Kinematic interpretation of 580 supernovae type 1a redshifts: A cosmic scale link to MOND acceleration?

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Abstract

We present an empirical analysis of redshift of 580 supernovae type 1a using special relativistic Doppler to derive velocity of recession. A theory of cosmological scale is developed in which scale history is parabolic in relation to observed distance and time. The parabolic relationship suggests that the present lies on the accelerated contraction side of the scale history. The first-order coefficient of the scale equation matches very precisely the post-Planck value of the Hubble parameter, H_0. The second-order coefficient of the parabolic scale history is taken as an acceleration parameter, I_0. H_0 is thus merely the slope of the parabola at the present time, and it can be eliminated by shifting the abscissa so that $t = 0$ aligns with the vertex. In this way, the scale history is entirely dependent on the acceleration parameter, I_0. A methodology is used to infer physical radial distance from scale. The resulting acceleration rate precisely matches modified Newtonian dynamics (MOND) universal acceleration a_0 and thus appears to provide a general cosmological link to that phenomenon, implying a universe under accelerated contraction.

Résumé

Nous présentons une analyse empirique du décalage vers le rouge de la supernovae 580 type 1a en utilisant un Doppler relativiste spécial pour déterminer la vitesse de récession. Une théorie de l'échelle cosmologique est développée, selon laquelle l'histoire de l'échelle est parabolique par rapport à la distance et au temps observés. La relation parabolique suggère que le temps présent se situe du côté de la contraction accélérée de l'histoire de l'échelle. Le coefficient du premier ordre de l'équation de l'échelle correspond très précisément à la valeur post-Planck du paramètre Hubble, H_0. Le coefficient du second ordre de l'historique de l'échelle parabolique est pris comme paramètre d'accélération, I_0. H_0 est donc simplement la pente de la parabole à l'heure actuelle, et peut être éliminée en décalant l'abscisse de sorte que $t = 0$ s'aligne avec le sommet. De cette façon, l'historique de l'échelle dépend entièrement du paramètre d'accélération I_0. Une méthodologie est utilisée pour déduire la distance radiale physique par rapport à l'échelle. Le taux d'accélération qui en résulte correspond exactement à l'accélération universelle a_0 de la dynamique newtonienne modifiée (MOND) et fournit donc de toute évidence un lien cosmologique générale à ce phénomène, impliquant un univers sous contraction accélérée.

Index terms: Hubble parameter, MOND acceleration, supernova type 1a, contracting universe, Doppler redshift

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1.0 Introduction

There is certain to be a prejudice against any study of cosmology today that embraces special relativity as adequate to the task. General relativity is used universally in published work in cosmology, despite the fact that on a cosmological scale, space is flat (Euclidean). For instance, we encountered on the web site of a well-known astrophysicist the statement that “special relativity probably does not apply” in cosmology. The word “probably” stuck with us.

We were curious to investigate the application of special relativistic Doppler to supernovae 1a redshift data. Some might consider such an effort to be primitive and fruitless, whereas it may in fact be more conservative, following Occam, compared to the standard models of today, with their requirement for exotic dark energy and dark matter, neither of which has been observed. Bunn and Hogg explore and defend the validity of SR Doppler in cosmology [1].

The predominant model for cosmology today is the Λ Cold Dark Matter or ΛCDM big bang theory. That theory is stressed in at least four major ways. The 13.8 billion year age of the universe is scarcely long enough to accommodate the estimated age of the oldest galaxies. Perhaps more important, the theory requires that 95% of the contents of the universe consists of a combination of the elusive dark energy to explain the inferred accelerated expansion, and the equally elusive dark matter to explain many observations of galactic phenomena that seem to behave in ways that defy ordinary gravitational force based on observed luminous mass. Lastly, there are serious questions about another key ingredient of today’s standard models, and that is inflation. Steinhardt, a key contributor to the original theory of inflation, is in recent years highly skeptical of it, and has been arguing that it is extremely unlikely to have occurred [2].

We investigated the basic Hubble relationship in the context of today’s far better data, and focused our empirical analysis entirely on redshift data for 580 supernovae type 1a, provided by the Supernova Cosmology Project (SCP). What follows, then, is not a critique of big bang theory but rather a completely new paradigm for cosmology.
This paradigm depends on special relativistic Doppler without reference to general relativity. Gravitational force in the so-called Hubble flow is “weak” in that there is, on cosmological scales, no major concentration of mass to disturb the flat field. The SN1a data in the SCP database are taken to represent objects in the Hubble flow. The distances between all massive objects in the Hubble flow change in a radial manner and such that the distances between them remain in constant proportion; i.e., distances change with scale. The latter is consistent with big bang theory. However, in our theory, it is not “space itself” which expands (or contracts), but the distances between massive objects in space that behave consistently with a changing scale. Thus, light is not carried along with a changing scale, but remains constant, independent of scale. We found only one other study that approaches cosmology by applying special relativistic Doppler to SN1a redshift, in that case using the union1 redshift data from SCP (the latest available at that time) [3]. In that paper, Farley derives a relationship between observed luminosity of SN1a and redshift in the context of SR Doppler, concluding that recession velocities are constant over time.

This analysis hinges on a revision of the original Hubble relationship, which was estimated based on what are now considered relatively nearby stars. The original form of the equation for the basic Hubble parameter, $v = H_0D$, historically provided an estimate of H_0. Of course, it has been known for many years that this relationship is only accurate for a very limited range of distance. The dependent variable for that equation is here modified to $v/(c-v)$ and a second-order distance term is added: $v/(c-v) = H_0D + I_0D^2$. The resulting parabolic relationship is the core of this analysis, which leads us to a postulate regarding universal scale as a function of time. Further, the Hubble parameter may be eliminated by reconstructing the parabola with time zero at its axis of symmetry, so that the current value of the Hubble parameter is simply the first derivative of scale at the present time.

Our estimate of H_0 matches the 2016 Planck Collaboration results. We also demonstrate that our I_0 parameter is, when appropriately scaled, consistent with the contractive acceleration parameter a_0 in the phenomenological theory of modified Newtonian dynamics. Thus, the empirically derived MOND acceleration may serve as evidence for our theory of accelerated cosmological contraction, and in turn, our theory provides the cosmological basis for the universality of a_0.

1.1 The Data and Statistical Analysis

Distance modulus (*DM*) from the Supernova Cosmology Project (SCP) data was converted to billions of light years (Gly):

$$D = 10^{-9}(3.26*10^{((0.2*DM)+1)}).$$

This distance is taken to be the distance that light has traveled at the rate c from the observed object to the observer. In doing so, we are making an initial assumption that the speed of light, even over cosmic distances over long intervals of time, is unaffected by the expansion or contraction of the universe. Let us see where this takes us.

The standard special relativity Doppler formula for velocity from z-shift was used to obtain velocity of recession expressed as a scalar:

$$v/c = [(z+1)^2 -1] / [(z+1)^2 +1].$$

This analysis began about six years ago with the Union1 SCP data [4]. During our work with Union1 data, Union2 data was released, and eventually Union2.1 [5][6]. During the Union1 analysis, we came upon an interesting relationship between $v/(c-v)$ and two independent variables, distance and distance squared:

$$v/(c-v) = H_0D + I_0D^2.$$

The expression for the dependent variable was empirical in origin. When the Union1 data was current, we looked at the inverse relationship of the traditional $v/c = H_0D$, and we obtained

$c/v = 1.13 + 13.84(1/D)$.

The R^2 was over 99%. While that result was interesting, the constant term was puzzling. The constant term was highly significant with respect to zero, but it was not significantly different from one. As an experiment, it was set equal to one:

$c/v - 1 = b_0(1/D)$,

or equivalently,

$(c-v)/v = b_0(1/D)$.

Then both sides were inverted to obtain a revised form for the Hubble equation, where b_0 is a coefficient to be estimated:

$v/(c-v) = b_0D$.

The coefficient b_0 was estimated using simple linear regression, testing it initially with a constant term. The constant term was barely significant at the 95% level, so the regression was rerun without it to obtain:

$v/(c-v) = 0.0663D$ ($R^2 = 96.6\%$).

But that regression result had a systematic bias. That bias was removed by adding a second-order distance term to the regression so it has the parabolic form:

$v/(c-v) = H_0D + I_0D^2$.

The parameters H_0 and I_0 were estimated. Note that $v/(c-v)$ approaches v/c for very small v. Small v corresponds to small D, so the equation reduces to $v/c = H_0D$ for nearby objects. Note that this expression is very similar to the traditional Hubble equation, $v = H_0D$, except velocity of recession is here expressed as the scalar v/c and H_0 has units of inverse distance rather than inverse time (maintaining dimensional consistency). Our expression could be rewritten $v = cH_0D$, where $c = 1$, and thus the *value* of $cH_0 = H_0$, but the units of cH_0 become inverse time, as in the traditional Hubble equation. It follows that our estimate of the value of H_0 in units of inverse distance is directly comparable to traditional estimates in units of inverse time.

The interpretation of $v/(c-v)$ will be discussed in the next section.

The analysis was eventually repeated with Union2 and Union2.1 data. Table I shows the results for these datasets, plus the result for a binned analysis of Union2.1.

In the binned analysis of Union2.1, the 580 observations of SN1a events were sorted by distance and bins of 10 observations each were created. This was done to reduce the impact of the large distance errors reported in the SCP data, in particular the observations at large distances. Figure 1 shows the unbinned observation errors and regression equation based on that data. The mean distance (Gly) and mean $v/(c-v)$ values for each bin were calculated. The bin size of 10 was chosen to avoid going too small and losing the benefit of binning, yet to assure that it would not be too large to capture characteristics of the relatively few more distant SN1a. No other bin size or binning technique was tested. This created a dataset of 58 observations.

Table I
Regression analyses for $v/(c-v) = H_0D + I_0D^2$

	Total number of SN1a observations	Number of SN1a with D>30 Gly	Most distant SN1a (Gly)	H_0 (1/Gly) (sigma) t-stat	H_0 (km/s per Mpc) (sigma)	I_0 (1/Gly^2) (sigma) t-stat	R^2 (through the origin)
Union1 (2008)	307	5	37.98	0.069321 (0.001875) t = 39.96	67.78 (1.70)	-0.00020036 (0.00009002) t = -2.23	96.54%
Union2 (2010)	557	8	34.44	0.069366 (0.001366) t = 50.78	67.83 (1.34)	-0.00019288 (0.00006761) t = -2.85	96.37%
Union2.1 (2011)	580	11	39.39	0.069755 (0.001091) t = 63.96	68.21 (1.07)	-0.00019965 (0.00004905) t = -4.07	97.51%
Union 2.1 (binned)	58 bins	1 bin (mean)	33.46 (bin mean)	0.069789 (0.001305) t = 53.48	68.24 (1.27)	-0.00020310 (0.00005922) t = -3.43	99.66%
Observed (Planck)				0.069340 (0.001023)	67.80 (1.0)	--	--
(Riess)				0.074904 (0.001780)	73.24 (1.74)		

The regression for binned Union2.1 had an R^2 of 99.66%, depicted in Figure 2. A closer look at the residuals in the lower range of distance is presented in Figure 3. The regression through the origin appears correct. For visualization of the contribution of the 2nd order distance term, the simple H_0D result is also included in Figure 2 (using the same H_0 so that the curves match perfectly near the origin). Note in Figure 2 that the data for the most distant bin was closely aligned with the estimated relationship, and there was no sign of any systematic bias. The resulting equation is:

$$\boldsymbol{v/(c-v) = 0.069789D - 0.00020310D^2}. \quad \textbf{[Eq 1]}$$

Note in Table I that our estimates of H_0 are in all cases well within the error term for observed (Planck+WP+highL+BAO) H_0, which is 67.80 km/s per Mpc [7]. The more direct astrophysical result reported by Riess *et al* is much higher at 73.24 km/s [8].

Taking those results, which frame our estimate, in combination with the excellent fit using the binned Union2.1 data, we put aside the possibility that the relationship of Equation 1 is a meaningless pragmatic correlation, and entertain a physical interpretation.

2.0 What is the meaning of v/(c-v)?

Our proposition is that there is physical significance to the relationship $v/(c-v) = H_0D + I_0D^2$. We take it that observed $D = cLB$, where LB is lookback time. Since forward-looking time is positive and lookback time is negative, then $D = -ct$. The equation may be rewritten as $v/(c-v) = -H_0ct + I_0c^2t^2$. With c equal to unity, we can drop the c terms on the right hand side, and the units for H_0 and I_0, which were Gly^{-1} and Gly^{-2}, become Gyr^{-1} and Gyr^{-2}, respectively, in Equation 2:

$$\boldsymbol{v/(c-v) = -H_0t + I_0t^2}. \qquad \textbf{[Eq 2]}$$

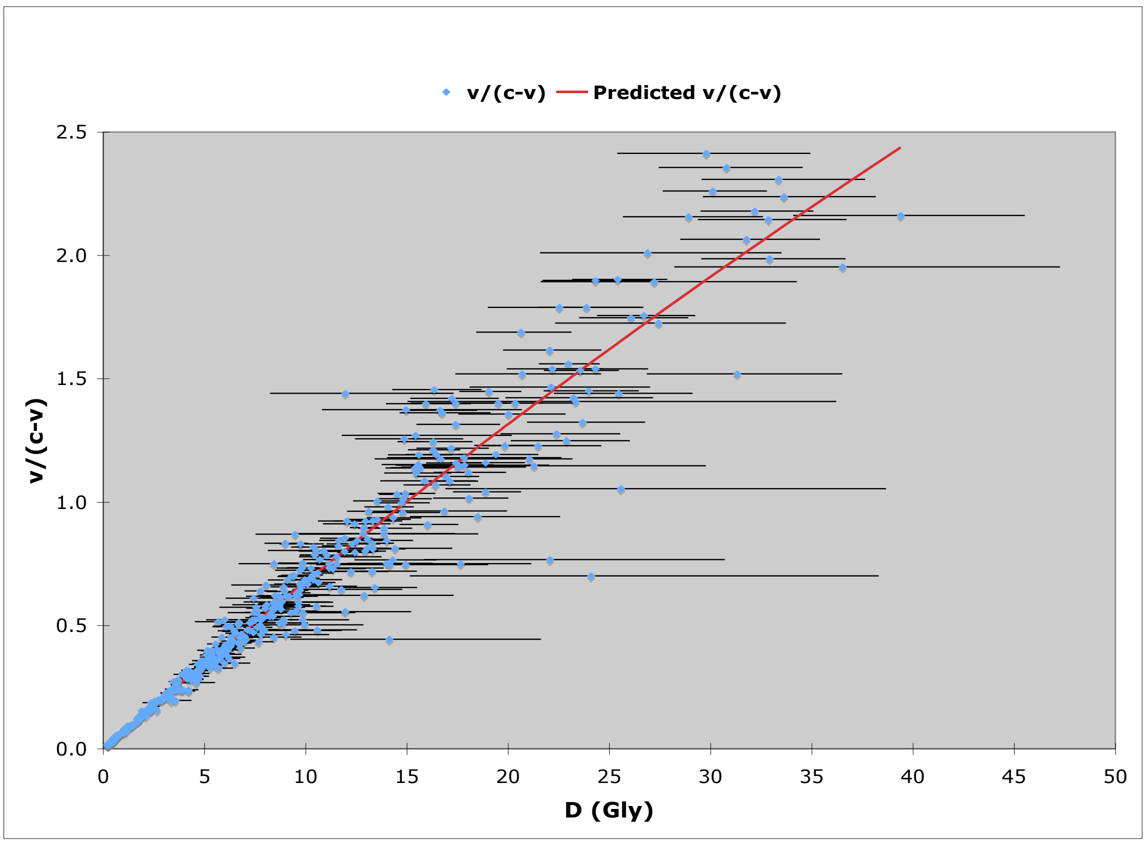

Fig 1 The dependent variable for the regression equation $v/(c-v) = 0.069755D - 0.00019965D^2$ is based on computed SR velocities using all 580 SN1a in the Union2.1 data (error bars reflect conversions to Gly after adding in Union2.1 reported distance modulus error terms).

Note that the H_0 dimension in Equation 2 is the same as in the conventional case for H_0, which is t^{-1}, and I_0, which is negative, has units of t^{-2}.

Using the values for the equation as statistically derived above (Equation 1), Equation 2 peaks at $t = -171.812$ Gyr. (The uncertainty in this estimate is considered in section 2.4.)

Consider that this maximum may represent the peak between expansion and contraction phases, with the parabolic curve suggesting a system with constant acceleration. The peak would then represent a stagnation epoch corresponding to $v/(c\text{-}v) = 5.995$. From the latter we have $v = 0.857c$, the velocity of recession of the observer with respect to the stagnation point at the peak of the parabola.

We propose that $v/(c\text{-}v)$ represents the change in scale of the universe between the present observer and the observed past event.

Now, if we add one to each side of Equation 2, we obtain $v/(c\text{-}v) + 1 = 1 - H_0t + I_0t^2$ which simplifies to $c/(c\text{-}v) = 1 - H_0t + I_0t^2$, or

$$\mathbf{1/(1\text{-}v/c) = 1 - H_0t + I_0t^2.} \qquad \textbf{[Eq 3]}$$

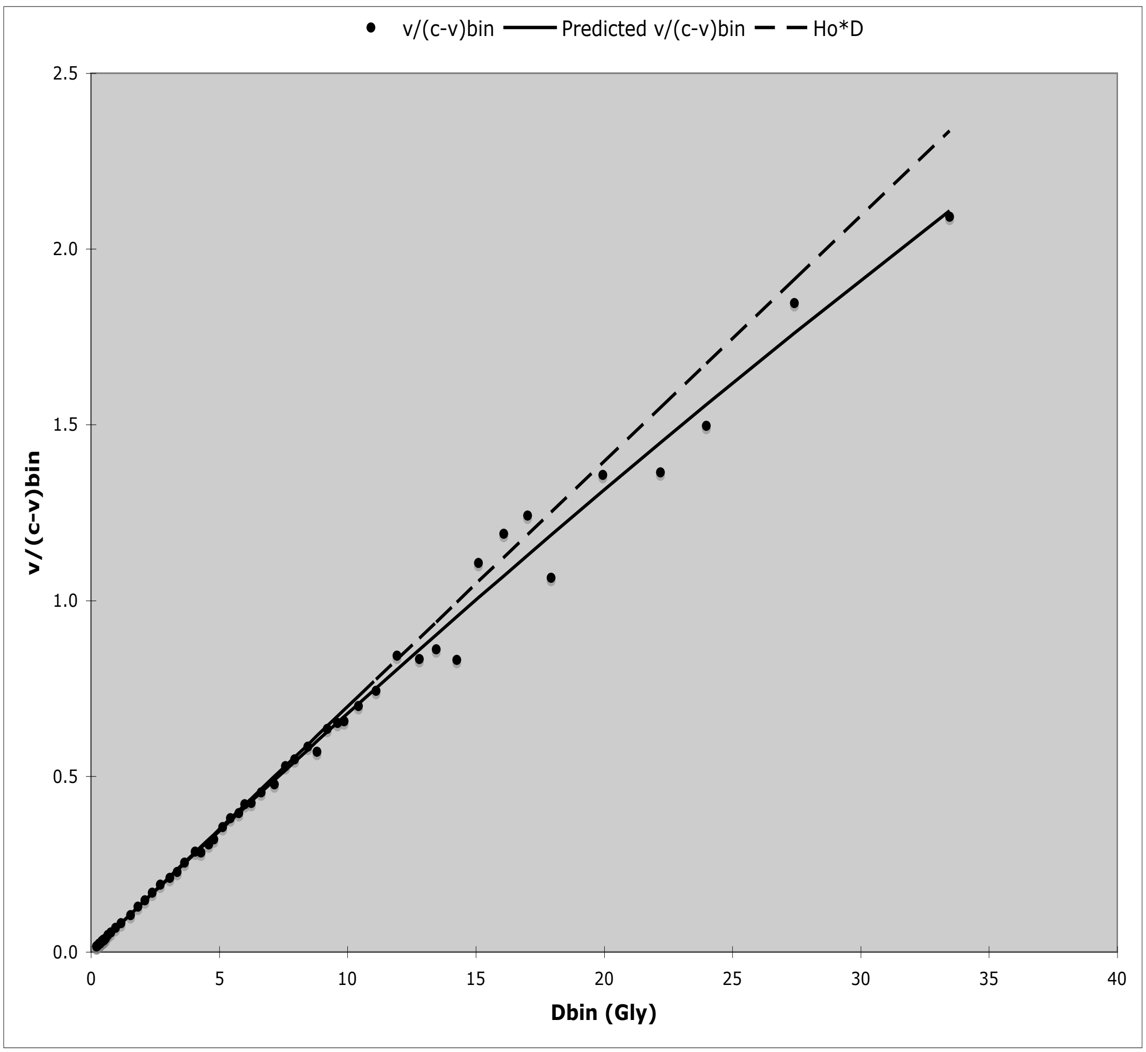

Fig 2 The solid line represents the regression equation: $v/(c\text{-}v) = 0.069789D - 0.00020310D^2$, with $R^2 = 99.66\%$, using SR velocities computed from binned SN1a data. Note the close match of the furthest bin to the estimated value, and that the furthest six bins (representing 60 stars) all lie below the linear Hubble curve (dashed line) and near the quadratic curve.

We *postulate* that $1/(1-v/c)$ represents the scale (S_e) of the universe for the epoch of emission of an SN1a event, in relation to the present, $S_0 = 1$. That is,

$$\boldsymbol{S_e = 1/(1-v/c).} \qquad \textbf{[Eq 4]}$$

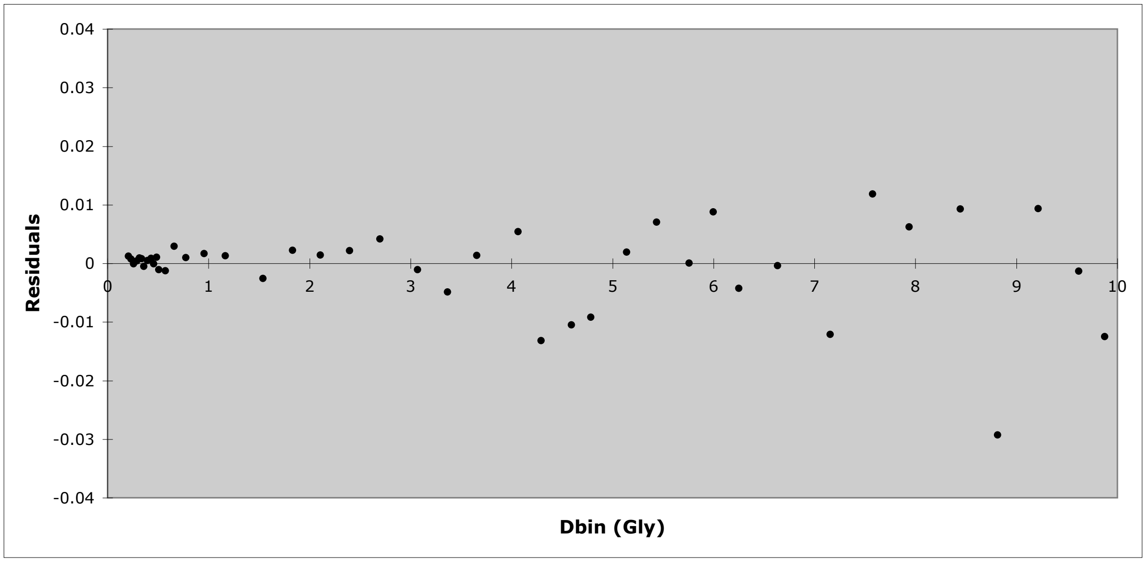

Fig 3 Close-up view of the error terms for observations near the origin, per Fig 2.

Figure 4 provides a graphic illustration of Equation 4. The scale on the ordinate is defined relative to the present, with $S_0 = 1$. Each SN1a event occurred during a unique epoch at scale S_e. The universe continued to contract so that later SN1a events occurred at smaller values of S_e. Our current observations of all these events take place during the present epoch, with $S_0 = 1$. The v/c values for each event comes from Equation 4, which can also be expressed as $v/c = (S_e - 1)/S_e$. This allows construction of a series of right triangles whose heights equal one and whose bases equal $1-v/c$. This provides the slopes of the diagonals, which intersect the ordinate at the various S_e values.

Now, combining Equations 3 and 4, we obtain

$$\boldsymbol{S_e = I_0 t^2 - H_0 t + 1.} \qquad \textbf{[Eq 5]}$$

Note that in all our analysis, we assume that the speed of light is constant and independent of scale.

2.1 The elimination of H_0 from the scale equation

As is well known, the first order term of a parabolic equation can be eliminated by simply shifting the origin or zero point of the abscissa so that it is coincident with the axis of symmetry of the parabola. We did this, and re-estimated the regression using the shifted time scale, $T = t + 171.812$, and obtained:

$\mathbf{S_e = 6.996 - 0.0002031 T^2}$. **[Eq 6]**

The R^2 is 99.33%. Note that 6.996 matches the maximum scale (6.995) from before, and that -0.0002031 matches I_0 from before. The Hubble parameter is nothing special, just the slope of the scale curve, so $H(T) = \mathrm{d}S/\mathrm{d}T$, or $2I_0T$. At T = 171.812 Gyr, which is the time now with respect to the apex of the parabola, the result is $H(T) = H_0$. The point here is simply to illustrate how H_0 is a time-dependent parameter. It is not proposed to substitute Equation 6 for Equation 5, because the constant term in T = t + 171.812 is itself determined from Equation 5, and subject to uncertainties.

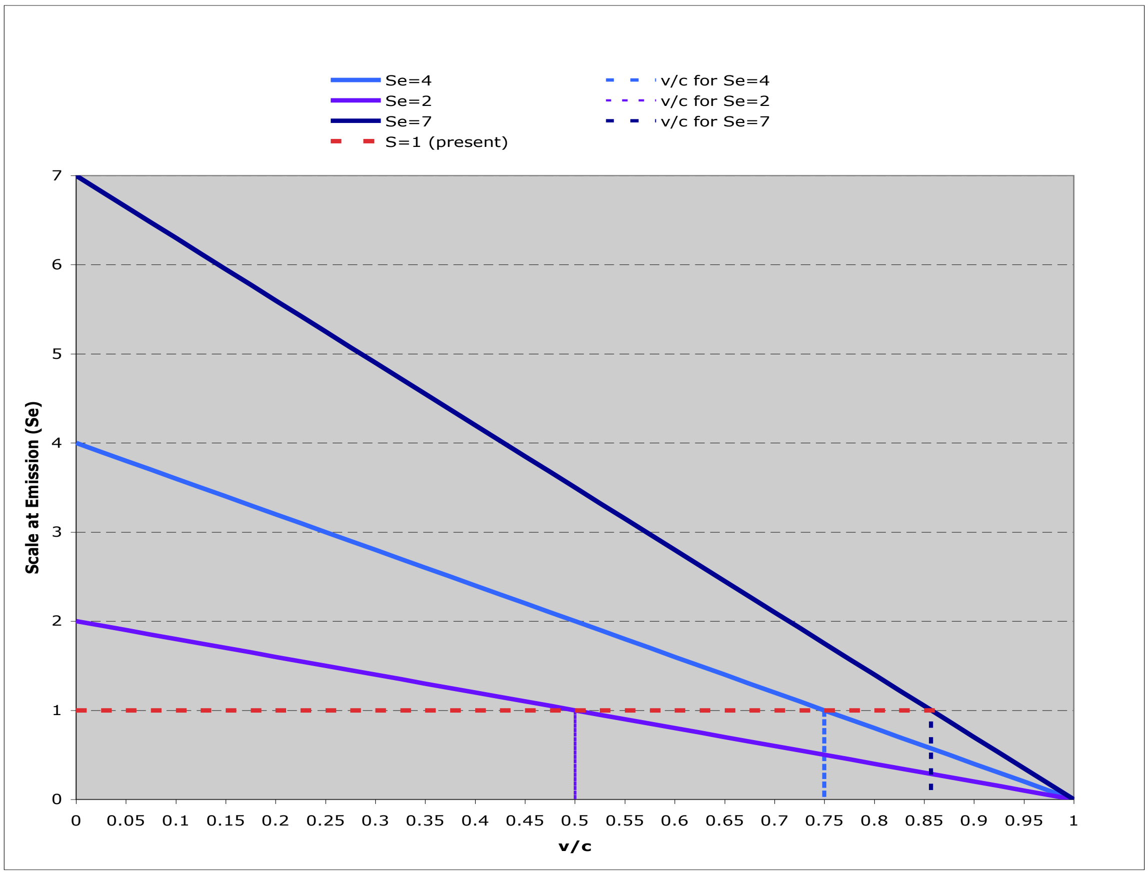

Fig 4 Illustration of $S_e = 1/(1-v/c)$

2.2 *v/c and scale at emission for SN1a*

Figure 5 presents a view of the binned SN1a data in relation to the present scale (S_0=1), so we have $v/c = (S_e - 1)/S_e$. The vertical dotted line at $S_e/S_0 \approx 7$ represents S_{max}, which occurs at the apex of the derived scale parabola (Equation 5). If an object that distant were observable, we would have $(v/c)_{max}$ = (7-1)/7 = 0.857. Note that this velocity corresponds to SR redshift. Both Figure 4 and Figure 5 depict that result.

In relation to the scale as defined in the present, the observer's scale will drop below its present value of unity as the universe contracts, and S_{max}/S_0 will increase. The horizontal dashed line in Figure 4 will move downward; the vertical dotted line in Figure 5 will move to the right, and $(v/c)_{max}$ will increase. In the limiting case, when S_0 approaches zero, maximum recessional velocity taken in relation to S_{max} at the stagnation epoch will approach $(v/c)_{max} = (S_{max} - S_0)/S_{max} = 1$, so recessional velocity is limited by c.

2.3 Redshift and scale at emission for SN1a

Another view of the SN1a binned data and scale is presented in Figure 6. From SR Doppler, we have $v/c = ((1+z)^2 - 1) / ((1+z)^2 + 1)$. From our work above, we have $v/c = (S_e - 1)/S_e$. Using the equality between the right-hand-sides of these two equations, we obtain redshift as a function of scale:

$$z + 1 = (2S_e - 1)^{0.5}. \qquad \textbf{[Eq 7]}$$

2.4 Hubble parameter and scale

In Equation 5, t equals zero at the present epoch, and time past is treated as negative. For the epoch t, when an SN1a event occurred, the scale of the universe is given by Equation 5. The value of $H(t)$ over time is simply the time derivative of scale, $dS(t)/dt = - H_0 + 2I_0t$. At present $t = 0$, this gives us $H(t) = dS(t)/dt = -H_0$. $H(t)$ becomes steeper as t approaches 13.777. When $S(t)$ approaches zero, this results in a value of $H(t) = -0.0754$ Gyr^{-1} (this corresponds to 73.73 km/s per Mpc compared to our estimate of today's value of $H_0 = 68.24$ km/s per Mpc from Table I).

The Hubble parameter in the context of big bang models is defined differently: $H_0 = (dS/dt)/S(t)$. That result will match ours only in the case of the present scale where $S(t) = 1$. However, we are interested in how the rate of change of scale is changing relative to the present scale, at $S(t) = 1$. Our interpretation of the Hubble parameter is therefore simply the slope of the scale curve which is defined such that $S(t) = 1$ at the present. This definition will accommodate the analysis in section 3.0.

The maximum scale occurred at the apex, where $dS/dt = -H_0 + 2I_0t = 0$. Solving that for t provides us with $S_{max} = 6.995$ at $t = -171.812$ Gyr (Figure 7). The 1-sigma ranges of uncertainty were calculated using the error terms for H_0 and I_0 from the regression and are (5.817, 9.149) for projected S_{max} and (-135.513, -237.998) for the times corresponding to those peaks. Also shown is the SN1a binned data in the context of the scale parabola, where scale is calculated using Equation 5. The line representing a constant Hubble parameter that matches the present value (same H_0) is included for reference.

Since scale is ubiquitous, it follows that the observer was at the same scale as the observed object at the time the light was emitted; thus *the parabola also represents the scale history of the observer.*

The full period of the parabola can be calculated from Equation 5 using the quadratic formula, and gives solutions for $S(t) = 0$ at $t = 13.777$ and -357.400, for a full period of 371.177 Gyr. The corresponding 1-sigma uncertainty ranges are (13.403, 14.180) Gyr

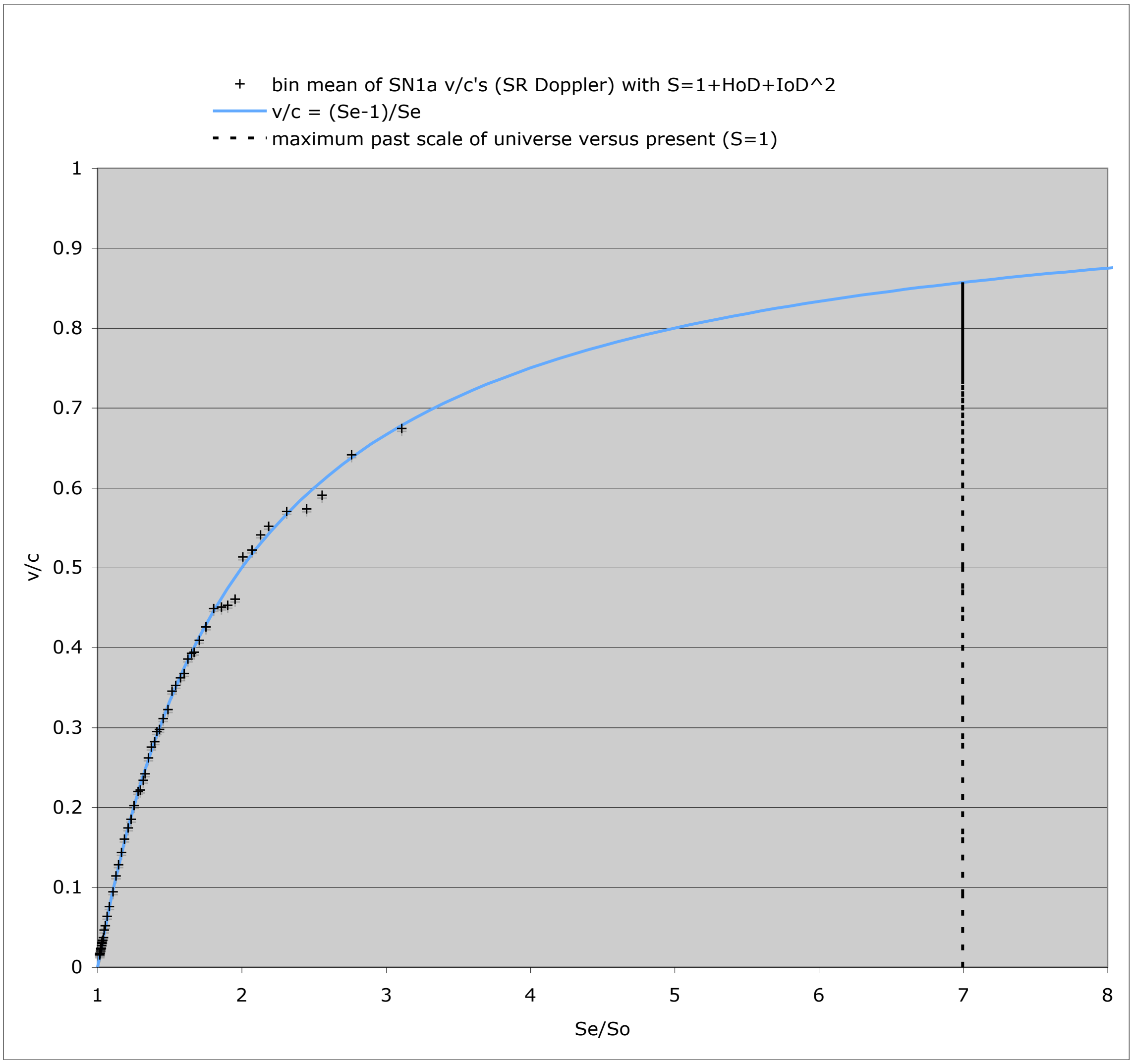

Fig 5 Illustration of $v/c = (S_e - 1)/S_e$, with $S_0 = 1$.

until a potential future crunch, and (-284.430, -490.156) Gyr back to the beginning of the projected history of the current parabolic cycle, which would have a full period of between 297.833 and 504.335 Gyr.

If we assume symmetry, the universe was expanding during the first half of the full period, and during the current second half it is contracting. (Obviously, there is no data on the other side of the apex.) The expansion and contraction eras have periods equal to 185.588 Gyr. From the present epoch, the maximum scale occurred 171.812 Gyr in the past, and the contraction era will continue for another 13.777 Gyr at which time the scale will approach zero. Given our interpretation of this parabolic model of expansion and contraction, the universe must have been stagnant at the moment of maximum scale, and *the stagnation epoch can be considered as an absolute rest frame*, with $H(t)$ equal to zero.

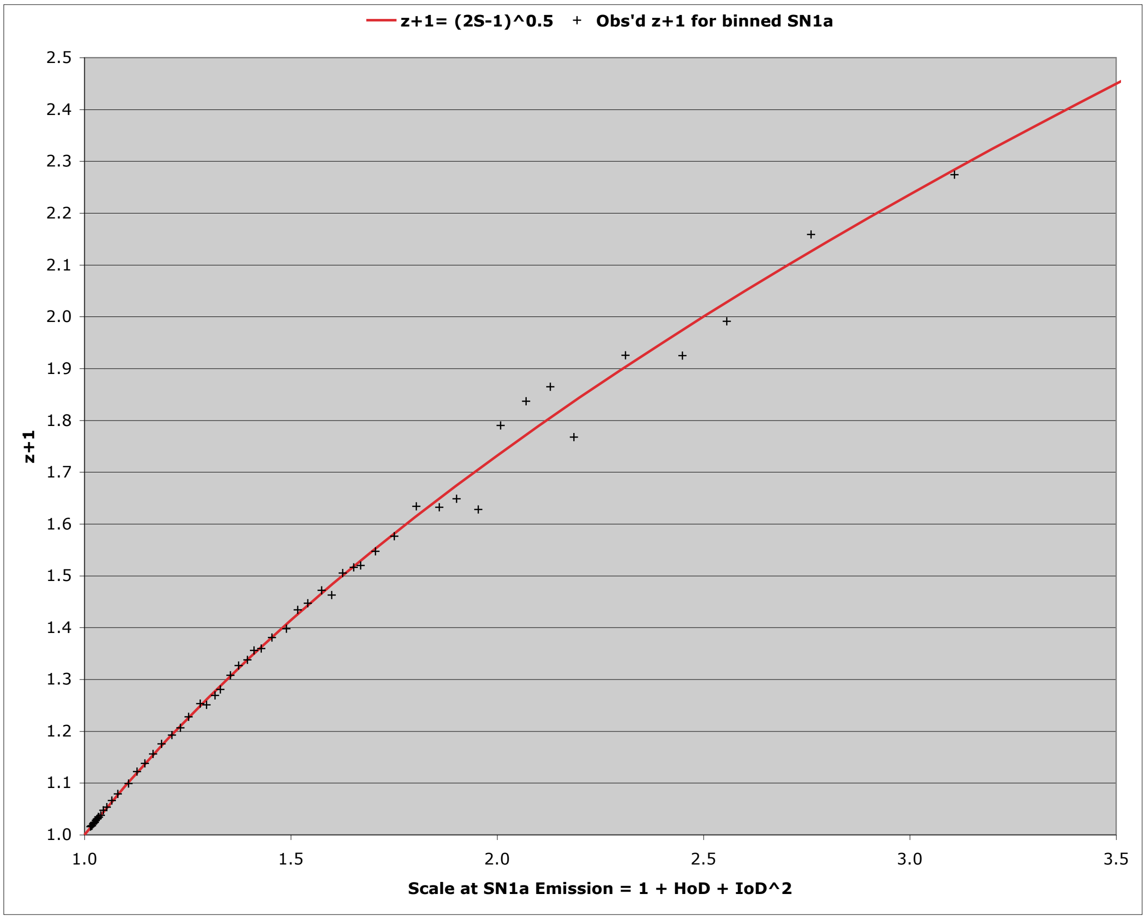

Fig 6 The relationship between redshift and scale at emission is $z + 1 = (2S_e - 1)^{0.5}$, with the observer in the present at $S_0 = 1$.

The current recession represents an accelerating contraction with respect to the epochs of the emitting objects. *By assuming that special relativistic Doppler shift is valid at cosmic scales, we abandon the notion that wavelength and observed* z+1 *are directly proportional to scale.* Instead, observed wavelength is dependent on v_{rel}, *the special relativistic velocity of the observer now relative to the emitting object then,* at the time of emission. Bunn and Hogg discuss the validity of using v_{rel} in the context of the redshift of distant galaxies [1].

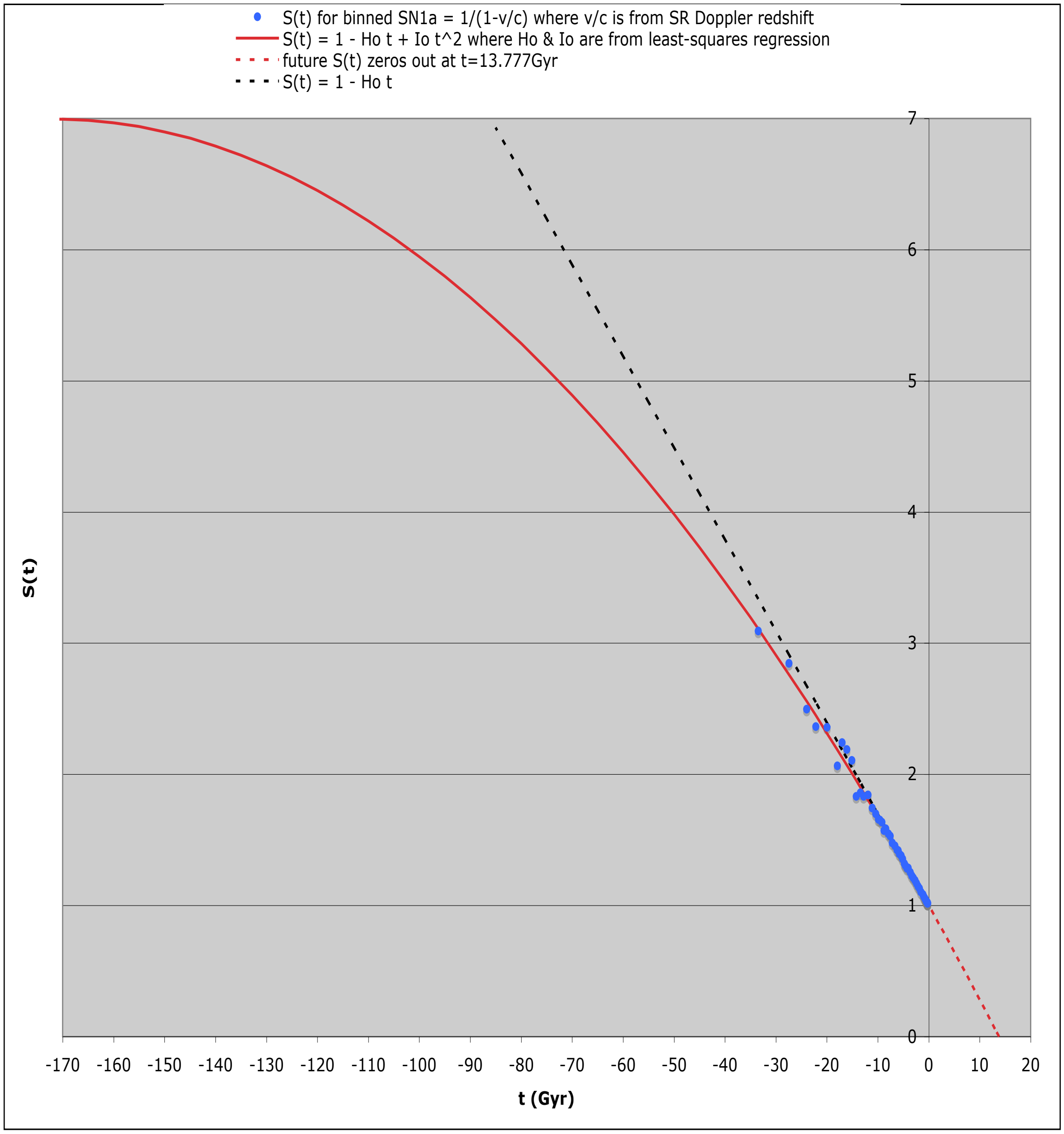

Fig 7 The relationship between scale and time with the present at $t = 0$. Negative time is lookback. Positive times are in the future, and the "crunch" occurs at $t = 13.777$ Gyr. The most distant six bins represent 60 SN1a observations, and all six lie below the linear projection (black dashed line) of H_0, which is the curve's slope at $t = 0$.

In our paradigm, the observer is interpreted to be in a frame that is contracting at a greater rate than that of the observed event due to the accelerated contraction of scale. One may not assume that the observer is in a passive or neutral frame. Instead, by virtue of this accelerated contraction of scale, today's observer, who is accelerating inward *as if from a non-zero radius*, must see a redshift when viewing distant (past) events that, though under the same inward acceleration, were at a lower velocity in the past. The observer is in free fall, and at the present time is falling at relativistic velocity equal to 0.857c in relation to the rest frame at the epoch of stagnation.

3.0 Physical Scale

Let us now assume that there exists a physical radial distance that corresponds to the units of scale. From the previous analysis, we know the period from the stagnation point to the collapse (or bounce). Let us call that time span ΔT. We propose that there exists a physical radius $R_{max} = c\Delta T = 185.588$ Gly. Reflecting on our initial assumption that $D = cLB = -ct$, this hypothesis maintains a certain consistency between distance and time. It purports to represent a causal or kinematic limit that is explicitly based on the speed of light, c. (The actual size of the universe may be far greater.) In this case, light emitted when the radius was at maximum observable scale would just reach an observer at the epoch of minimum scale when $R(t) = 0$.

Now we define a proportionality constant $r_s = R_{max}/S_{max} = 185.588/6.995 = 26.530$ Gly per unit of scale. From that it follows that $R(t) = r_s S(t)$. At $t = 0$, when $S(t) = 1$, $R_0 = r_s S(t) = 26.530$ Gly. Of course, it follows that $dR(t)/dS(t) = r_s$.

Following on Equation 5, we have $R(t) = r_s S(t) = r_s(I_0 t^2 - H_0 t + 1)$. Entering the value for r_s from the previous paragraph and the values for H_0 and I_0 from Table I, we have:

$$\boldsymbol{R(t) = 26.5305 - 1.851536t - 0.00538827t^2}. \quad \textbf{[Eq 8]}$$

Figure 8 depicts $R(t)$ from Equation 8. For the SN1a data, $R(t) = r_s S(t)$, where $S(t)$ for each SN1a bin is calculated from $1/(1-v/c)$, with v/c coming from the bin's mean z using SR.

The 1st derivative of $R(t)$ is

$$\boldsymbol{dR(t)/dt = -1.85154 - 0.0107765t}. \quad \textbf{[Eq 9]}$$

The 2nd derivative of $R(t)$ represents the accelerated contraction of the radius:

$$\boldsymbol{A = d^2R/dt^2 = -0.0107765\ \text{Gly/Gyr}^2}. \quad \textbf{[Eq 10]}$$

That is, the radius is contracting at the fixed rate of acceleration, A. This rate is independent of scale.

From that, we see that the present value ($t = 0$) of $dR/dt = -1.85154$ Gly/Gyr, so the present radius, now at $R_0 = 26.530$ Gly, is contracting – away from the stagnation rest frame which was at $R(t) = 185.588$ Gly – at well over the speed of light.

It is worth noting the difference between v/c and dR/dt. The ratio v/c, as discussed above, is derived from z based on SR, but - per our postulate - reflects changes in *scale* over discrete intervals of time (Figure 5). In contrast, dR/dt is the rate the radial *length* is changing at a moment in time.

Keeping time in relation to the present ($t = 0$), then as t approaches 13.777 Gyr, $R(t)$ approaches zero, and dR/dt, per Equation 9, will approach $-2.0c$ with respect to the stagnation epoch. This contrasts with the observed recessional velocity from Section 2.2, which is limited by c.

3.1 Distance Then and Distance Now

For an observed distance D_0 from an SN1a event, calculation of the distance then (D_{THEN}) between the hypothetical observer and the SN1a at the time of the event, as well as the

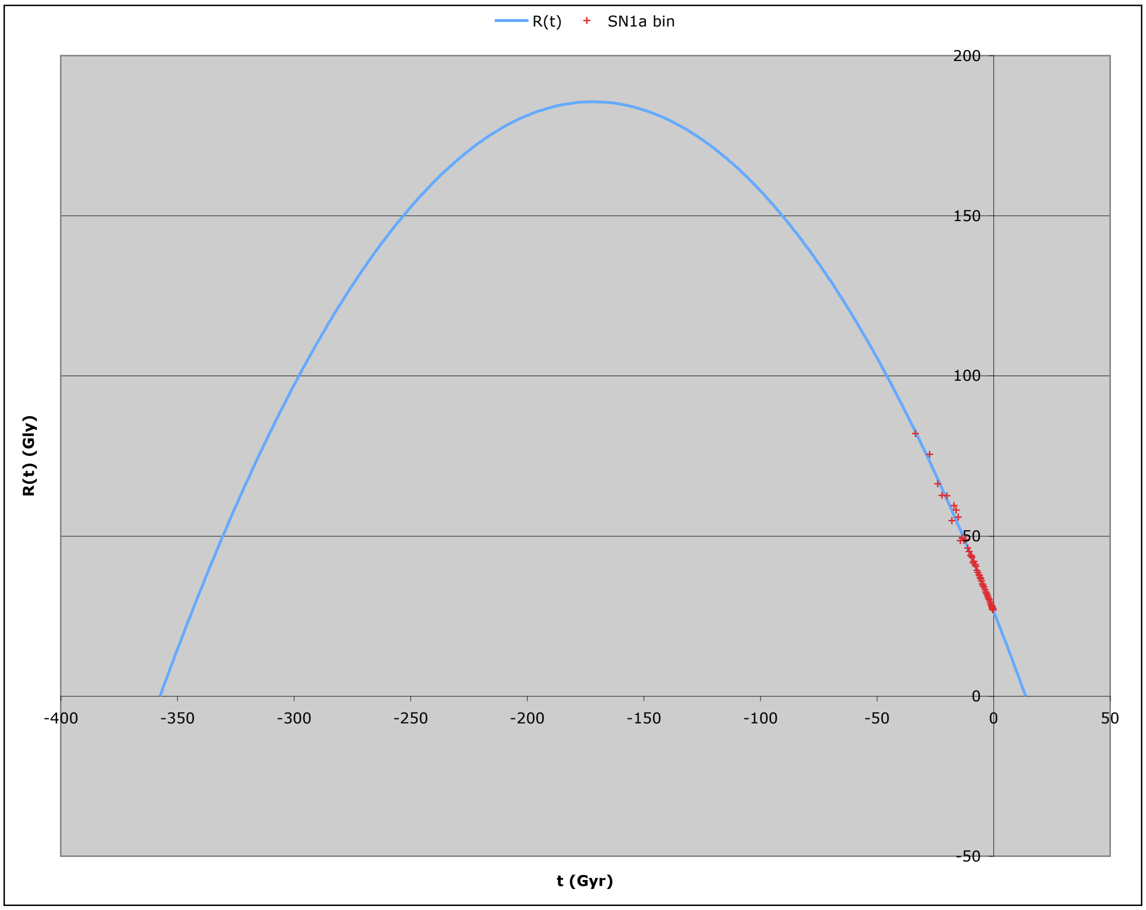

Fig 8 $R(t) = 26.5305 - 1.851536t - 0.00538827t^2$

distance now (D_{NOW}) between any relics of the event and the observer now, are obtained by solving two simultaneous equations:

(1) $D_{THEN}/D_{NOW} = S_e$
(2) $D_{THEN} - D_{NOW} = D_0$

Note that $D_0 = -ct$, the distance the light has traveled from the event to the observer during the time between D_{THEN} and D_{NOW}.

From these, it follows that
(2b) $D_{THEN} = D_0 + D_{NOW}$ and then

(1b) $(D_0 + D_{NOW})/D_{NOW} = S_e$ or
`
(1c) $D_{NOW} = D_0/(S_e - 1)$

For example, let D_0 = 40 Gly, so that t = -40 Gyr. Using Eq 5 for scale, we obtain S_e = 3.4666, so from (1c) D_{NOW} = 16.217 Gly, and from (2b) D_{THEN} = 56.217 Gly. This example is illustrated in Fig 9.

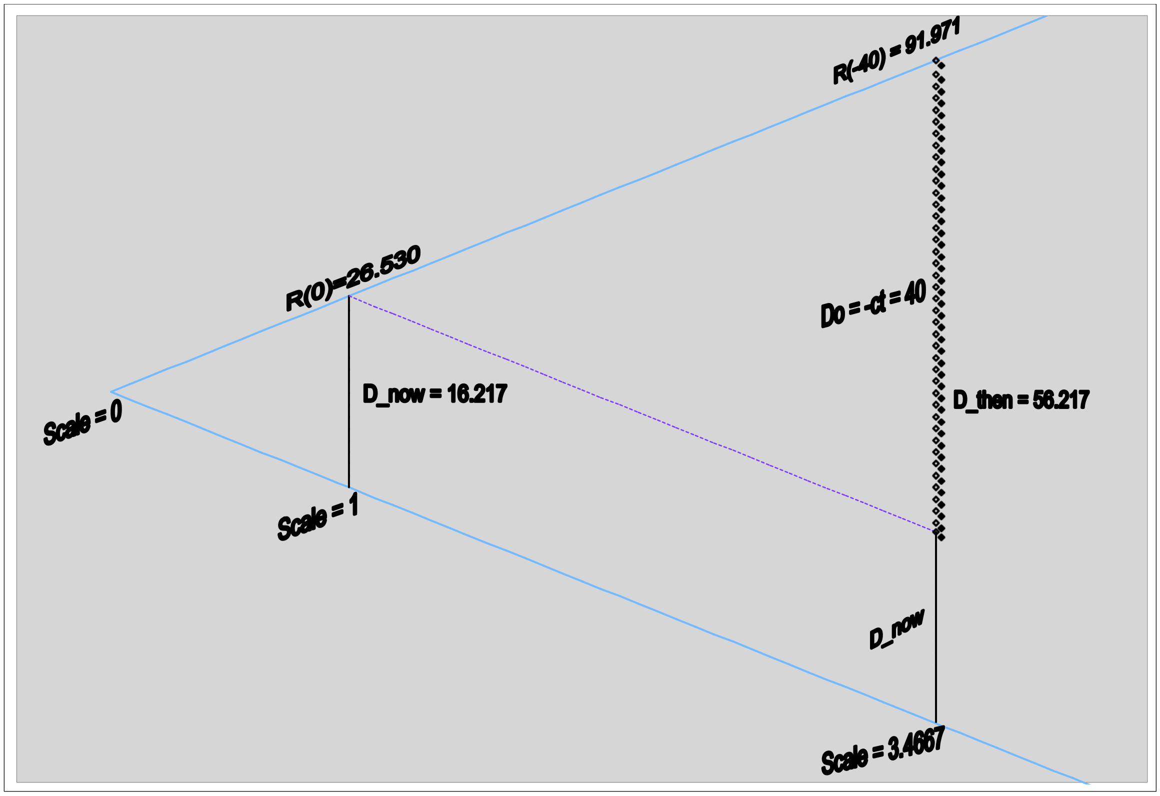

Fig 9 This is an illustration of the relationships between D_0, D_{THEN}, and D_{NOW} for the case of observed distance equal to 40 Gly. This meets the two criteria: (1) D_{THEN}/D_{NOW} = Se = 3.4667 (scale at the time of the SN1a event); and (2) $D_{THEN} - D_{NOW}$ = 40 Gly. At the time of the event, the SN1a was at a distance of 56.217 Gly from the observer's concurrent location. During the time it took for that distance to contract to 16.217 Gly, the light will have traveled 40 Gly.

3.2 The Observable Universe

We suggest that the limit of the observable cosmos is where the parabola for $R(t)$ intersects a line of slope = -1, back in time from the present (Figure 10). Thus, $R(t) - R_0 = \Delta R$ and $\Delta R = c\Delta t = D_0$ at that point of intersection. D_0 must be less than or equal to ΔR in order to be potentially visible. Beyond that distance the light from an event would not yet have reached the observer. When the observer would theoretically arrive at the point where $R(t)$ approaches zero, the epoch of stagnation at the apex of $R(t)$ would just then become visible.

Also, there would have been an epoch in the past where that 45-degree line would be tangent to $R(t)$, namely where $dR/dt = -1$. Using the derivative of $R(t)$ (Eq. 3), it is easy to calculate that at that point $t = (1 - R_0H_0)/2R_0I_0 =$ -79.016 Gyr. For a hypothetical observer at that lookback time or earlier, there would exist no observable history; the cosmos would appear as devoid of distant stars or galaxies.

At present, we could potentially see back to the epoch at 13.777 Gyr after the stagnation point when t = -158.035 Gyr, or where observed distance D_0 equals 158.035 Gly and $R(t)$ equals 184.566 Gly.

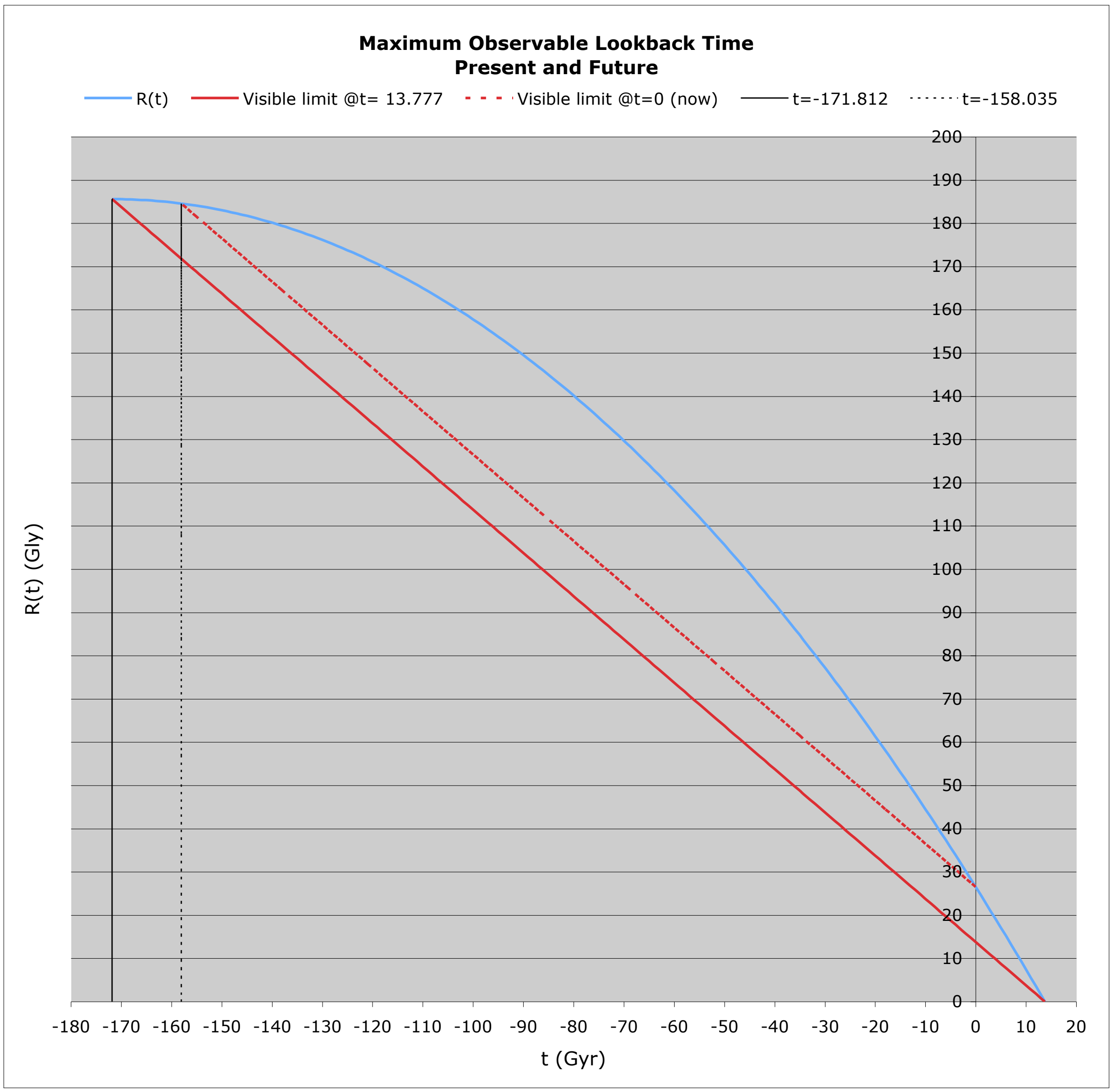

Fig 10 The limits of potential observation for the present scale and for the future at R(t) = 0 at t = 13.777 Gyr.

Applying the method of the previous section for calculating D_{NOW} for that D_0, one obtains 26.530 Gly, which is also equal to the radius now. The result for D_{THEN} is

184.566 Gly, which also matches the radius then. These matches occur only for the limit of visibility. Thus, the most distant causally connected objects, by virtue of their being observable (the so-called particle horizon), are now at a distance of 26.530 Gly.

Whether the observed CMB may somehow correspond to our proposed limit of visibility is beyond our scope. Certainly, our visibility distance does not match the distance reported by the big bang theory, where the CMB is calculated to be about 46 Gly distant. An interesting paper by Bonnet-Bidaud explores the uncertainties in the conventional interpretation of the CMB and presents several alternative interpretations [9].

The equality between the 13.777 Gyr time interval between the stagnation point and the limit of visibility on the one hand, and the 13.777 Gyr time interval from the present to the future collapse on the other hand (discussed in Section 2.4), can be algebraically demonstrated, and this equality is characteristic of parabolas. What is most interesting is the coincidence between our 13.777 Gyr results (again, the1-sigma range is 13.403 to 14.180) and the conventional big bang age of the universe, which is currently estimated to be 13.799 Gyr (sigma = 0.021). The precision of this match is intriguing, despite the fundamental conflicts between the two theories.

3.3 MOND Acceleration

MOND refers to modified Newtonian dynamics. This phenomenology originates with Mordehai Milgrom in 1983, and it remains a field of very active research. The theory is that there exists an inward acceleration, beyond Newtonian gravitational acceleration based on ordinary matter, that causes the size evolution of rotating galaxies to stick together more than would be expected based on the observable masses and rotational rates of those bodies. Many detailed analyses have studied the MOND acceleration, for example [10]. It portends an alternative to hypothesized dark matter. But MOND acceleration has not been derived in the context of any general physical or cosmological structure, so it is referred to as phenomenological. An overview and discussion of MOND is provided by McGaugh [11]. Additional background is provided by Sanders [12][13].

It is extremely interesting that our SN1a derived values for A (Equation 9 and Table II) match the values independently estimated for MOND acceleration, a_0, based on galactic observations. Milgrom estimates a_0 at 1.2(±0.2)E-10 m/s^2 while McGaugh *et al* estimate it is 1.2±0.02 (random) and ±0.24 (systematic) E-10 m/s^2 [14][15]. Zhou estimates it at 1.02±0.02(random) E-10 m/s^2 [16]. Both McGaugh and Zhou use a dataset consisting of 2693 data points (stars) within 147 galaxies included in the Spitzer Photometry and Accurate Rotation Curves (SPARC) dataset. Astoundingly, the Zhou estimate based on these galaxies precisely matches our cosmologically determined value (Table II). Please note that our value was estimated long before we were even aware of MOND.

While the dimensions of a galaxy are about three orders of magnitude smaller than the closest SN1a in the SCP union2.1 dataset, the resulting universal acceleration rates are an accurate match. Thus, we offer a broad cosmological basis for a_0 based on SN1a observations as distant as 40 Gly (proper distance). Conversely, MOND's estimated universal a_0 serves as empirical support for our theory of universal contraction.

4.0 Summary

Our paradigm assumes that light travels though the cosmos at the rate *c*, *independent of scale*. Thus, observed distance, *D*, equals $cLB = -ct$.

Table II
Results of derivations of *A* (acceleration)

SCP data (release date)	Present Radius (Gly)	Present Radius (m)	*A* (Gly/Gyr^2)	*A* (m/s^2)
Union1 (2008)	26.858	2.5409 e+26	0.0107623	1.0238 e-10
Union2 (2010)	26.766	2.5323 e+26	0.0103789	9.8733 e-11
Union2.1 (2011)	26.717	2.5276 e+26	0.0106682	1.0149 e-10
Union2.1 Binned	26.530	2.5100 e+26	0.0107765	1.0252 e-10
Observed refs[14][15] ref [16]	--	--	--	(MOND) 1.2e-10 1.02e-10

Once the *scale to redshift proportionality is abandoned*, the door is open for alternative interpretations of redshift. With special relativity, the redshift is dependent on the relative velocity of recession of the observer with respect to the observed past *events*, not the objects as they are now. We hold that the special relativistic Doppler velocity from *z* is valid on a cosmic scale.

The observer is at a nonzero radius, under constant *free fall* acceleration. Recession, in itself, has no *a priori* direction in scale, and requires only that the observer is moving away from the location of the observed *event*, even though the object or its artifacts may be moving closer to the observer. (This is a beauty of SN1a, that they offer a snapshot in cosmic time rather than a continuous process.)

Our postulated scale relationship is consistent with a contracting universe. The expansion and contraction follows the familiar pattern of the parabola, which reflects an initial motion (velocity) under the influence of our empirically based constant acceleration (or deceleration), like a projectile in a realm of constant *G*. But instead of an object being elevated, we have a radial expansion peaking at an apex followed by an accelerated contraction. The period of the posited cycle of the universe's expansion and contraction is about 371 Gyr. The current phase of accelerated contraction will continue for a remaining period of 13.777 Gyr. The parabolic pattern suggests a bounce paradigm.

MOND acceleration a_0 matches our derived acceleration A**,** where both are treated as universal constants. We propose that our A is the cosmological key to MOND phenomenology.

The highest possible observed cosmological redshift with reference to the present would have a z+1 value of about 3.59 based on our present recessional velocity of 0.856c with respect to the limit of visibility. The upper bound at 1-sigma is 4.16, and at 2-sigma is 5.29. On that basis, we can make one prediction with 95% confidence:

PREDICTION: *No SN1a will ever be observed with a* z+1 *greater than 5.3*.

For comparison, the highest redshift of any SN1a in the SCP union2.1 release has z+1 = 2.41.

We consider SN1a to be the gold standard for redshift. On that basis, we suggest that z+1 values reported in the literature that are higher than 5.3 for distant galaxies should be re-examined in terms of galactic morphological explanations in the context of our much relaxed time constraints.

Further Research

It seems natural to think there must be a relationship between our universal acceleration rate and Newton's G. It's not only Newton's G, but Einstein's, as Einstein had the basic insight defining the equivalence principal, that gravitational acceleration cannot be distinguished from acceleration against inertia. We did, in fact, derive G from our A, the accelerated contraction of the universe [17]. The derived value for G was about 12% below the accepted value of G. While that was fairly accurate given the uncertainties of the input values, including the baryonic density, our equation for G seemed to imply that G would be decreasing over time at a rate that was inconsistent with the constraints put on (dG/dt)/G produced by the laser lunar ranging project [18].

Despite that outcome, if there is in fact such a universal contractive acceleration, it seems there must be a connection with G. So that is an area for further research.

Another area for further research involves MOND theory. It may be productive to explore the potential for our theory of universal accelerating contraction to contribute to the development of MOND theory.

Final Comments

The work presented here is the product of research conducted independently by one individual. As Thomas Kuhn has observed in his seminal work, *The Structure of Scientific Revolutions*, new paradigms are usually discovered by either young professionals in the field, or by outsiders [19]. I am not among the former group.

In conclusion, my derivations of H_0 and A are supported by empirical data. The precise match between MOND's universal acceleration and my cosmic acceleration lends support to my theory of accelerated contraction of the cosmos.

I hope that there will be, among both MOND theorists and others in the broad community of cosmologists, those who are willing to seriously consider whether this paradigm may offer a plausible alternative to that of the prevailing big bang theory, which I believe an objective observer should consider to be very vulnerable. Despite its successes, 95% of the universe is a persistent mystery according to that theory. The phantom dark matter has been with us for half a century, and dark energy has never been detected. Galactic behavior cannot be adequately accounted for, and the time requirements estimated for the evolution of galaxies presses against the BB's estimated age of the universe. Moreover, the required inflation theory is no longer supported by one of its prominent originators. As Kuhn has said, "paradigm-testing occurs only after persistent failure to solve a noteworthy puzzle has given rise to crisis." Yet the scientific community seems very far indeed from *perceiving* a crisis.

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List of Figures

Figure 1. The dependent variable for the regression equation $v/(c\text{-}v) = 0.069755D - 0.00019965D^2$ is based on computed SR velocities using all 580 SN1a in the Union2.1 data (error bars reflect conversions to Gly after adding in Union2.1 reported distance modulus error terms).

Figure 2. The solid line represents the regression equation: $v/(c\text{-}v) = 0.069789D - 0.00020310D^2$, with $R^2 = 99.66\%$, using SR velocities computed from binned SN1a data. Note the close match of the furthest bin to the estimated value, and that the furthest six bins (representing 60 stars) all lie below the linear Hubble curve (dashed line) and near the quadratic curve.

Figure 3. Close-up view of the error terms for observations near the origin, per Fig 2.

Figure 4. Illustration of $S_e = 1/(1\text{-}v/c)$

Figure 5. Illustration of $v/c = (S_e - 1)/S_e$, with $S_0 = 1$.

Figure 6. The relationship between redshift and scale at emission is $z + 1 = (2S_e - 1)^{0.5}$, with the observer in the present at $S_0 = 1$

Figure 7. The relationship between scale and time with the present at $t = 0$. Negative time is lookback. Positive times are in the future, and the "crunch" occurs at $t = 13.777$ Gyr. The most distant six bins represent 60 SN1a observations, and all six lie below the linear projection (black dashed line) of H_0, which is the curve's slope at $t = 0$.

Figure 8. $R(t) = 26.5305 - 1.851536t - 0.00538827t^2$

Figure 9. This is an illustration of the relationships between D_0, D_{THEN}, and D_{NOW} for the case of observed distance equal to 40 Gly. This meets the two criteria: (1) $D_{\mathrm{THEN}}/D_{\mathrm{NOW}}$ = Se = 3.4667 (scale at the time of the SN1a event); and (2) $D_{\mathrm{THEN}} - D_{\mathrm{NOW}} = 40$ Gly. At the time of the event, the SN1a was at a distance of 56.217 Gly from the observer's concurrent location. During the time it took for that distance to contract to 16.217 Gly, the light will have traveled 40 Gly.

Figure 10. The limits of potential observation for the present scale and for the future at R(t) = 0 at t = 13.777 Gyr.

List of Tables