On the Advantages of a Different Redshift Scale-Factor Relation and the Basis of a New Cosmology

ABSTRACT

In the 25 years following the introduction of dark energy to cosmology there has been little progress in understanding this phenomenon. A radical solution is considered - to change the redshift scale-factor relation. The new relation explains why Concordance Cosmology, using the wrong relation, needs a low matter density and dark energy. An alternative cosmology is described that explains how the new relation comes about. There are solutions to the flatness problem, the coincidence problem and the Hubble tension.

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INTRODUCTION

Since the 1990s there has been apparently increasing evidence for a universe with dark matter, dark energy and a period of inflation - the LCDM model. The model has (until recently) matched observational data well, although there are many variable parameters.

The main features are that LCDM is a solution of Einstein's equations

$$\frac{\ddot{a}}{a} = \frac{-4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) + \frac{\Lambda c^2}{3} \qquad (1)$$

$$\left(\frac{\dot{a}}{a}\right)^2 + \frac{kc^2}{a^2} = \frac{8\pi G\rho + \Lambda c^2}{3} \qquad (2)$$

Where the scale factor a is related to redshift as

$$a = \frac{1}{1+z} \qquad (3)$$

LCDM finds, apparently, from observational data, a low matter density Ω_m of about 0.3 and a dark energy parameter Ω_Λ for a flat universe, of 0.7

$$\Omega_m = \frac{\rho}{\rho_{crit}} \qquad (4)$$

where the critical density is

$$\rho_{crit} = \frac{3H(z)^2}{8\pi G} \qquad (5)$$

and $H(z) = \left(\frac{\dot{a}}{a}\right)$ (6)

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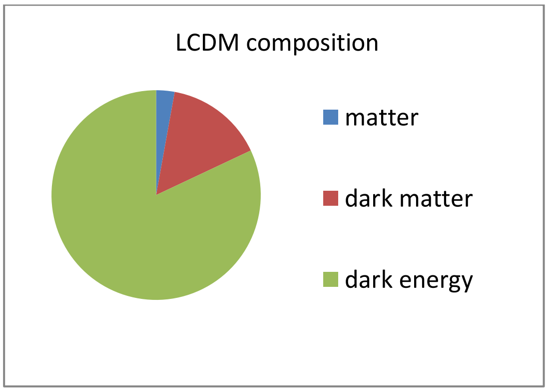
Figure 1 Composition of the universe, LCDM



However the Hubble tension and other tensions, have become challenging for LCDM, [Riess, 2020]. There is also the unexplained nature of the dark energy and the coincidence problem.

These difficulties perhaps indicate that an alternative approach is required.

The layout of this paper is as follows. In section 1 the alternative relation is introduced. By considering supernovae data and the clusters of galaxies, it's shown how LCDM (using a wrong relation), could incorrectly infer a low matter density and a cosmological constant.

In section 2 it's shown how the alternative approach can resolve the Hubble tension.

Section 3 describes a possible reason for the new relation and an alternative cosmological model.

Section 1. The Alternative relation

For an expanding universe, with constant expansion parameter

$$\frac{\dot{a}}{a} = H \qquad (7)$$

and for a flat universe, equations (1) and (2) reduce to

$$3H^2 = -4\pi G\left(\rho + \frac{3p}{c^2}\right) + \Lambda c^2 \qquad (8)$$

$$3H^2 = 8\pi G\rho + \Lambda c^2 \qquad (9)$$

with the cosmological constant $\Lambda = 0$,

$$\rho = \frac{3H^2}{8\pi G} \qquad (10)$$

the universe is at the critical density, $\Omega_m = 1$.

and

$$p = -\rho c^2 \qquad (11)$$

It's shown that this solution with the alternative redshift scale-factor relation

$$a = \frac{1}{\sqrt{1+z}} \qquad (12)$$

has some advantages. A possible reason for the new relation is in section 3.

From (7) and (12)

$$1 + z = e^{2Ht} = \frac{1}{a^2} \qquad (13)$$

(with the convention from cosmology that positive times are into the past).

1.1 The Redshift of light

An object, a distance d away, would have an apparent velocity v, depending on the redshift.

$$\frac{v}{c} = z = e^{2Hd/c} - 1 \approx \frac{2Hd}{c} \qquad (14)$$

$$v = 2Hd \qquad (15)$$

comparing with Hubble's law, the expansion constant H is half of the Hubble constant H_0, approximately 37.5 kms^{-1}Mpc^{-1}

$$H = \frac{H_0}{2} \qquad (16)$$

The Hubble parameter h is also halved.

1.2 The Flatness and coincidence problems.

The flatness problem does not occur. The universe is always naturally at critical density, $\Omega_m = 1$ and $\Omega_\Lambda = 0$. The coincidence problem (that LCDM leaves unexplained) does not occur.

However let's see what LCDM would conclude, from (4), (5) and (10), repeated below

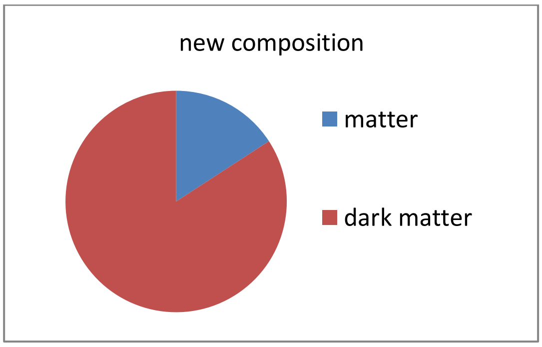
$$\Omega_m = \frac{\rho}{\rho_{crit}} \qquad (4)$$

$$\rho_{crit} = \frac{3H(z)^2}{8\pi G} \qquad (5)$$

$$\rho = \frac{3H^2}{8\pi G} \qquad (10)$$

Since the $H(z)$ used in (5), would be twice the true value, then the denominator of (4), would be four times too large, so LCDM would conclude, incorrectly, from some observations (below), that $\Omega_m = 0.25$ (although really 1.0), Figure 2

Figure 2 Composition of the universe (new)



1.3 Abundancies of the elements

Measurements of deuterium abundance from quasars and Big Bang nuclear synthesis (BBN) give the baryon density $\Omega_b h^2 = 0.024$ [Tytler, 1996]. With the new value for h of about 0.375, half of the traditional value, the new value for Ω_b is four times larger, about 17% of the universe.

1.4 The Matter density

LCDM has apparent evidence for a low matter density. Late universe, low redshift evidence for a low matter density (around 0.25) comes from the motion of stars around galaxies and from clusters of galaxies [Ferramacho, 2006] and [Allen, 2007].

The low matter density was inferred from the X-ray gas mass fraction. The matter density is from

$$\Omega_m = \frac{\Omega_b}{f_{gas}(1+0.19h^{0.5})} \qquad (17)$$

[Allen, 2002] The denominator contains h and the term f_{gas} that's determined by measuring the mass of gas in a cluster from X-ray luminosity and the total mass of the cluster. An estimate of f_{gas} was required.

The main change needed, however, would be to the numerator. Ω_b is calculated from an $\Omega_b h^2$ value of 0.024, obtained from the Deuterium to Hydrogen ratio in quasars. Hence Ω_b should be four times larger, this increases Ω_m by a similar factor to approximately 1.0.

1.5 Supernovae data

A new formula for luminosity distance is derived in Appendix A

$$D_L = \frac{2c}{H_0}(1+z)(\sqrt{1+z}-1) \qquad (18)$$

Plotting the distance moduli for supernovae binned data [Betoule, 2014] gives Figure 3 (top), with an enlargement (bottom). It shows the new relation, top curve. LCDM with a matter density of 0.3 is the middle curve, and matter density of 1.0 is the bottom curve.

LCDM has two variable parameters, Ωm and H_0. The new relation has only one, H_0.

Let's look at binomial expansions for LCDM and the new relation. For the new relation

$$D_M = \frac{c}{2H}\left(z - \frac{z^2}{4} + \cdots\right) \qquad (19)$$

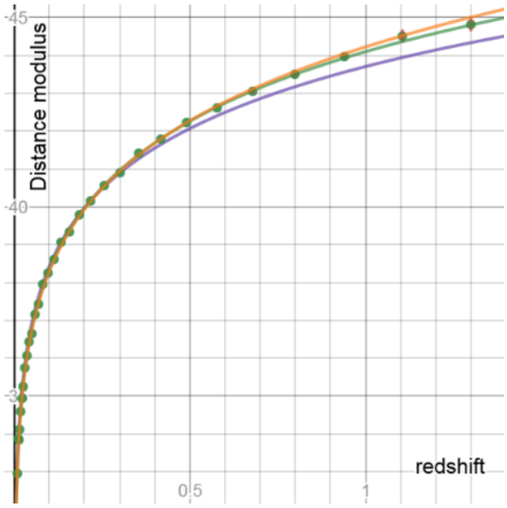
For LCDM

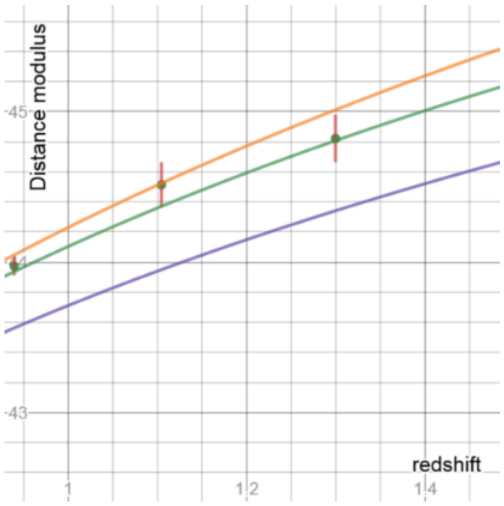
$$D_M = \frac{c}{H_0}\left(z - \frac{3mz^2}{4} + \cdots\right) \qquad (20)$$

Details are in Appendix B. By comparing (19) and (20) there is a match if $3m = 1$, where m is short for Ωm . Most of the data points are at low values of z, so if LCDM is not correct but is varying the matter density to match (19), we would expect it to predict an Ωm value of about 1/3.

The matter density inferred from supernovae [Abbot, 2018] is 0.331.

Figure 3 New relation, LCDM Ωm = 0.3 and 1.0





1.6 Anisotropies in the CMBR

WMAP9 [Hinshaw, 2012] finds Ω_m= 0.2815 from $\Omega_m h^2$ = 0.1368 $\pm$ 0.005 and a h value of 0.697 $\pm$ 0.02. If h is halved, Ω_m becomes four times as large, giving an Ω_m value of 1.126 $\pm$ 0.10.

There is a similar situation for PLANCK data.

Data from early universe studies and those calibrated with supernovae (such as BAO or the Cosmic Chronometer method) tend to give matter density values towards 0.33, values from local studies and lensing give approximately 0.25

Often studies combine data from different methods and find a value between 0.25 and 0.33. In a flat universe Ω_Λ is wrongly deduced by LCDM to be about 0.7, but is really 0.

It's possible that there has been a serious and longstanding error with our redshift scale-factor relation, starting shortly after the development of General Relativity in about 1920.

Section 2. The Hubble Tension

Below, the value for H_0 is derived in three different ways, from CMB data, BAO and the local distance ladder. Compatibility is found at 75-76 kms^{-1}Mpc^{-1}.

2.1 The CMB data of PLANCK and WMAP

From Planck data [Aghanim, 2018], $\Omega_m h^2$ = 0.1430 with the new relation we assume that $\Omega_m = 1$, then $h = 0.37815$ and $H_0 = 75.63$ kms^{-1}Mpc^{-1}

From WMAP [Hinshaw, 2012], the values are $\Omega_m h^2 = 0.1367$, if $\Omega_m = 1$ then $h = 0.3697$ and $H_0 = 73.95$ kms^{-1}Mpc^{-1}

We can see why the value of H_0 from the CMB data is too low, it's due to the faulty Ω_m value. If we calculate it from $\Omega_m h^2$ = 0.1430 as above, but this time using the value for Ω_m of 0.316 [Aghanim, 2018], (slightly below 1/3 from trying to match supernovae data), then the value obtained is $H_0 = 67.3$ kms^{-1}Mpc^{-1}

2.2 BAO measurements

BAO measurements parallel to the line of sight constrain $H(z)$. Due to the changes made in Appendix A, the comoving distance for LCDM

$$D_M = \int_0^z \frac{c}{H(z)} dz \tag{21}$$

becomes

$$D_M = \int_0^z \frac{c}{2H\sqrt{1+z}} dz \tag{22}$$

and we can determine the real expansion parameter by putting

$$\frac{c}{2H_{true}\sqrt{1+z}} = \frac{c}{H_{LCDM}(z)} \tag{23}$$

The data point with lowest standard deviation [Aubourg, 2015] is at $z = 0.57$, the modelling of LCDM would need to pass near that point, so

$$2H_{true}\sqrt{1.57} = H_{LCDM}(0.57) \tag{24}$$

$$H(z) = H_0\sqrt{\Omega_m(1+z)^3 + \Omega_k(1+z)^2 + \Omega_\Lambda} \tag{25}$$

with $\Omega_m = 0.316$, $\Omega_k = 0$

$$H_{LCDM}(0.57) = 67.3\sqrt{0.316(1.57)^3 + 1 - 0.316}$$

$2H_{true} = 74.2$ kms^{-1}Mpc^{-1}

This depends on the parameters used, the above parameters are from Planck data.

BAO is not used alone to find H_0, the method is often used with supernovae or CMB data, but typically it's found that (23) makes $2H_{true}$ about 9 to 11% larger than previous BAO results, about 74.2 ± 1.2 kms^{-1}Mpc^{-1}

2.3 Direct local distance method

Riess [Riess, 2019] recently measured the value of H_0 directly and found 74.03 kms^{-1}Mpc^{-1}. A deceleration parameter of $q = -0.55$ was used. Using $q = -1$ raises the distance ladder value to approximately 75 kms^{-1}Mpc^{-1} (Appendix C)

2.4 A combined estimate for the Hubble constant

The data from the methods above and lensing data from H0LiCOW [Wong, 2019] are summarised in Table 1.

Table 1 Values of the Hubble constant

Method	The Hubble Constant (kms^{-1}Mpc^{-1})
CMB (WMAP)	73.95 ± 1.4
CMB (Planck)	75.63 ± 0.29
BAO	74.2 ± 1.2
Local	75.06 ± 1.4
Lensing	73.3 ± 1.7

The errors in the CMB measurements have been lowered as now the only uncertainty is from the measurement of $\Omega_m h^2$, for Planck it's as low as 0.0011.

The amended CMB method from Planck is most precise and agreement can be found at a value for H_0 of about 75-76 kms^{-1}Mpc^{-1}.

The new redshift scale-factor relation enables us to understand the Hubble tension and also why LCDM seems to require dark energy.

In the next section a reason for the different relation is proposed and the basis of an alternative cosmological model is described.

Section 3. Towards a new cosmology

A reason is given why the alternative redshift scale-factor relation could be true.

In LCDM the scale factor determines the distance between galaxies - there is now an important distinction with the new model.

The changing scale factor a now applies not only to space, but to matter too, and all distances. This includes atoms, people, the sizes of stars, galaxies and the distances between all objects – they all now depend on the scale factor. All physical constants which contain length dimensions are changed by the changing scale factor too.

Every quantity Q with n length dimensions changes according to Qa^n so, for example

Table 2 Changes of physical quantities

Physical Quantity	**Change with time**
Planck's constant h	he^{2Ht}
Masses m	m constant
Fine structure constant α	α constant
Gravitational constant G	Ge^{3Ht}
Pressure p	pe^{-Ht}
Speed of light c	ce^{Ht}
Density ρ	ρe^{-3Ht}

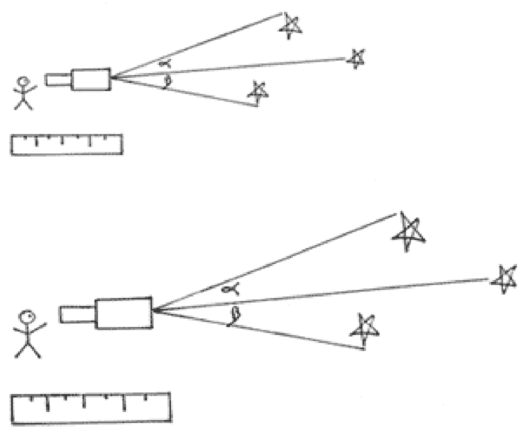
With t in the table being positive into the future.

With this system all measurable quantities and all physics equations remain unchanged as time passes. It's global conformal transformation, a continuous and ongoing expansion.

This model universe is expanding yet static. Expanding in the sense that there is a continuous expansion (of all length scales) – but static in the sense that it would be impossible for any observer to measure the expansion locally. For them the universe could be regarded as static - for example G appears constant in time if measured locally.

Measurements at a distance would also yield a null result. If we tried to measure any change in the fine structure constant α [Murphy, 2016], for distant stars, since Plancks constant h, the relative permittivity of free space ε_0 and the speed of light c all change, the exponential factors cancel and α is left unchanged.

Figure 4 Cartoon to show the expanding universe



The universe would always appear to be at critical density from (10), if the correct value of the expansion constant H is used.

3.1 Redshift

The continuing expansion of all length scales causes a redshift as follows.

If the energy of a photon emitted (subscript 1) from a distant star towards an observer is conserved.

$$h_0 f_0 = h_1 f_1 \quad (26)$$

Since Planck's constant was lower in the past, there is a redshift of received light according to

$$f_0 = f_1 \frac{h_1}{h_0} \tag{27}$$

$$\lambda_0 = \lambda_1 e^{2Ht} \tag{28}$$

This leads to a new redshift scale-factor relation. The redshift of received light is given by

$$z = \frac{\lambda_1 e^{2Ht} - \lambda_1}{\lambda_1} \tag{29}$$

$$1 + z = e^{2Ht} = \frac{1}{a^2} \tag{30}$$

so

$$a = \frac{1}{\sqrt{1+z}} \tag{31}$$

An object, a distance d away, would have an apparent velocity v, depending on the redshift.

$$\frac{v}{c} = z = e^{2Hd/c} - 1 \approx \frac{2Hd}{c} \tag{32}$$

$$v = 2Hd \tag{33}$$

comparing with Hubble's law, the expansion constant is half of the Hubble constant approximately 37.5 $\mathrm{kms^{-1}Mpc^{-1}}$

$$H = \frac{H_0}{2} \tag{34}$$

The same equations as (12-16) of section 1.

3.2 Gravity

In Appendix D it's suggested that gravity is *caused* by the expansion, with G having the value to conserve energy as the expansion occurs, giving a very natural explanation of why the universe is at critical density, equation (10) .

It's also suggested that the strength of gravity reduces when the mass to radius ratio of a region of matter approaches c^2/G.

Although apparently static on the largest scales, in this model there is a great deal of motion on a smaller scale. The Big Bangs occur when large quantities of matter collapse under gravity and then 'bounce'. So although apparently static in terms of scale factor, the universe is in a dynamic equilibrium.

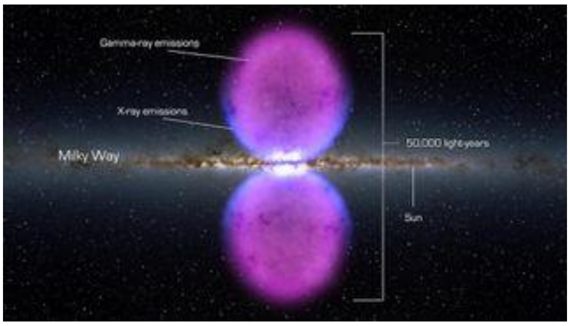
An outward pressure is generated by these 'bounces' preventing the universe from collapsing inwards and allowing it to remain static on the large scale.

The universe is eternal in this model, with no beginning. The age of the oldest stars would be limited, however, by the time it takes for regions of matter such as galaxies to collapse and bounce.

The horizon problem is a problem for the Big Bang model, with a definite start of time. In the new model there is no beginning of time, and no particular single Big Bang event, although there would have been many enormous explosive events, and perhaps one larger than the others.

Other problems faced by LCDM might be overcome by this approach. The James Webb Space Telescope (JWST) has recently discovered what's been called 'impossible early galaxies' [Treu, 2022]. In an eternal universe these 'early' galaxies could exist.

Figure 5 The Fermi bubbles



The gigantic Fermi Bubbles, Figure 5, approximately the same size as the Milky Way, whose origin isn't understood, may be fuelled by a strong outflow of matter. (Image credit: Nasa Goddard).

Phenomena such as galactic jets, and other bouncing, or ejection phenomena, throughout the entire universe, may be able to mimic the successes of Big Bang Theory such as the Cosmic Microwave Background Radiation and the abundancies of the elements.

The growth of structure is discussed in Appendix E.

Summary

It is possible that there has been a serious and longstanding misunderstanding of the redshift scale-factor relation, starting in about 1920. A different redshift scale-factor relation and a new cosmological model is proposed. The Hubble tension occurring in LCDM could be due to the faulty relation.

The advantages of the new model are as follows. It is simple philosophically, with time symmetry (Appendix F) and scaling symmetry. There is no need for a cosmological constant, dark energy or inflation and no coincidence problem. The flatness and horizon problems are naturally solved.

References

Abbott T (2018) "First Cosmology Results using Type Ia Supernovae from the Dark Energy Survey: Constraints on Cosmological Parameters" arXiv:1811.02374

Aghanim N (2018) "Planck 2018 results. VI. Cosmological parameters" arXiv:1807.06209

Allen S (2002) "Cosmological constraints from the X-ray gas mass fraction…" MNRAS 334:L11,2002 arXiv:astro-ph/0205007

Allen (2007) "Improved cosmological constraints on dark energy" arXiv:0706.0033

Aubourg E (2015) "Cosmological Implications of Baryon Acoustic Oscillations" arXiv:1411.1074v3

Betoule M (2014) "Improved Cosmological constraints from a joint analysis of SDSS-II and SNLS supernova samples." arXiv:1401.4064

Ferramacho L (2006) "Gas mass fraction from XMM-Newton…" astro-ph:0609822v2

Guzzo L (2018) "Measuring the Universe with galaxy redshift surveys" arXiv:1803.10814

Hildebrandt (2018) "KiDS+VIKING-450: Cosmic shear tomography…" arXiv: 1812.06076

Hinshaw G (2012) "Nine-Year Wilkinson Microwave Anisotropy Probe…" arXiv:1212.5226

Matsuo K (2013) "Temporal variations in the Earth's Gravity Field from multiple SLR satellites…" cddis.nasa.gov

Murphy M (2016) "Precise limits on cosmological variability of the fine-structure constant…" arXiv:1606.06293

Riess A (2016) "A 2.4% Determination of the Local Value of the Hubble Constant" arXiv:1604.01424

Riess A (2019) "Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant and Stronger Evidence for Physics Beyond ΛCDM" arXiv:1903.07603v2

Riess A (2020) "The expansion of the Universe is Faster than Expected" arXiv:2001.03624

Treu T (2022) "Early Results from Glass-JWST XII. The Morphology of Galaxies…" arXiv:2207.13527

Tytler D (1996) "The Cosmological Baryon Density from the Deuterium Abundance…" arXiv:astro-ph/9603069

Wong K (2019) "H0LiCOW XIII. A 2.4% measurement of H_0 from lensed quasars" arXiv:1907.04869v2

Appendix A. Luminosity distance

$$D_M = \int_t^0 \frac{c}{a(t)} dt \quad \text{(A1)}$$

from (12) $\quad a = \frac{1}{\sqrt{1+Z}} \quad$ (A2)

$$\frac{da}{dt} = \frac{da}{dz} \times \frac{dz}{dt} = -\frac{1}{2(1+z)^{3/2}} \times \frac{dz}{dt} \quad \text{(A3)}$$

$$H(z) = H = \frac{\dot{a}}{a} = \frac{-1}{2(1+z)} \times \frac{dz}{dt} \quad \text{(A4)}$$

$$dt = \frac{-1}{2H(1+z)} dz \quad \text{(A5)}$$

$$D_M = \int_0^z \frac{c}{2H\sqrt{1+z}} dz \quad \text{(A6)}$$

$$D_M = \frac{2c}{H_0}\left(\sqrt{1+z} - 1\right) \quad \text{(A7)}$$

Appendix B. Binomial expansions

$$D_M = \frac{2c}{H_0}(\sqrt{1+z} - 1)$$

for the new relation (A7). Omitting c/H_0 , the binomial expansion, for small z is

$$= 2\left(1 + \frac{1}{2}z - \frac{1}{8}z^2 + \cdots - 1\right) \quad \text{(B1)}$$

$$= z - \frac{1}{4}z^2 \quad \text{(B2)}$$

For LCDM

$$D_M = \int_0^z \frac{c}{H(z)} dz$$

$$= \int_0^z \frac{c}{H_0\sqrt{\Omega_m(1+z)^3 + \Omega_k(1+z)^2 + \Omega_\Lambda}} dz \quad \text{(B3)}$$

a flat universe approximation, again omitting c/H_0 and using m for Ω_m

$$= \int_0^z (m(1+z)^3 + 1 - m)^{-1/2} dz \quad \text{(B4)}$$

$$= \int_0^z (m(1 + 3z + 3z^2 + \cdots) + 1 - m)^{-1/2} dz$$

$$= \int_0^z (1 + 3mz + 3mz^2)^{-1/2} dz \quad \text{(B5)}$$

$$= \int_0^z \left(1 - \frac{3}{2}mz + \cdots\right) dz \quad \text{(B6)}$$

$$= z - \frac{3m}{4}z^2 \quad \text{(B7)}$$

Comparing (B2) and (B7) there is a match for low z if Ω_m is 1/3. Most of the supernovae are at low z.

Appendix C . The Direct local distance method

Riess [Riess, 2019] recently measured the value of H_0 directly and found 74.03 kms^{-1}Mpc^{-1}

Details of the calculations used are in [Riess, 2016]. The derived value for H_0 is proportional to

$$X = 1 + \frac{1}{2}(1 - q_0)z - \frac{1}{6}[1 - q_0 - 3{q_0}^2 + j_0]z^2$$

Equation (C1), see also equations (4) and (5) of [Riess, 2016], q_0 is the deceleration parameter

$$q_0 = -\frac{a\ddot{a}}{\dot{a}^2} \quad \text{(C2)}$$

A value of q_0 of - 0.55 is used to determine the local value of H_0 and a jerk parameter $j_0 = 1$

In the new model from (7)

$$a = e^{-Ht}$$

so $q_0 = -1$ and the jerk parameter is still $j_0 = 1$

For the new model X simplifies to

$$X_{new} = 1 + z \quad \text{(C3)}$$

For the local method it simplifies to

$$X_{local} = 1 + 0.775z - 0.27375z^2 \quad \text{(C4)}$$

X is then determined from 600 supernovae with redshifts between 0.023 and 0.15 (Figure 8 of [Riess, 2016], page 47). The average redshift is approximately $z = 0.06$ and from (C3) and (C4) X_{new}/X_{local} at $z = 0.06$ is 1.01385

So the new estimate of H_0 is 74.03 $\times$ 1.01385 $=$ 75.06 kms^{-1}Mpc^{-1}

Appendix D. The strength of gravity

The type of expansion proposed in this model ensures conservation of energy as the universe expands - (without any slowing of the expansion due to gravity).

Imagine a mass m, it's rest energy varies during the expansion (in the absence of gravity) as

$$mc^2e^{2Ht} \quad \text{(D1)}$$

Energy would not be conserved.

With gravity included however, the total energy of the mass varies as

$$\left(mc^2 - \frac{GMm}{R}\right)e^{2Ht} \qquad \text{(D2)}$$

where the second term represents contributions from the rest of the universe of mass M and radius R. Small numerical constants are omitted for simplicity. Energy can be conserved if the quantity in the bracket of (D2) is zero.

$$G = \frac{Rc^2}{M} \qquad \text{(D3)}$$

Formula (10), from the Friedman equations can be regarded as a necessary condition

$$G = \frac{3H^2}{8\pi\rho} \qquad \text{(D4)}$$

It is to conserve energy as the universe expands. Gravity and the value of G is *caused* by the expansion, but does not change the rate of expansion - that remains constant.

For a large stationary mass

$$\left(mc^2 - \frac{GMm}{R} - \frac{Gm^2}{r}\right)e^{2Ht} \qquad \text{(D5)}$$

and using (D3)

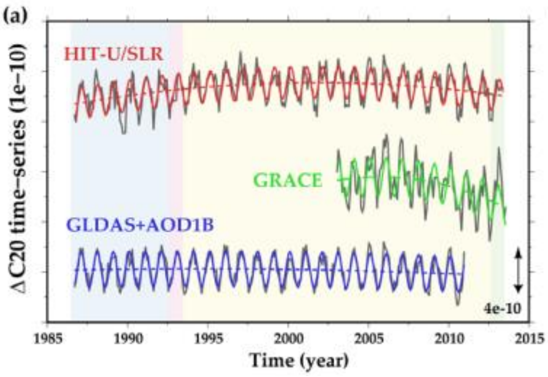
$$G_{reduced} = \frac{c^2}{\frac{M}{R}+\frac{m}{r}} = \frac{G}{1+\frac{Gm}{rc^2}} \qquad \text{(D6)}$$

a reduction in the strength of gravity for regions of matter where m/r approaches c^2/G. These arguments give an indication that a future gravitational theory, or reinterpretation of General Relativity, should include the feature that the strength of gravity reduces for dense regions of matter.

The above formula is for a large stationary mass, it's interesting to wonder however, that, as the earth gets nearer or further away from the sun over a year, whether a cyclic change in G would be measured.

We would expect, from (D6), an annual cyclic variation in G of amplitude $1.69 \times 10^{-10}G$. In [Matsuo, 2013] such a variation of the Earth's gravity field has been noted, (Fig 1a of Matsuo). It's from Satellite Laser Ranging (SLR) data - and has the same amplitude and period.

Figure D1 Variation of Earth's Gravitational Field



These variations are being interpreted as being due to mass redistributions of ice and water, but might possibly be showing a variation of G.

Appendix E. Large Scale Structure

Measurements of the growth of large scale structure measure the quantity $f\sigma_8(z)$ where $f(z)$ is the growth factor and σ_8 is the amplitude of the matter fluctuations on a scale of 8 Mpc.

Figure E2 shows an approximately constant value for $f\sigma_8(z)$ with little or no variation with redshift.

In the new model, $f(\Omega_m)$ is predicted to be constant at $-1 + \sqrt{5/2} \approx 0.5811$ as follows

From perturbation theory, in the growth factor D is a solution of

$$\ddot{D} + 2H(z)\dot{D} - \tfrac{3}{2}\Omega_m H_0^2(1+z)^3 D = 0 \qquad \text{(E1)}$$

In the new model Ω_m remains constant at 1.0

and $H(z) = H$

$$\ddot{D} + 2H\dot{D} - \tfrac{3}{2}H^2 D = 0 \qquad \text{(E2)}$$

for a solution of the form $D = e^{kHt}$

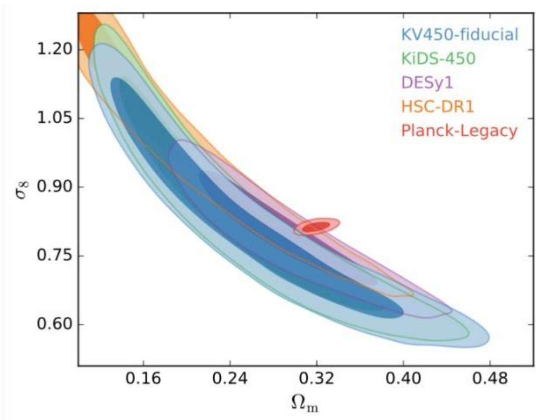
$$k^2 + 2k - \tfrac{3}{2} = 0 \qquad \text{(E3)}$$

$$k = \sqrt{(5/2)} - 1 \approx 0.5811 \qquad \text{(E4)}$$

$$f(\Omega_m) = \frac{1}{H}\frac{\dot{D}}{D} = k \qquad \text{(E5)}$$

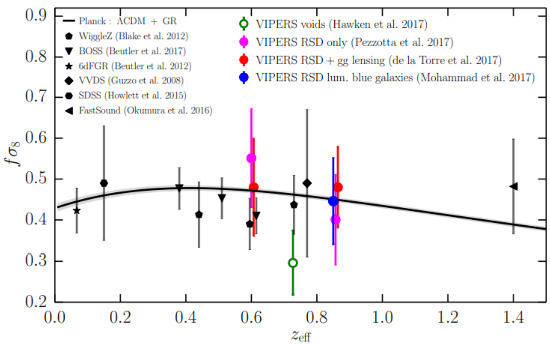
so in the new model $f(z)$ is constant at about 0.5811

Figure E1 σ_8 against Ω_m from cosmic shear



Data from KV450 and Figure E1 [Hildebrandt, 2018], show that σ_8 is about 0.81, so $f\sigma_8(z)$ is constant ≈ 0.47 a good match to the data of Figure E2, [Guzzo, 2018].

Figure E2 Growth parameter against redshift



Appendix F. Time symmetry and antimatter

The universe in the new model is infinitely old.

There are explosive or bounce events due to collapsing matter reaching the critical mass/radius ratio, perhaps one larger than others, as described in Appendix D and section 3. However there is no definite beginning of time.

Other areas of physics have laws with time symmetry. If we do a time reversal

$$t \rightarrow -t \quad \text{(F1)}$$

$$H \rightarrow -H \quad \text{(F2)}$$

the equations of the model look the same, e.g.

$$a = e^{Ht}$$

and gravity would still be attractive, from (D4)

$$G = \frac{3H^2}{8\pi\rho}$$

As the fundamental laws of electromagnetism and atomic physics are time symmetric, then in a time reversed universe, after a 'big bounce' then stars, galaxies and planets would form and life would evolve, just the same as a forward time universe.

The model is unchanged by a change of time direction.

To conserve the measured CPT symmetry, a time reversed universe would have a charge conjugation and a parity reversal. It would be an antimatter universe.

One of the problems of Big Bang cosmology is that we are left with the question of why there is more matter than antimatter.

In the new cosmology, there is no distinction between a $+t$ matter universe and a $-t$ antimatter universe. It is valid to claim that we are living in the $-t$ antimatter universe.

So perhaps the fact that we normally only observe matter isn't a mystery after all. Even in a time reversed universe, we would still observe time flowing forward and observe matter to be normal matter (instead of antimatter), there would be a redshift and gravity would still be attractive.

The mystery of why there is more matter than anti-matter disappears. We could equally well be asking ourselves, why is there more antimatter than matter?