe is not observable by different observers. We cannot observe the nearest star as it is "now," but as it was a few light-years ago. Our present time t, or point of view, is thus a collection of past times at different temporal distances away from us. Only the location where we are is presently real for us. The distant galaxies we see in telescopes were like that millions or billions of years ago.

So there is a need for two different time scales. The expansion time t is related to the largely unobservable physical Universe, while the look-back time τ is related to the expanding Universe that is currently observable to us.

4 THE TEMPORAL EVOLUTIONARY MODEL (TEM)

Brian Greene used the “loaf of bread” analogy for the Universe in his book *The Fabric of the Cosmos* (Greene 2005: 51-61, 127-142, 243-250). He showed how the Universe can be thought of as a loaf of spacetime that can be sliced differently by different observers. Our TEM model (Temporal Evolutionary Model) of the time-space of the Universe is similar, although it differs in fundamental ways from Greene’s approach. Greene seems to come to the eternalist conclusion that the past, present, and future are all equally real and do exist simultaneously in the absolute spacetime.

Space and time can be modeled in different ways. They can be thought of as existing separately, even if one thinks that they are relative. And they can be thought of as combining in a single absolute spacetime in the Minkowskian way. But there is a third possibility: one may think of the Universe as consisting of a “time-space” which is a “space” consisting of time. This time-space is the basis of the TEM model of the Universe introduced in this essay, and we will look at its 2-dimensional form, where there are two temporal dimensions. The first dimension is the expansion time or the “age” of the Universe. The second dimension is the expansion distance or the “stretched” distance and radius of the Universe expressed as time.

These two dimensions turn out to be of equal magnitude. The expansion distance can be measured in meters, but these meters can be turned into seconds, and the distance can be thought of just in temporal terms. This follows from the fact that distances have a dual nature. A distance can be thought of as consisting of two parameters:

[E4] $$Distance = \frac{m}{s} \, which \, is \, \frac{meters}{seconds} \vee \frac{length}{duration}$$

The trick is not to do the calculation, but to read, for instance, that the radius of the Universe equals 46.4 billion light years over 13.9 billion years. This gives us two crucial pieces of information: the length of the radius in meters (light years) and seconds (years). And we can use both values or just one of them to indicate the radial distance of the Universe.

The above definition of distance differs from the standard approach. Usually, the above formula refers to velocity, and the calculation gives us the magnitude of the velocity in meters per second. But the idea above is that the distance may be read as "distance in meters over distance in seconds". This way, all the information about the components of the distance is preserved.

And now is the time to introduce the graphical form of the time-space model used in this essay. We will do a mathematical analysis in the next major section of the essay, but here is Figure 1.

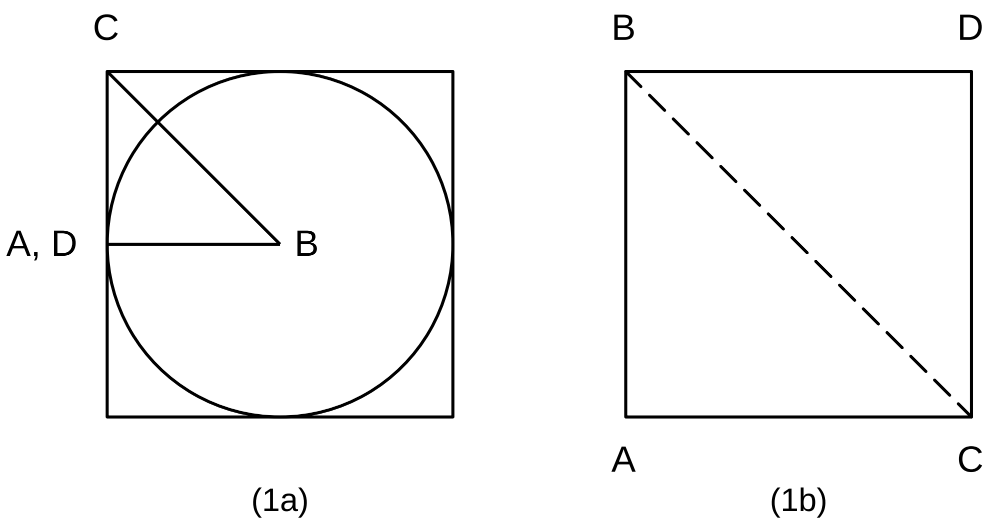

Figure 1. The basic TEM model of the Universe.

Let's begin with Figure 1b. It depicts the time-space of just one observer at a particular time. That observer is located at point B now (today). Line BD is the physical radius of the Universe in terms of time today. Point A is the origin of time or the point in time-space where the Big Bang originally happened from the observer's point of view. Point C is the stretched and expanded view of the Big Bang that the observer sees today. This means that the line BC is the look-back point of view for the observer.

It is to be noted that equations E2 and E3 describe the look-back time or the line BC (the diagonal of the square), while equation E1 describes the expansion time and expansion distance in terms of time (the sides of the square). This expansion time (t) can also be calculated in the following way if the look-back time τ is known:

[E5] $$t = \frac{\tau}{\sqrt{2}}$$

So the observer today is located at point B in Figure 1b. The observer may only see the part of the Universe depicted by the line BC. The observer cannot see his/her own past or the line BA. Also, the observer cannot see the present configuration of the Universe depicted by line BD.

This leads us to conclude that there are 3 presents or "nows" for the observer today at point B. First, there is the direct physical location at point B. It is in this location that the observer is located in the time-space, and here the observer can interact with his/her physical environment. Second, there is the present physical configuration of the Universe depicted by the line BD, but which is unobservable for the observer at point B. And thirdly, there is the look-back point of view associated with the look-back time and the line BC. This is the observable Universe for the observer “now”. It is all that the observer can see, and this is what the telescopes show us when we look into the sky.

Figure 1a is another depiction of the time-space of the observer located in time at point B. The circle represents the dimensions of the square depicted in Figure 1b. The line B(A/D) represents the expansion time and expansion distance. The line BC represents the observable Universe, or the look-back point of view. The inner circle in Figure 1a thus represents the physical Universe and the square in Figure 1b. And the half diagonal of the outer square in Figure 1a represents the line BC or the look-back time in Figure 1b.

The above analysis can be extended with the help of Figure 2.

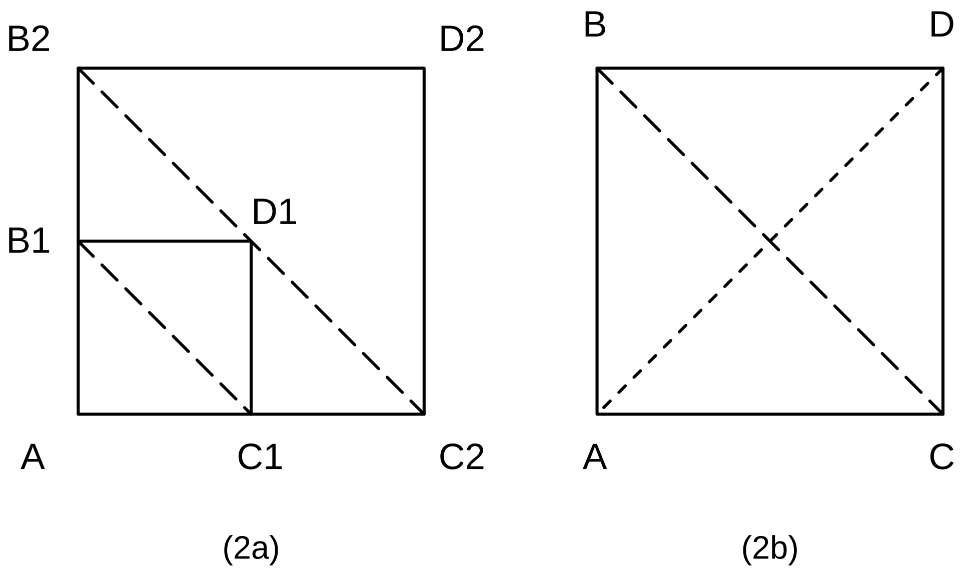

Figure 2. Evolution of the time-space (2a) and a model of two observers (2b)

Figure 2a illustrates how the Universe evolves temporally according to the TEM model. Point A in the lower left corner of the square represents the Big Bang. In the beginning, everything was concentrated at this point. The points B, C, and D did not exist. The small square in the lower left corner of the square represents the Universe when it was half the current age. The age of the Universe is represented by the AB1 line, the expansion distance in seconds by the B1D1 line, and the look-back time by the B1C1 line. The larger square represents the Universe today.

The lines AC1 and AC2 represent the Big Bang. The observer at points B1 and B2 cannot observe point A or the Big Bang as such. But the Universe has been expanding, and C1 and C2 represent this expansion. The observer can thus see the Big Bang at a distance AC2 with the look-back point of view represented by line B2C2.

We can also look at how the situation changes when we have two observers at points B and D. This is depicted in Figure 2b. Let's call these observers John and Jane. John is located at point B, and his look-back point of view is the line BC. Jane is located at point D, and her look-back point of view is the line DA.

John and Jane are separated by the expansion distance of BD of the current Universe, and cannot directly observe each other. For John, the Big Bang occurred at point A, and he sees the Big Bang at point C because of the expansion of the Universe. John has been stationary during the expansion time given by the line AB, but the Universe has stretched the amount given by the line AC during this time because of the expansion of the Universe.

For Jane, the situation looks completely different. Her temporal center of the Universe is currently at point D. For her, the Big Bang occurred at point C, and the Universe has been expanding from there since then. Her look-back point of view is the line DA. She sees the Big Bang at this temporal distance. The current Universe for Jane is the line DB, but Jane cannot observe John at point B directly. Since John is located on the other side of the temporal Universe from Jane's point of view, Jane can only observe John's historical position at point A, or the Big Bang.

For John, the past is given by the triangle ABC, and the future is given by the triangle BDC. And for Jane, the past is given by the triangle ADC, and the future is given by the triangle DBA. John and Jane look at the Universe from different points of view and can see its history at different times at different temporal distances.

But they can agree on some common values. Both John and Jane can agree on the average expansion time and distance of the Universe, and they can agree on the look-back time of the Universe. They can agree on most of the major physical parameters that define the Universe, but they are just looking at the Universe from different temporal points of view.

The situation can be further illustrated by Figure 3.

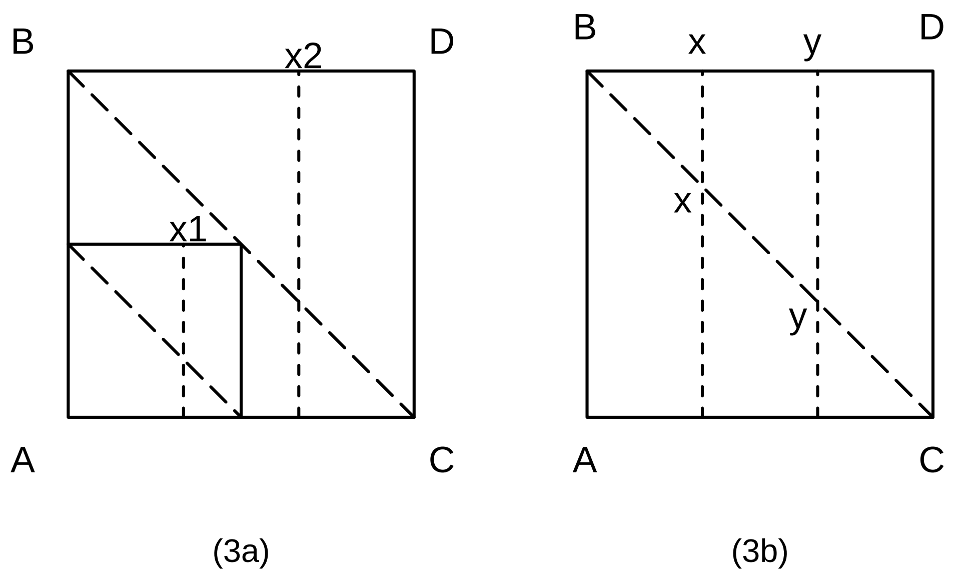

Figure 3. The expanding Universe from the point of view of B. With additional observers.

The situation in Figure 3a is basically the same as in Figure 2a, but now we have another observer x. Let’s call him Frank. Frank’s position when the Universe was half its current age was at point x1. Frank is currently situated at point x2. John at point B cannot directly observe Frank. John is only able to see into the past of Frank at the point where the lines BC and x2 cross. This was billions of years ago.

Figure 3b introduces yet another observer, Betty, at point y (Frank is at point x). The line B, x, y, D represents the Universe today, or the current configuration of the temporal Universe, or time-space. All four observers are separated temporally by large distances and cannot see each other “now”. However, John at point B can see into the past of Frank, Betty, and Jane. This is the line BC, or the look-back time and point of view for John. Jane at point D would see John, Frank, and Betty at different temporal distances from her point of view.

What this analysis points us toward is not the eternalist conception of time, but the presentist conception of time. What currently exists in the Universe is the configuration space given by the line BD. This is not observable to the individual observers, but that is what can be said to exist simultaneously at a given point in time.

Everything below line BD belongs to the past, and everything above this line is in the future and has not happened yet. The line for the look-back time, or BC, does provide John at the temporal point B a way to see into the past of the Universe at different temporal intervals, but these observable distances and things do not exist anymore. They exist at BD.

The situation can be illustrated if we think in terms of ontology and epistemology. Ontology tells us what exists physically, and epistemology tells us what is knowable or observable. Only the line BD exists physically at a given moment in the history of the Universe. The look-back line BC only provides the observer at point B with information about the past configurations of the physical Universe.

So this analysis implies that the eternalist "block universe," where the past, present, and future are all equally real, does not exist. Instead, we must think in terms of the presentist point of view, which indicates that only the present is physically real. This is given by the line BD. However, the past, the present, and the future can be thought of as existing simultaneously as information about the Universe. Different observers will observe the Universe from different points of view, as illustrated by Figure 2b. The information about the past, the present, and the future of the Universe does exist as a block that is observable from different points of view, depending on the location of the observer in the temporal time-space.

So we must be careful to differentiate between the ontological and the epistemological points of view of the Universe. They tell us different things about the Universe. Ontology tells us what exists physically, and epistemology tells us what exists as observable information given the present state of the Universe, and the temporal location of the observer relative to the other observers.

And the main conclusion is that only the present simultaneous configuration of the time-space exists physically at a given expansion time of the Universe. But this is not observable by the individual observers. However, the past, the present, and the future can be said to exist simultaneously as information about the Universe. This “block of information" is observable by the different observers at different points in time. They will not agree on the information they see, but all the information is there.

And there is one more thing to notice about the three figures explained in this section. The point C, or the look-back point of view for the observer at point B, is not fully observable. The Universe became transparent only when it was a few hundred thousand years old. This means that observers at point B cannot see all the way to point C. But the difference is small, so that they will be able to see most of the distance back in time. This time is when the first galaxies formed. This is good to keep in mind, but it does not change the interpretation of the three figures.

Finally, to help the reader interpret the figures introduced in this section, it is worth pointing out that they are 2-dimensional and not 3-dimensional. The vertical dimension in the figures represents time, and the horizontal dimension in the figures represents physical distance expressed in terms of time. This means that while the observer located at point B in the figures is at the center of his/her temporal Universe, lines BD and BC only represent temporal radial distances from point B toward just one direction away from point B. These figures are thus simplifying devices with which to analyze the Universe. They do not represent the whole 3-dimensional spherical space out there, but only the 2-dimensional temporal time-space.

5 TEM EQUATIONS

In this part of the essay we are going to take a look at the equations behind the approach developed in the essay. So let’s begin.

We will first take a look at the gravitational constant G:

- $G = 6.674\,30 * 10^{-11} m^3 kg^{-1} s^{-2}$

The dimensions of the gravitational constant provide the basis for the basic equation which includes the look-back time τ.

[E5] $$G = \frac{m^3}{(kg * s^2)} \Rightarrow \frac{R^3}{(M * \tau^2)}$$

It can be seen that the gravitational constant G can be calculated from the variables of the Universe:

- R = Radius of the Universe (m)
- M = Mass of the Universe (kg)
- τ = Look-back time of the Universe (s)

From the above equation for G we can solve the equation for the look-back time τ. This is equation E2 introduced earlier:

[E2] $$\tau = \left(\frac{R^3}{(G * M)}\right)^{(1/2)}$$

This can be rearranged to give the average expansion acceleration of the look-back distance:

[E6] $$\frac{R}{\tau^2} = \left(\frac{(G * M)}{R^2}\right)$$ which is the equation for g.

This can be further rearragned to give the average expansion velocity of the look-back distance:

[E7] $$\frac{R}{\tau}=\left(\frac{(G*M*\tau)}{R^2}\right)$$

One should also note that equation E6 is of the same form as the equation for the gravitational acceleration g. This means that equations E2, E5 and E6 are all closely related to each other and to the equation for gravitational acceleration g.

The above equations are related to the look-back line BC in Figure 1b. Now we will consider the equations for the physical Universe represented by lines AB and BD.

The equation for the expansion time (t) of the Universe is the same as equation E1 introduced earlier:

[E1] $$t=\left(\frac{R^3}{(2*G*M)}\right)^{(1/2)}$$

The associated equations are as follows. First, the equation for the physical radius of the Universe:

[E8] $$R^3=2*G*M*t^2$$

Then the equation for the mass of the Universe:

[E9] $$M=\frac{R^3}{2*G*t^2}$$

The equation for the expansion velocity of the physical radius is:

[E10] $$\frac{R}{t}=\frac{2*G*M*t}{R^2}$$

The equation for the escape velocity is:

[E11] $$v_{esc}=\left(\frac{2*G*M}{R}\right)^{(1/2)}$$

Equation E11 is standard physics, and both equations E10 and E 11 give the same result so that the average expansion velocity of the Universe equals the escape velocity of the Universe.

Finally, we can also calculate the total energy (E) of the Universe. If we plug Einstein's famous formula for energy (E = m*c^2) to the mass equation E9 of the Universe, and solve for energy, we get:

[E12] $$E=\frac{R^3*c^2}{2*G*t^2}$$

So there is the complete list of all the relevant equations. The following provides the reader with the values used for the Universe today:

- Ho = 70 km/s/Mpc (Provides the basis for the age (t) of the Universe.)
- 1 ly (light year) = 9.461*10^15 m
- 1 year = 3.1557*10^7 s
- G = 6.67430*10^-11 m^3 kg^-1 s^-2
- c (speed of light) = 2.99 792 458*10^8 m s^-1
- t (expansion time) = 4.4*10^17 s (13.9 billion years)
- τ (look-back time) = 6.2226*10^17 s (19.7 billion years)
- R (radius) = 4.3928*10^26 m (46.4 billion light years)
- M (mass) = 3.28*10^54 kg
- R/t (Average expansion velocity) = 9.98*10^8 m s^-1
- E (Energy of the Universe) = 2.952*10^71 J (kg m^2 s^-2)

With these values everyone can experiment with the equations given above. The values represent the Universe today.

Finally, the value of the gravitational constant G can also be calculated from the expansion time (t) of the Universe as follows:

[E13] $$G=\frac{R^3}{2*M*t^2}$$

6 THE GENERAL EVOLUTIONARY MODEL (GEM)

This section of the essay takes yet another look at the Universe. We will abandon the time-space model of the Universe and focus instead on the radial expansion of the physical Universe in meters. The relevant equation for this is equation E8, which can be rewritten as:

[E14] $$R(D,M,t)=(D(t)*G*M(t)*t^2)^{(1/3)}$$

The above GEM (General Evolutionary Model) model of the Universe seeks to provide a simple and coherent mathematical model for analyzing the evolutionary dynamics of the expanding Universe. It uses the standard meters, seconds, and kilograms as units of space, time, and mass to describe this evolution. The model has four parameters that define the evolution of the physical radius or expansion distance R in time. The first parameter is time t, the second parameter is mass M(t), G is the Newtonian Gravitational constant, and D(t) is the parameter that describes the evolution of the mass density in the Universe. For a flat geometry of the Universe, the value of D is a constant 2.

The general idea is that D(t) and M(t) evolve in time, and that they are functions inside a function. These inner functions can be just about anything that can be used to model the evolution of mass and mass density of the Universe. That is, the GEM is not just one model of the Universe, but a general model that can be used to analyze and describe multiple evolutionary paths.

Equation E14 relates the radius R or the expansion distance to the parameters D(t), G, M(t), and t^2. G is the Gravitational constant, t is the expansion time, M(t) is the total mass-energy that influences the expansion, and D(t) is the density parameter that takes into account the density of the mass of the Universe. G and t pretty much do not need a closer explanation, but the other two parameters need an explanation.

M(t) or the total mass-energy driving the expansion of the Universe can be written as follows:

[E15] $$M_{tot}=M_R+M_M+M_\Lambda+M_K$$

Here, M_R is the mass caused by the radiation of the Universe, M_M is the mass caused by matter (visible and dark matter), M_Λ is the mass caused by dark energy, and M_K is the mass caused by the curvature of the Universe.

We can see that the total mass M_{tot} is composed of variable components. This enables one to study how the components of the total mass-energy driving the evolution of the expansion distance vary in time. The radiation, matter, and dark energy-dominated eras differ from each other, and this has to be taken into account.

The general idea is that the cosmologist doing research would insert his/her own function that describes the evolution of the mass of the universe in kilograms to this place in the master equation. The master equation does not itself tell us how the total mass-energy evolves in time. This evolution must be described by using another model, such as the standard ΛCDM model.

The situation is similar with regard to the density parameter D(t). The components of the density parameter evolve in time. But the standard value for a flat Universe that grows at the critical mass density is 2 for the density parameter D(t).

The total mass density of the Universe is given by the following equation:

[E16] $$\Omega_{tot}=\Omega_R+\Omega_M+\Omega_\Lambda+\Omega_K$$

This parameter is known to all cosmologists, and it describes these values in relation to the critical mass density ρ_{crit}. The value of this critical density is 1. The components refer to the radiation, matter, dark energy, and curvature densities as a fraction of the critical mass density.

So one can see that the value of Ω_{tot} is equal to 1 in a flat Universe. But the density parameter D(t) takes the value of 2 in a flat Universe. This means that the cosmologist doing research must have a formula for translating the value of Ω_{tot} into D(t).

The other thing to notice is that as Ω_{tot} is a variable, and can take other values from 1, then the whole value of D(t) is variable. If the total mass-energy density is less than the critical density, then Ω_{tot} will be <1 and D(t) will be >2. If the total mass-energy density is greater than the critical density, then Ω_{tot} will be >1 and D(t) will be <2.

This follows from the fact that if the total mass-energy density gets smaller than the critical density, this will cause gravity to get smaller also, which speeds up the expansion of the expansion distance R. If the total mass-energy density gets bigger than the critical density, this will cause gravity to get stronger, which slows down the expansion of the expansion distance R.

The fact is that current observations support the idea that we live in a flat Universe, so that parameter D(t) takes the constant value of 2 in equation E14. But in principle, the GEM model supports the idea of variable geometry of the Universe, so that it may have a positive or negative curvature along with the flat curvature observed.

The above discussion also illustrates the versatility of the GEM model. It is possible to plug in different models and functions inside both D(t) and M(t) inside the R(D,M,t) master function (equation E14), and so it is possible to study different models and evolutionary expansion paths of the Universe under a single model.

The GEM model is not intended as a substitute for the established models in cosmology, but as a complement to these. It is based on the interplay of the dynamics between space, time, and mass, and uses standard SI units of distance (meters), time (seconds), and mass (kilograms). It is intended as a simple tool for the cosmologist, but it could also be used as a pedagogical tool to teach students about the expansion of the Universe.

7 CONCLUSIONS

This essay introduced two simple cosmological models that are readily accessible to the general public and which can be used to teach students introductory cosmology without the need for the full machinery of General Relativity.

Also, time as a concept is central to this essay, since the TEM model models the temporal expansion of the Universe. There are authors such as Julian Barbour (Barbour 2000) and Carlo Rovelli (Rovelli 2018) who would like to see time taken away from physical equations. On the other hand, there are authors like Unger & Smolin (Unger & Smolin 2015) who want to see time brought back in.

The central idea in this essay is that we need to include time in our cosmological models and mathematical equations. This was done with both the TEM and GEM models introduced in this essay.

Also, we reached the conclusion that the temporal Universe is best described by presentism and not by eternalism. Only the present physical configuration of the Universe is real. The past still exists as information, carried by light across the Universe. And some of this past is also future information for other observers.

The key takeaway of this essay is that time is not a physical process or dimension itself. It is a mathematical dimension and also the measure of the rate of change of physical processes. We cannot exist without time.

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