The Shape of the Universe

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ABSTRACT

The universe is a non-Euclidian 3-sphere where the radius is the dimension of time and the surface at any given time is composed of the three dimensions of space. We have no instruments to measure time directly and can only infer its passage based on how it effects objects in space (e.g. the hands of a clock, the vibrations of an atom). Previous metrics have assumed a linear relation between space and time. Here we show that space instead grows exponentially with time and – as a result of light fighting for progress against the geometric expansion of space – our universe is $211\ Gyr$ old, has a circumference of $93\ Gly$ and is expanding at 88% the speed of light. The most fundamental question of science is the nature of this unseen dimension of time and its relation to the measurable dimensions of space.

1. Introduction

Ptolemaic Astronomy began with a flawed view of the universe. To medieval astronomers the assumption that Earth was at the center of the universe was *a priori* knowledge: you didn't need to get up off the couch and go outside to see if it was true. These early scientists invented a complicated system of formulas, tables and charts that they adjusted over the course of 800 years until it was able to roughly predict the location of planets in the past and future. While useful for astrologers, this model told us almost nothing about the true structure of the solar system.

The Big Bang model suffers from the same deficiencies as the Ptolemaic model. When the large scale structures of the universe turned out to be too mature for a universe only a dozen billion years old, a new form of matter was invented to make gravity work faster. When distant supernovae failed to follow Hubble's Law, a new form of energy was invented and the sign on the Einstein's deceleration constant[2] was flipped around. Each new observation that contradicted a past prediction is handled not by throwing away the broken model, but by scratching out an old table entry and penciling in a new one.

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[2] The 'Cosmological Constant' as it is now called, was originally intended to offset gravity. Einstein believed this was necessary because of his belief in a static universe.

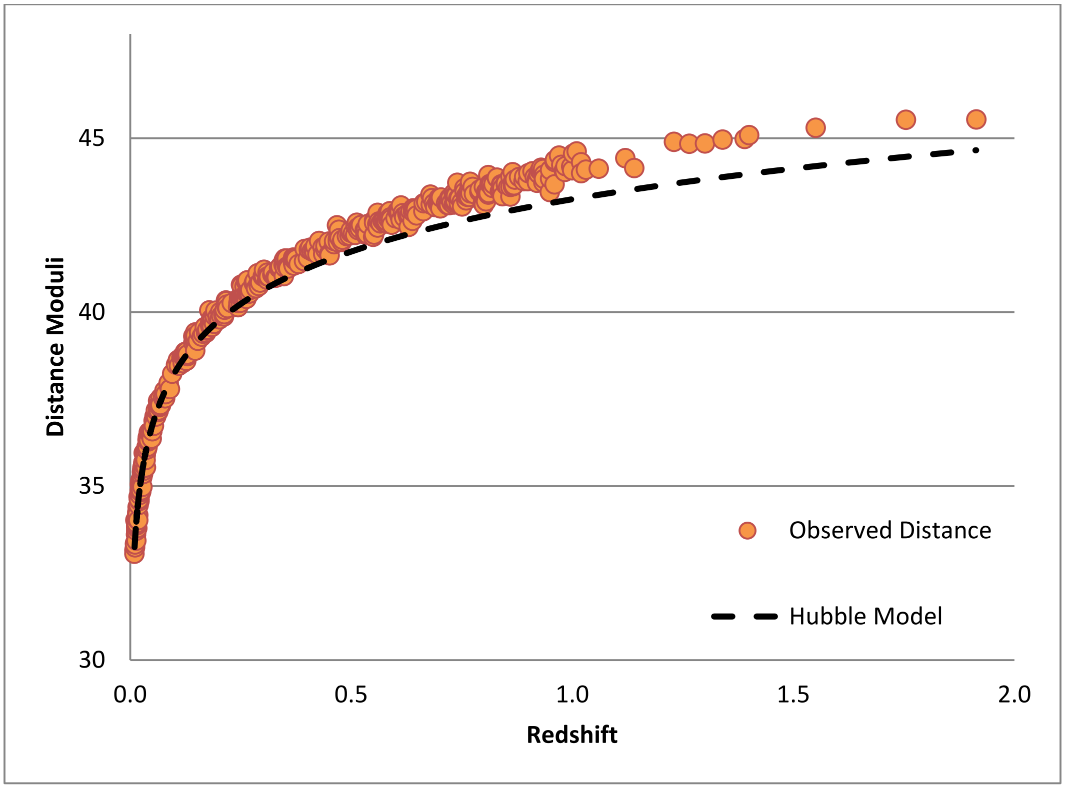

Figure 1 This figure shows the predictions of the original Hubble model with the relatively recent observations of Type Ia Supernovae (SNe Ia) which act like standard candles in the distant cosmos. The chart uses Hubble's Law and the most recent calculation of the Hubble parameter – 67.15 km/s/Mpc[3]. The observed distances come from the recent Supernova Legacy Survey(SNLS)[4].

This paper introduces a model of the universe which doesn't accumulate assumptions of exotic fields, invisible matter, and phantom energy of the previous theories. It explains the apparent acceleration of distant supernovae without violating the First Law of Thermodynamics and has only two simple assumptions: that time is absolute[5] and progresses irresistibly from one moment to the next and that space is related to time in a simple - though non-Euclidian - geometry.

[3] Ade et al. "Planck 2013 results. I. Overview of Products and Scientific Results". Astronomy & Astrophysics, March 2013.

[4] Conley et al.; "Supernova Constraints and Systematic Uncertainties from the First 3 Years of the Supernova Legacy Survey" Astrophysical Journal, April 2011.

[5] Any observer in any inertial reference system will be able to measure the expansion of the universe through the red-shift of distant supernovae and agree on the age of the universe when the coordinate systems are normalized.

2. The Laws of Nature

It would be a mistake to assume *a priori* that the universe followed a Euclidian geometry when deciding which relationship to posit between space and time. A geometry where the space is a linear function of time, $x = 2\pi t$ for example, would yield a linear expansion. Since the redshift of distant stars indicates the expansion of our universe is accelerating, we must either invent a form of energy that isn't conserved or choose a geometry that grows exponentially. Since we desire to keep the total amount of energy in a closed system constant, we'll chose the latter. To accomplish this requires the statement of some new laws that describe nature in the most fundamental way possible. The **First Law of Nature** is:

Time is absolute and progresses linearly and inexorably from one moment to the next. There is no force of nature that can alter the progress of time.

The **Second Law of Nature** describes the geometry of time and space:

The universe is a hypersphere where the radius is the dimension of time and the surface at any given time consists of the three dimensions of space. The surface is the locus of points sharing the same time from the center and the circumference of each dimension of space is equal to the square of the time.

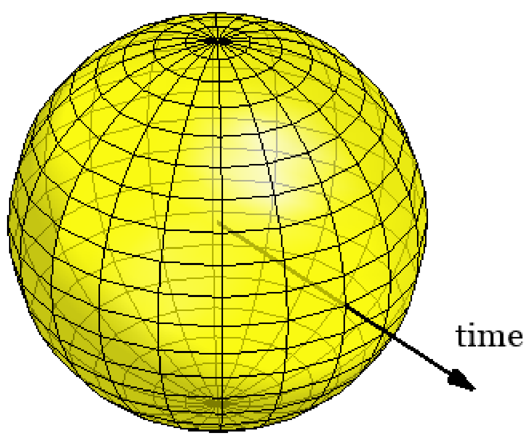

Figure 2 This figure shows a simplified projection of the universe ignoring one of the dimensions of space. The interior of this sphere is simply the previous states of the universe arranged like a Russian nesting doll.

Applying these new laws, the circumference of each of the dimensions of space grows geometrically as a function of the time:

$$y = t^2 \tag{1}$$

Where t is the time (s) and y is the circumference of the sphere (s^2). While this sphere has the mathematical property that the surface is the locus of all points equidistant from the center, it doesn't share the Euclidian ratio of circumference to diameter. The surface of the sphere - the three dimensions which we experience and can measure - grows geometrically as a function of time.

Units of square seconds (s^2) are not useful to us since all our distances are measured in units of space, so we'll need a way to relate the surface of our hypersphere to something we can measure directly.

$$x = \varphi t^2 \tag{2}$$

Where x is the circumference of the universe (km) and φ is the ratio of one kilometer to a square second $(km\ s^{-2})$[6].

3. Time and Velocity in a Non-Euclidian Hypersphere

A model is only useful when it explains observations and makes predictions that can be tested. For our universe the data that is most useful in describing the large scale structure comes from Type Ia Supernovae which act as standard candles. The redshift of these objects is relatively easy to obtain and tells us how the universe has expanded since the light was emitted. The luminosity is less easy to measure accurately for extremely distance objects but provides us with a proxy for a yard-stick distance. Some formulas are needed to validate this model by calculating the expected observed distance, d_L, from the redshift, z.

As a photon travels through an exponentially expanding universe, the destination moves away at an ever increasing rate. The two components of the vector that determine the distance that a beam of light will travel are the velocity of that photon in a vacuum and the tangential velocity of the universe as it expands. Integrating over the time that the light travels will give us an expression for the distance travelled. The tangential velocity of the universe at any given moment is:

$$v_t = \frac{d}{dt}\,\varphi t^2 = 2\varphi t$$

The value 2φ is the constant tangential acceleration of the universe which we'll represent with the symbol ω. Substituting this symbol, $\omega = 2\varphi$ yields:

$$v_t = \omega t$$

[6] The choice of units for the dimensions is arbitrary.

Therefore, the distance travelled by a photon in this universe, where the light is travelling towards the destination and the universe is effectively travelling away, is described by the following integration:

$$\Delta x = \int_{t0}^{t1} (c - v_t)\, dt$$
$$\Delta x = \int_{t0}^{t1} (c - \omega t)\, dt$$
$$\Delta x = \int_{t0}^{t1} c\, dt - \int_{t0}^{t1} \omega t\ dt$$
$$\Delta x = ct_1 - ct_0 - \frac{\omega}{2}{t_1}^2 + \frac{\omega}{2}{t_0}^2$$
$$\Delta t = t_1 - t_0$$
$$\Delta x = c\Delta t - \frac{\omega}{2}{t_1}^2 + \frac{\omega}{2}(t_1 - \Delta t)^2$$
$$\Delta x = c\Delta t - \frac{\omega}{2}{t_1}^2 + \frac{\omega}{2}({t_1}^2 - 2t_1\Delta t + \Delta t^2)$$
$$\Delta x = c\Delta t - \omega t_1 \Delta t + \frac{\omega}{2}\Delta t^2 \tag{3}$$

Where Δx is light travel distance, Δt is the light travel time, c is the velocity of light in a vacuum, t_1 is the age of the universe at the time of the observation and t_0 is the age of the universe at the time the photon was emitted.

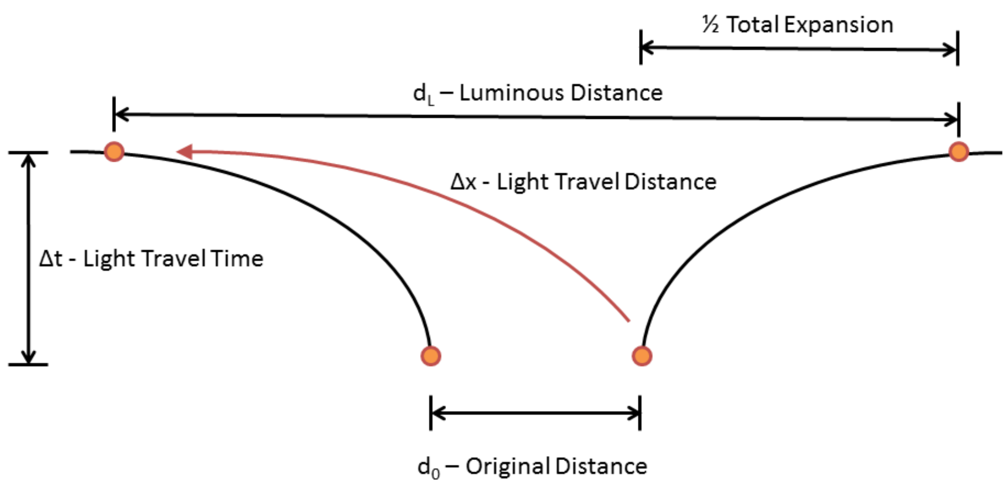

Figure 3 The total light travel distance, Δx, is the observed distance to the object, d_L, less one half of the expansion that occurred while the light was travelling.

To calculate the luminous distance in terms of the travel distance and time, we start with the relationship between the observed distance, d_L, and the distance between the objects when the light was emitted, d_0, which is:

$$\frac{d_L}{\varphi t_1^2} = \frac{d_O}{\varphi t_0^2}$$

This simply states that the proportion of space between the observer and emitter and the circumference of the universe is independent of time. That they are co-moving distances.

$$d_L = \frac{d_O \varphi t_1^2}{\varphi t_0^2}$$

$$d_L = \frac{d_O \varphi t_1^2}{\varphi (t_1 - \Delta t)^2}$$

$$d_L({t_1}^2 - 2t_1\Delta t + \Delta t^2) = d_O t_1^2$$

$$\frac{d_L {t_1}^2 - 2d_L t_1 \Delta t + d_L \Delta t^2}{t_1^2} = d_O$$

$$d_L - d_O = d_L \frac{2\Delta t}{t_1} - d_L \frac{\Delta t^2}{t_1^2} \qquad (4)$$

Equation (4) represents the amount of expansion that has occurred between the observer and the emitter while the light was travelling. We can now express the luminous distance in terms of the light travel time and the light travel distance:

$$\Delta x = d_L - \frac{1}{2}\left(d_L \frac{2\Delta t}{t_1} - d_L \frac{\Delta t^2}{t_1^2}\right)$$

$$\Delta x = d_L - d_L \frac{\Delta t}{t_1} + d_L \frac{\Delta t^2}{2t_1^2}$$

$$d_L = \frac{\Delta x}{1 - \frac{\Delta t}{t_1} + \frac{\Delta t^2}{2t_1^2}} \qquad (5)$$

Substituting equation (3) into (5) gives us the relation between the luminous distance and the light travel time:

$$d_L = \frac{c\Delta t - \omega t_1 \Delta t + \frac{\omega}{2}\Delta t^2}{1 - \frac{\Delta t}{t_1} + \frac{\Delta t^2}{2t_1^2}} \qquad (6)$$

Now we need to express the light travel time in terms of redshift in order to derive a formula relating redshift to observed distance. The redshift is a direct indication of how a single wavelength of light has expanded from the time the light was emitted to the time it was observed. We'll employ this relation to calculate the elapsed time.

$$z = \frac{\lambda_{OBSERVED} - \lambda_{EMIT}}{\lambda_{EMIT}}$$

$$z + 1 = \frac{\lambda_{OBSERVED}}{\lambda_{EMIT}}$$

On a larger scale, what happens to a single wavelength of light happens to the entire universe. The redshift tells us how the size of the entire universe has changed since the emission of the photon.

$$z = \frac{\varphi t_1^2 - \varphi t_0^2}{\varphi t_0^2}$$

$$z + 1 = \frac{t_1^2}{t_0^2}$$

$$z + 1 = \frac{t_1^2}{(t_1 - \Delta t)^2}$$

$$t_1^2 = (z+1)({t_1}^2 - 2t_1\Delta t + \Delta t^2)$$

$$0 = (z+1)\Delta t^2 + (-2zt_1 - 2t_1)\Delta t + z{t_1}^2$$

$$\Delta t = \frac{2zt_1 + 2t_1 \pm \sqrt{(2zt_1 + 2t_1)^2 - 4z^2{t_1}^2 - 4z{t_1}^2}}{2z+2} \qquad (7)$$

Equation (6) gives us the predicted luminous distance to an object in our model universe given the light travel time. Equation (7) gives us the light travel time based on the redshift. With these two formulas we can now analyze the universe using information about distant Type Ia Supernovae.

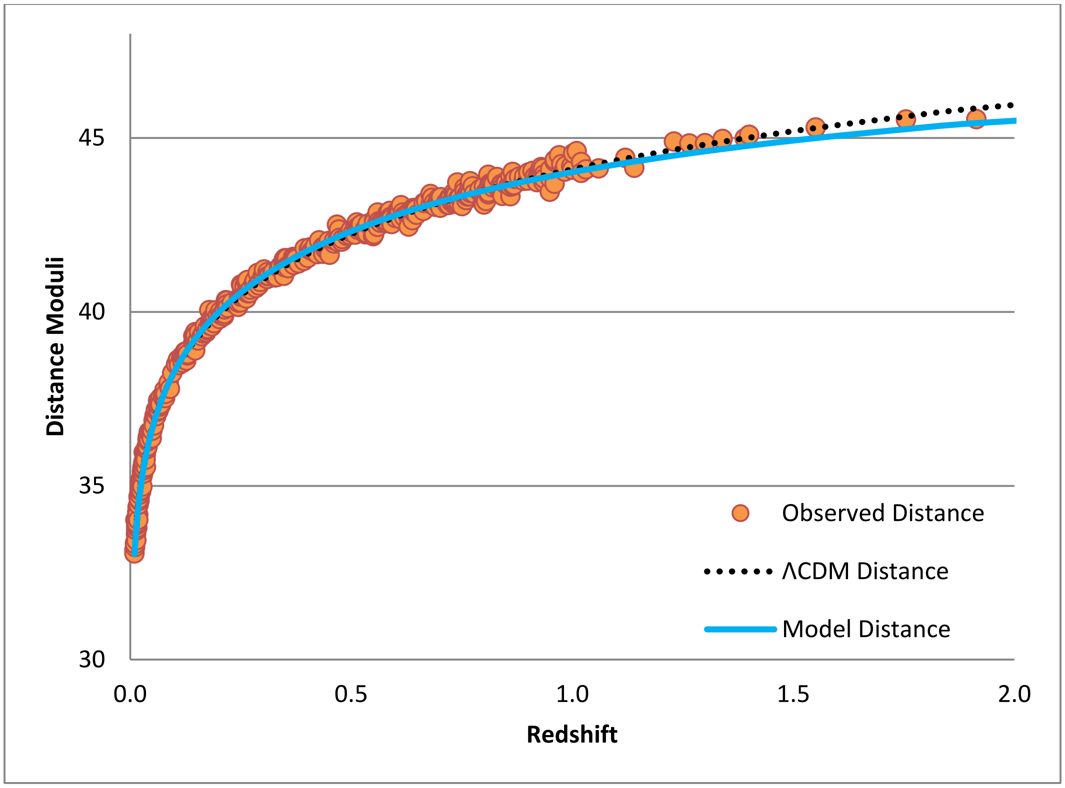

Figure 4 Here we employ our model in the analysis of the data from Type Ia Supernovae. The formula used for the distance moduli is $5\log(d_L) + 25$ (d_L in units of megaparsecs). Overlaid on this chart is the distance moduli caulcated according to the ΛCDM using $\Omega_\Lambda = 0.73$, $\Omega_M = 0.27$, $H_0 = 71.6$.

Least squares curve fitting produces the following values using the data from the Supernovae Lights Survey (SNLS): the age of the universe, t_1, is $211\ Gyr$ and the acceleration constant, ω, is $3.95 \times 10^{-14}\ km\ s^{-2}$. The adjusted R^2 of this model is 0.9953 which indicates a perfect fit with just two parameters.

The age of the universe is an order of magnitude older than that predicted by the ΛCDM model which assumes a linear expansion. There's considerable evidence that the growth of the universe is currently geometric[7]. If we accept an eternal principle of constant acceleration, then an age of 211 billion years is a mathematically simple solution given the redshift data of distant Type Ia SNe. The alternative to a model of constant acceleration is a series of 'phases' where the universe jerks forward and backward and forward again by some unseen force, much like the planets of the Ptolemaic Model.

[7] Riess et al.; "Type Ia Supernova Discoveries at z > 1 From the Hubble Space Telescope: Evidence for Past Deceleration and Constraints on Dark Energy Evolution" Astrophysical Journal, June 2004

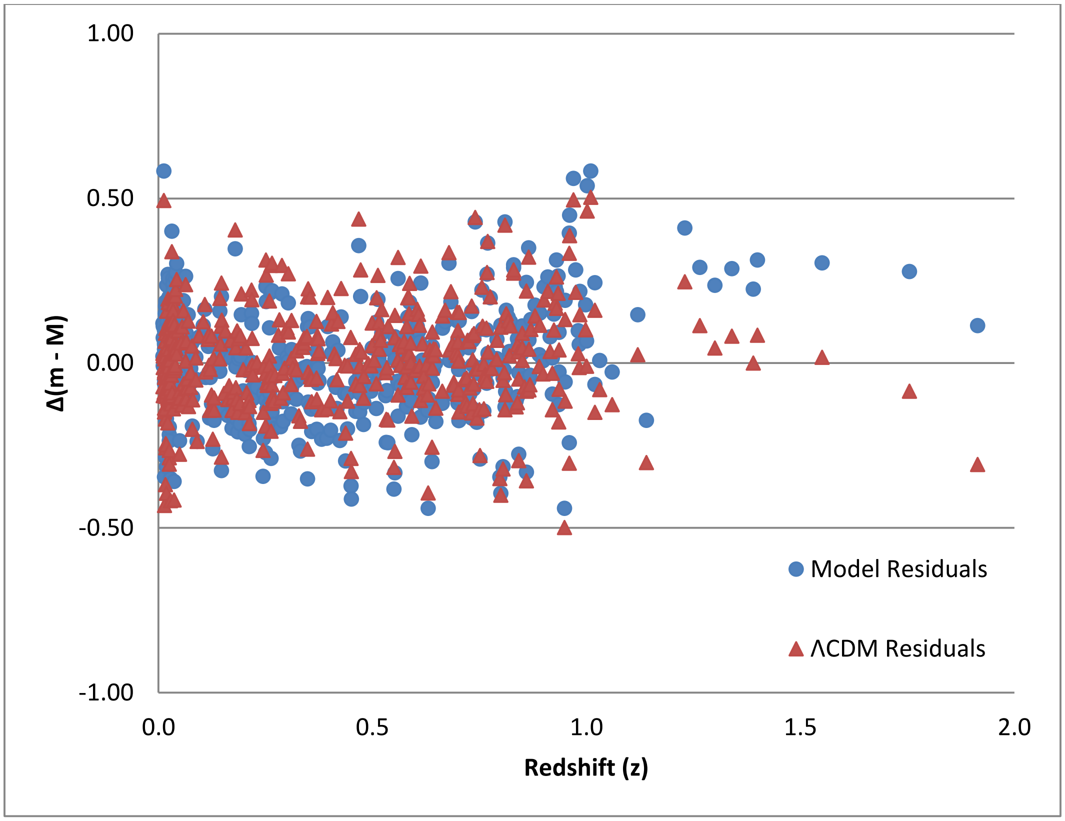

Figure 5 This figure plots the residuals of our model versus the observed luminous distance values. Overlaid on this chart is the residuals of the ΛCDM using the latest cosmological parameters from Sullivan.[8]

4. Discussion

There are serious consequences to sustained acceleration. Velocity accumulates quickly and distance accumulates exponentially. Even a tiny acceleration will have a profound impact when compounded over billions of years. Currently, the tangential velocity of the universe is $2.63 \times 10^5\ km\ s^{-1}$ or 87.68% of the velocity of light. The universe is far older than we had imagined because the light must fight against a current that is much stronger than previous linear models of expansion had guessed. For example, the effective speed of a photon from a SNe with a redshift of 1.00 reaching Earth today is roughly one-third that of a photon in static space.

[8] C. Bennett et al, "Nine-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Final Maps and Results", The Astrophysical Journal, June 2013.

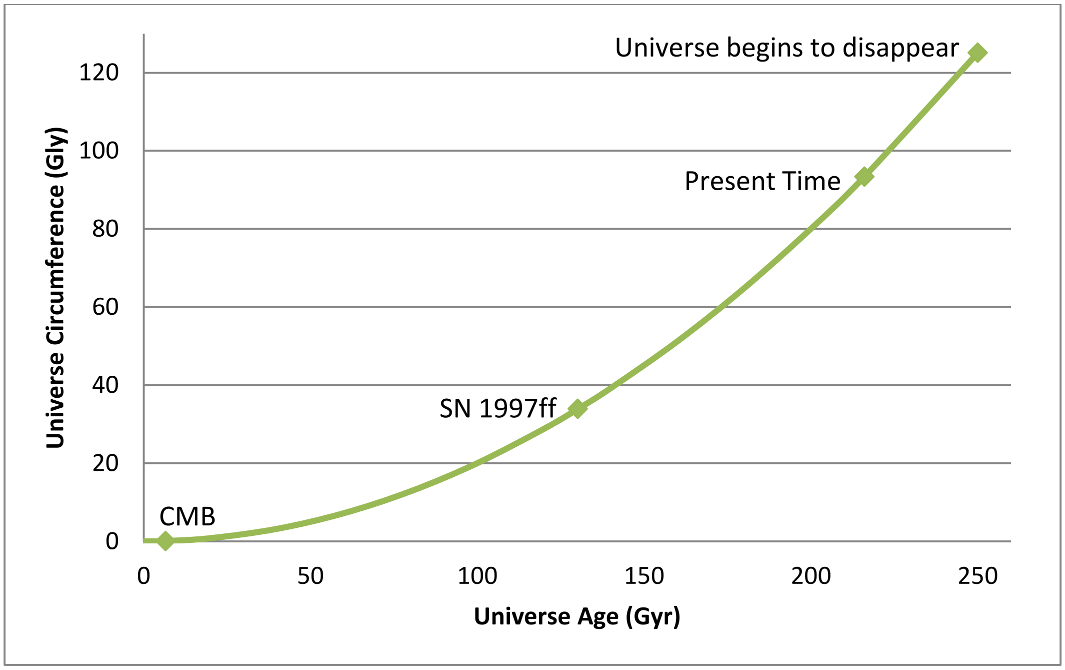

Figure 6 Here we show the change in the circumference of the cosmos with time. The recombination era occurred when the universe was 6 Gyr old and was 86 Mly around. The light from SN 1997ff, with a red-shift of 1.756, has been travelling for 86 Gyr and began its trip when the cosmos was 130 Gyr old. The entire universe is currently visible but in 34 Gyr parts will begin disappearing beyond the horizon imposed by the speed of light.

This model doesn't require any violation of the *First Law of Thermodynamics* to explain the acceleration. There is no assumption of multiverses, vacuum energies or enchanted particles needed to set the heavens in motion or accelerate them to the speed of light. The total amount of energy and mass in the universe has always been constant and will always be constant. The energy books are balanced using long established laws of physics.

This universe started very slowly. After three seconds it was the size of an atom. After one year, the universe was only 18 km around. It took 700,000 years to reach a circumference of just one light year. Because of this slow but inexorable progress there is no issue with stability or flatness. The infant universe simply grew out of the singularity from which it came without the need for borrowed energy or fine tuning the initial conditions to get the desired result.

There is no issue with information horizons. The law is the law, so to speak, and every part of the universe obeys the same law no matter how far away. Just as every part of the universe knows what the speed of light is, so it knows what the density of matter and temperature are. The relation between time and space is the same everywhere so there's no information that needs to be transferred.

In addition, this universe is extremely smooth. What began as an evenly distributed ball of hot plasma has expanded from an infinitesimal point to its current size without any trauma. The only irregularities in the otherwise perfect structure are those introduced by the Heisenberg Uncertainty Principal when the universe was less three seconds old[9]. These subatomic irregularities would be magnified with perfect clarity as space expanded and would show up today as large scale structures in the cosmos that had over 200 billion years to form.

5. Flatness

The major failing of the Big Bang Model is that our universe should not be flat but it is. A flat universe requires that the total product of mass and energy in it should be equal to a very specific value. Even the slightest deviation from that value results in an unstable universe. Measurements of the antistrophes in the CMB radiation have determined that space is almost perfectly flat. However, there is no explanation of how the universe knew it should be flat when it could have any amount of energy and, thus, any one of an infinite number of geometries.

The curvature of the universe in the model presented here is zero. Time is a different dimension than space and so it will appear completely orthogonal to all dimensions of space on a cosmic scale. General Relativity is the science of how space is curved by mass. As such it has a perfect application to the spatial surface of our universe but it has no place as the foundation of a cosmology. Any theory that attempts to apply the laws of gravity to unstructured space containing mass and energy will either instantly curl up on itself or expand rapidly and freeze. The Laws of Nature stated here provide the structure for a stable universe where the Laws of Gravity are relegated to describing the shape the spatial surface.

6. Conclusion

The universe can be modeled as a non-Euclidian 3-sphere where the circumference of the sphere is a function of the square of the radius. The radius of this sphere is the dimension of time which increases irresistibly and linearly from moment to moment. At any given time the surface of this sphere is composed of the three dimensions of space and increases geometrically as a function of time.

The universe is $211\ Gyr$ old and has a $93\ Gly$ circumference. The spatial surface has been accelerating since the beginning of time at a constant rate of $3.95\ \times 10^{-14}\ km\ s^{-2}$ and now has a tangential velocity that is 88% that of light. The dimensions of space are orthogonal, isotropic and homogenous with respect to time. Every point in space will have the same density and temperature as every other part of space at any given time because that is the way space and time are shaped.

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[9] Roughly the diameter of a hydrogen atom.

The present large scale cosmic structure is the result of perfectly magnified flaws left over from when the universe was the size of an atom. The entire universe is currently visible to us but in just $34\ Gly$ distant parts of it will begin to disappear beyond an event horizon.

Statistical analysis of the predicted luminosities against the data collected for Type Ia Supernovae from the Supernovae Light Survey confirm this model with an adjusted R^2 coefficient of 0.9953. This can be compared to the ΛCDM model with an adjusted R^2 of 0.9978[10] which requires six parameters, two hypothetical particles, one hypothetical field, finely tuned initial conditions, and a hypothetical form of energy that isn't conserved.

The model presented here has two simple assumptions: that time is absolute and linear and that the size of any single dimension of space is equal to the square of time. It requires only two parameters to predict the luminous distance of Type Ia Supernovae with great accuracy. Like the heliocentric model of the solar system and the relativistic model of gravity, this model is the result removing human biases about nature and recognizing the higher dimensions that speak to us through the data we collect.

[10] Using the parameters from the Sullivan Study: $\Omega_\Lambda = 0.73$ $\Omega_M = 0.27$, $H_0 = 71.6$

7. Appendix: The Full Sample

Table 1- Full Data Set

SNe	Redshift[11]	Observed μ[12]	Travel Time[13]	Model μ[14]
SN 1998bp	0.01	33.21	1.12	33.38
SN 1999cp	0.01	33.56	1.12	33.38
SN 1997do	0.01	33.73	1.12	33.38
SN 1997E	0.01	34.02	1.41	33.91
SN 1999dq	0.01	33.73	1.45	33.97
SN 1992al	0.01	34.12	1.51	34.05
SN 1991ag	0.01	34.13	1.51	34.05
SN 1999dk	0.01	34.43	1.51	34.05
SN 1995bd	0.02	34.11	1.62	34.22
SN 1999aa	0.02	34.58	1.68	34.29
SN 1994S	0.02	34.50	1.72	34.35
SN 2001V	0.02	34.13	1.73	34.36
SN 2000dk	0.02	34.41	1.75	34.39
SN 1996bo	0.02	33.82	1.76	34.40
SN 1997Y	0.02	34.54	1.77	34.41
SN 1996bv	0.02	34.21	1.78	34.43
SN 1998ef	0.02	34.18	1.81	34.47
SN 1998V	0.02	34.47	1.81	34.47
SN 1998co	0.02	34.68	1.82	34.48
SN 1997cn	0.02	34.52	1.87	34.53
SN 1992bo	0.02	34.70	1.90	34.57
SN 1993ae	0.02	34.29	1.92	34.59
SN 1992bc	0.02	34.96	1.98	34.67
SN 2000B	0.02	34.59	2.06	34.75
SN 2000fa	0.02	35.06	2.32	35.02
SN 1995ak	0.02	34.70	2.33	35.03
SN 2000cn	0.02	35.14	2.47	35.17
SN 1998eg	0.02	35.36	2.48	35.18
SN 1994M	0.02	35.09	2.59	35.27
SN 1993H	0.03	35.09	2.66	35.33
SN 1999X	0.03	35.41	2.72	35.39
SN 1999gp	0.03	35.62	2.76	35.41
SN 1992ag	0.03	35.06	2.78	35.43
SN 1992P	0.03	35.64	2.81	35.46
SN 2000bk	0.03	35.36	2.82	35.46

[11] In z
[12] In Distance Moduli
[13] In Gyr
[14] In Distance Moduli

SNe	Redshift	Observed μ	Travel Time	Model μ
SN 1996C	0.03	35.90	2.92	35.55
SN 1993ah	0.03	35.53	3.03	35.63
SN 1994Q	0.03	35.70	3.07	35.66
SN 1997dg	0.03	36.12	3.14	35.71
SN 1990O	0.03	35.90	3.24	35.79
SN 1999cc	0.03	35.85	3.34	35.85
SN 1998cs	0.03	36.08	3.45	35.93
SN 1991U	0.03	35.54	3.49	35.96
SN 1996bl	0.03	36.17	3.66	36.07
SN 1994T	0.04	36.01	3.79	36.15
SN 1992bg	0.04	36.17	3.79	36.15
SN 2000cf	0.04	36.39	3.79	36.15
SN 1999ef	0.04	36.67	3.99	36.27
SN 1990T	0.04	36.38	4.20	36.39
SN 1992bl	0.04	36.53	4.50	36.55
SN 1992bh	0.05	36.97	4.70	36.65
SN 1992J	0.05	36.35	4.81	36.70
SN 1995ac	0.05	36.52	5.11	36.85
SN 1993ac	0.05	36.90	5.11	36.85
SN 1990af	0.05	36.84	5.21	36.89
SN 1993ag	0.05	37.08	5.21	36.89
SN 1993O	0.05	37.16	5.41	36.98
SN 1998dx	0.05	36.97	5.51	37.03
SN 1991S	0.06	37.31	5.81	37.16
SN 1992bk	0.06	37.13	6.01	37.24
SN 1992au	0.06	37.30	6.30	37.35
SN 1992bs	0.06	37.67	6.50	37.43
SN 1993B	0.07	37.78	7.29	37.71
SN 1992ae	0.08	37.77	7.67	37.83
SN 1992bp	0.08	37.94	8.06	37.96
SN 1992br	0.09	38.07	8.92	38.21
SN 1992aq	0.10	38.73	10.15	38.54
SN 1996ab	0.12	39.20	12.27	39.03
SN 1997I	0.17	39.79	16.49	39.82
SN 1997N	0.18	39.98	17.16	39.93
SN 1999fw	0.28	41.00	24.94	41.01
SN 1996J	0.30	41.01	26.57	41.20
SN 1997ac	0.32	41.45	28.01	41.37
SN 1997bj	0.33	40.92	29.00	41.47
SN 2001iw	0.34	40.71	29.42	41.52
SN 1996K	0.38	42.02	32.14	41.80
SN 1995ba	0.39	42.07	32.68	41.85
SN 2001iv	0.40	40.89	33.27	41.91

SNe	Redshift	Observed μ	Travel Time	Model μ
SN 1995aw	0.40	42.04	33.46	41.93
SN 1997am	0.42	42.10	34.50	42.02
SN 1997bh	0.42	41.76	34.75	42.05
SN 1996E	0.43	41.70	35.07	42.08
SN 1997Q	0.43	41.99	35.39	42.11
SN 1996U	0.43	42.33	35.39	42.11
SN 1998ba	0.43	42.36	35.39	42.11
SN 1997ce	0.44	42.08	36.02	42.16
SN 1997aw	0.44	42.57	36.02	42.16
SN 1997ai	0.45	42.10	36.64	42.22
SN 1995az	0.45	42.13	36.64	42.22
SN 1999ff	0.46	42.29	36.95	42.25
SN 1998ac	0.46	41.83	37.26	42.28
SN 1999Q	0.46	42.56	37.26	42.28
SN 2000ee	0.47	42.74	37.87	42.33
SN 2000ec	0.47	42.77	37.87	42.33
SN 1997P	0.47	42.46	37.99	42.34
SN 2002dc	0.48	42.14	38.17	42.36
SN 1999fn	0.48	42.38	38.29	42.37
SN 1995K	0.48	42.48	38.35	42.37
SN 1995ay	0.48	42.37	38.47	42.38
SN 2000eh	0.49	42.41	39.07	42.43
SN 1996ci	0.50	42.25	39.36	42.46
SN 1997cj	0.50	42.74	39.66	42.48
SN 1999U	0.50	42.75	39.66	42.48
SN 2000dz	0.50	42.75	39.66	42.48
SN 1997as	0.51	41.64	40.13	42.52
SN 1997bb	0.52	42.83	40.71	42.57
SN 1997H	0.53	42.56	41.17	42.61
SN 2002hr	0.53	43.01	41.17	42.61
SN 2001jp	0.53	42.77	41.28	42.62
SN 1997eq	0.54	42.66	41.85	42.67
SN 2000eg	0.54	41.96	41.96	42.68
SN 2000fr	0.54	42.68	42.13	42.69
SN 1996I	0.57	42.81	43.64	42.81
SN 2001iy	0.57	42.88	43.64	42.81
SN 1997af	0.58	42.86	44.13	42.85
SN 1997F	0.58	43.04	44.18	42.85
SN 1997aj	0.58	42.63	44.24	42.86
SN 1995ax	0.62	42.85	46.06	43.00
SN 1996H	0.62	43.11	46.32	43.02
SN 1998M	0.63	42.62	46.84	43.06
SN 2003be	0.64	43.07	47.36	43.09

SNe	Redshift	Observed µ	Travel Time	Model µ
SN 1997R	0.66	43.27	48.22	43.16
SN 2003bd	0.67	43.19	48.88	43.21
SN 2001ix	0.71	43.05	50.85	43.35
SN 2002kd	0.74	43.09	52.04	43.43
SN 1998bi	0.74	43.35	52.28	43.45
SN 2001fo	0.77	43.12	53.72	43.55
SN 1997ez	0.78	43.81	54.04	43.57
SN 2001hx	0.80	43.88	54.94	43.63
SN 2001hy	0.81	43.97	55.52	43.67
SN 1999fj	0.82	43.76	55.70	43.68
SN 2001jf	0.82	44.09	55.70	43.68
SN 1998J	0.83	43.61	56.27	43.72
SN 1996cl	0.83	43.96	56.27	43.72
SN 1997ap	0.83	43.85	56.36	43.72
SN 2001hs	0.83	43.55	56.44	43.73
SN 2003eq	0.84	43.86	56.75	43.75
SN 1997ek	0.86	44.03	57.65	43.81
SN 2001fs	0.87	43.75	58.20	43.84
SN 2001hu	0.88	43.90	58.58	43.87
SN 2001jh	0.88	44.23	58.66	43.87
SN 1998I	0.89	42.91	58.75	43.88
SN 2003eb	0.90	43.64	59.29	43.91
SN 2003lv	0.94	43.87	60.95	44.02
SN 1999fm	0.95	43.99	61.31	44.04
SN 2002dd	0.95	44.06	61.35	44.04
SN 2003es	0.95	44.28	61.51	44.05
SN 2001jm	0.98	43.91	62.41	44.11
SN 1999fk	1.06	44.25	65.39	44.28
SN 2002ki	1.14	44.84	68.38	44.46
SN 1999fv	1.19	44.19	70.08	44.55
SN 2003az	1.27	45.20	72.51	44.69
SN 2002fw	1.30	45.27	73.61	44.75
SN 2002hp	1.31	44.70	73.77	44.76
SN 2003dy	1.34	45.05	74.83	44.81
SN 2003ak	1.55	45.30	80.80	45.12
SN 1997ff	1.76	45.53	85.91	45.38