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Redshifts and Scale Factors: A New Cosmological Model

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Abstract

A new cosmological model is considered which doesn't require dark energy. The 'expansion' of the universe is reinterpreted as a 'rescaling' whereby the whole universe can change scale, yet appear static. Rescaling is a symmetry whereby there is a simultaneous change of every length in the universe and all physical constants which contain length dimensions.
It is shown that this interpretation of 'expansion' of the universe, can lead to a redshift of light, due to a changing of Plancks constant with time. This results in a new relationship between scale factor of the universe and redshift. The misunderstanding of the true relationship is the cause of the apparent dark energy phenomenon.
Predictions for the magnitudes of supernovae against redshift are made and found to be in good agreement with supernovae data, without dark energy. An apparent value for omega(matter), of 0.25 (but really 1.0), now occurs naturally in a solution of Einsteins equations, in accordance with values inferred from WMAP data – thus removing the need for 'dark energy'. It is concluded that the reinterpretation of 'expansion', in the equations of General Relativity, is necessary.
A reduction in gravitational mass for compact objects arises from rescaling theory. This feature means that the successes of 'Big Bang' theory can be mimicked by the effect of many smaller bangs for collapsed objects, giving the abundance of elements and the foam like large scale structure.

Key Words: Cosmology: theory, distance scale, cosmological parameters, Dark energy, Gravity

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1 INTRODUCTION

Currently the ‘concordance model’ is widely accepted, the Big Bang model based on General Relativity with inflation, dark energy and dark matter. Although the concordance model has been successful in explaining many observations, its whole philosophical foundation seems to be lacking. In only a few decades many new concepts have had to be introduced to adapt the Big Bang/General Relativity model.

Inflation was introduced in 1981 (Guth 1981), to explain observations that the universe is near critical density. There is, however, no understanding of why it began or ended, or of the nature of the underlying cause of inflation.

Due to the observations of distant supernovae (Riess et al 2007), and WMAP measurements of the Cosmic Microwave Background Radiation (Komatsu et al, 2008), cosmologists have concluded that there exists ‘dark energy’, the nature of which is poorly understood. There is a lack of an understanding of a physical mechanism, by which dark energy causes an accelerating expansion of the universe.

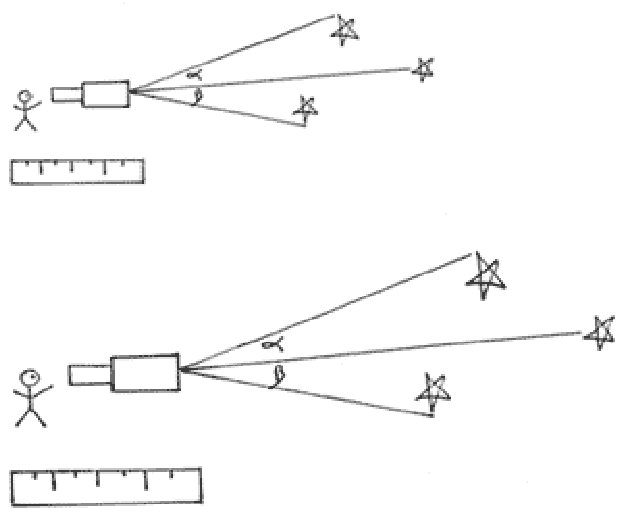
It is found that the two concepts above are unnecessary if there is an alternative interpretation of the expansion of the universe - a continuous, simultaneous and global changing of all length scales, and all physical constants, which is undetectable to us.

2 THE RESCALING SYMMETRY PRINCIPLE AND ITS CONSEQUENCES

2.1 The rescaling symmetry principle.

According to the rescaling symmetry principle, every length in the universe may increase or decrease with almost no noticeable effect to the inhabitants, (figure 1). This continuous and ongoing change in length scale must happen to every length in the whole universe simultaneously, including the size of people, atoms and distances between all objects. Every physical constant must vary too, with the change depending on the number of length dimensions in the quantity.

Figure 1 Sketch to show a rescaling universe



A common cosmological time (t) is assumed.

Quantities then rescale according to

$$\frac{dQ}{Q} = nHdt \qquad (1)$$

where ‘n’ is the number of length dimensions in quantity Q. H is the rescaling constant, which is half of Hubbles constant H_0

$$Q = Q_0 \exp(nHt) \qquad (2)$$

Table 1. The value of ‘n’ for various physical quantities.

Quantity	***n***
All lengths	1
Speed of light	1
Plancks constant	2
Particle masses	0
Permittivity of free space	-3
Fine structure constant	0
Gravitational constant	3
Hubbles constant	0
Forces	1
Quanity with n length dimensions	n

There has been no convincing evidence for the change of any physical constant with time, although there have been various proposals starting with Dirac’s hypothesis of a varying G, (Dirac, 1937). With this proposal the changes would not be measurable.

The symmetry principle requires that any local experiment, to measure the change of any physical quantity, in a rescaling universe, would yield a null result. This is due to other relevant quantities rescaling too.

For example if an attempt were made to measure the change in the speed of light by timing the passage of a light beam over a given distance, since both the distance and the speed of light rescale in proportion the time of passage would remain the same.

Lunar Laser Ranging has restricted changes in the value of G to 1 part in 10 billion per year. Local measurements would not reveal any change in G with time, due to the symmetry principle. Measurements using distant sources, would also not reveal a change in G with time. An attempt could be made by measuring the velocity of rotation (with Doppler shift) and radius of rotation, of a system similar to the earth-sun system, but many light years away. We would decide (due to the speed of light rescaling too) that the velocity is the same as for the solar system. The radius too would appear the same (e.g. the time of light to cross the orbit would be unchanged) and we would conclude that G was the same in both cases.

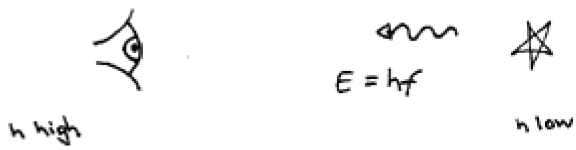
The model is consistent with observations that there is no significant change in the fine structure constant with time (Murphy et al. 2001), as it is dimensionless.

The rescaling symmetry principle applies to the whole universe simultaneously. It seems as though the universe could be regarded as static, with no change of any physical quantity. However because a rescaling universe is one that is larger now than it used to be, there are some observational differences between the static and rescaling universe cases. These arise from the conservation of energy, as described below.

2.2 The redshift of light.

In a rescaling universe, a photon of light arriving from a distant star, would be emitted at a time when Plancks constant was lower (h_0).

Figure 2. The redshift of light



By the time it has arrived at earth Plancks constant would be

$$h = h_0 \exp(2Ht) \qquad (3)$$

where t is the time since the emission of the photon. H is the rescaling constant (half of Hubbles constant, H_0).

If the energy of the photon is conserved

$$f = f_o \exp(-2Ht) \qquad (4)$$

Where f is the frequency measured at earth, f_0 is the frequency of the photon when emitted from a distant star. So light becomes redshifted with time. In this model the redshift of light is due to the rescaling universe, instead of an expanding universe.

The redshift of light is from

$$1 + z = \exp(2Ht) \qquad (5)$$

which matches observations for low z.

The ratio of the scale factor of the universe, at the time of arrival, to the scale factor at the time of emission of the photon is

$$\frac{a_0}{a_t} = \exp(Ht) = \sqrt{1+z} \qquad (6)$$

Equations (5) and (6) show that there is a different relationship, to the conventional cosmology, between ratio of scale factor and redshift. In section 3, there is a solution of Einsteins equations for the universe, and it is shown that this misunderstanding of the relationship between redshift and change in scale factor is the cause of the dark energy problem.

2.3 A Reduction of Gravitational and Inertial Mass for Compact Objects

It is proposed that the gravitational and inertial mass of compact objects may reduce significantly if the mass to radius ratio approaches c^2/G. Einstein's theory is regarded as incomplete, or in need of reinterpretation, as singularities are predicted for such objects. There is no replacement theory, but two simple arguments are discussed, which both indicate that such a reduction might well occur. The spherical void nature of the large scale structure can then be understood due to 'bouncing' of collapsing matter. A mechanism for ejection phenomenon in cosmology such as AGNs might also be provided.

2.3.1. Gravitational and inertial mass

Taking the self gravitational potential energy into account, the total internal energy, of any mass m of radius r is

$$mc^2 - \frac{Gm^2}{r} \qquad (7)$$

Where m includes contributions from pressure, internal kinetic energy. Experiments show that deviations from unity of the ratio of gravitational to inertial mass is limited to 0.0005 (Williams, 2009), i.e. the Strong equivalence principle is not violated.

So it is concluded that the gravitational and inertial masses stay equal and both reduce to

$$m\left(1 - \frac{Gm}{rc^2}\right) \qquad (8)$$

Equation (2) indicates that for masses of extremely high m/r ratio, the attractive gravitational (and inertial mass) will decrease and approach zero as

$$\frac{m}{r} \rightarrow \frac{c^2}{G}$$

2.3.2 The Value of G from rescaling theory

General Relativity has traditionally, no 'explanation' for the value of the gravitational constant, G. With the rescaling interpretation, it is clear why the universe should be at critical density - it is so that energy is conserved in a rescaling universe. The rescaling (which has a constant rate) causes gravitation so that energy is conserved, and the value of G is determined by the rate of rescaling. It is expected that a cosmology based on a future amended or reinterpreted version of General Relativity will incorporate Big Bang theory. It is suggested below how this might come about.

By using Newtonian considerations, other features expected from of a reinterpretation of General Relativity which incorporates rescaling are now considered.

If the total energy due to each mass m is conserved in a rescaling universe, then

$$mc^2 - \frac{GMm}{R} = 0 \qquad (9)$$

as, at a later time the total energy would be

$$(mc^2 - \frac{GMm}{R})\exp(2Ht) \qquad (10)$$

the second term in (9) represents the combined contributions to the potential energy due to the rest of the universe, of mass m, up to the Hubble radius R, from (9)

$$G = \frac{Rc^2}{M} \qquad (11)$$

This formula gives the value of the gravitational constant for 'normal' masses i.e. the value expected from a Cavendish type experiment of from solar system experiments. Small numerical constants are omitted for simplicity.
The significance of equation (11) is that gravity is caused by rescaling – i.e. the phenomenon of gravitation and the value of G, is a result of the conservation of energy in a rescaling universe. This naturally leads to a universe at critical density, and to a reduction in the value of G (or gravitational mass) for masses of high mass to radius ratio as shown below.

For a large stationary mass, (9) is amended to

$$mc^2 - \frac{GMm}{R} - \frac{Gm^2}{r} = 0 \qquad (12)$$

giving

$$G_{effective} = \frac{c^2}{\left(\frac{M}{R} + \frac{m}{r}\right)} \qquad (13)$$

so, from (11)

$$G_{effective} = \frac{c^2}{\left(\frac{c^2}{G} + \frac{m}{r}\right)} \tag{14}$$

Equation (14) indicates that a reinterpretation of General Relativity which incorporates the rescaling symmetry principle will have an effective value of G (or attractive gravitational mass of a body), which varies from object to object. For masses of extremely high m/r ratio, G will decrease.
So both the arguments in 2.3.1 and 2.3.2 lead to the same conclusion...that gravitational (and inertial) mass reduce for compact objects. The prediction of General Relativity of an increase of gravitational mass, due to the pressure term, and the formation of singularities, shows, in the author’s opinion, a problem with the current interpretation of General Relativity.

Such a reduction in gravitational mass may allow a large collapsing mass to ‘bounce’ giving rise to explosive, or ejection phenomenon. Such a future theory may be able to account for the spherical void phenomenon of the large scale structure, and incorporate Big Bang cosmology. The Big Bang may have occurred due to a reduction of gravitational mass for one very massive region. Alternatively the abundance of elements and Cosmic Microwave Background Radiation may be accounted for by numerous smaller bangs at the centres of galaxies.

If and when the nature of dark matter is understood, there may remain the outstanding question of why it is distributed in such a way as to give the flat rotation graphs (Zwicky, 1933). Formula (14) may account for the flat shape of galactic rotation graphs, due to the distribution of dark matter being determined by (14). Matter approaching a galactic centre could only spiral in at a such a rate, so as to give a constant m/r ratio for every value of r. If matter approached faster, the value of G would be reduced, allowing matter to drift away from the centre, reducing the m/r ratio. A constant m/r ratio, then leads to the constant velocity of rotation, at each radius.
It is proposed that the incoming matter is then ejected periodically from the centre of galaxies, due to sudden reduction in gravitational and inertial mass, inAGNs.

3 A SOLUTION OF EINSTEINS EQUATIONS.

For constant H, $a = a_0 \exp(Ht)$, where a is the scale factor of the universe, Einsteins equations of General Relativity reduce to those below. Any change of scale factor is now interpreted as a ‘rescaling’ not ‘expansion’ in the traditional sense. The rescaling constant is H, half of Hubbles constant, which is $H_0 = 2H$.

$$8\pi G \frac{\rho}{c^2} = -\Lambda + \frac{3H^2}{c^2} + \frac{3k}{a^2} \tag{15}$$

$$8\pi G \frac{p}{c^4} = \Lambda - \frac{3H^2}{c^2} - \frac{k}{a^2} \tag{16}$$

so for a flat universe with k = 0, and $\Lambda = 0$

$$p = -c^2\rho \qquad \text{(i.e.}\ \omega = -1\text{)} \tag{17}$$

and

$$\rho = \frac{3H^2}{8\pi G} \tag{18}$$

therefore the traditionally inferred value of omega(matter) would be

$$\Omega_m = \frac{3H^2 \big/ 8\pi G}{3H_0^2 \big/ 8\pi G} = 0.25 \tag{19}$$

because $H_0 = 2H$

In reality $\Omega_m = 1$, as the denominator should contain H not H_0, and $\Omega_\Lambda = 0$. It is not necessary to include the concepts of inflation, or dark energy, in this model as the universe is naturally at critical density. The horizon problem is also solved, as the universe is infinitely old, with the pressure term being interpreted as being due to bounces or explosions of collapsed regions of matter, as described in section 2.3.

This value is consistent with the WMAP results.
Measurements from WMAP5, lead to an inferred value (Komatsu et al, 2008) for omega(matter) of 0.258 (0.030), ($\Omega_m h^2 = 0.1358$). Their preferred model is a flat ΛCDM model with k = 0, and an equation of state parameter, ω, of -1. A value for the maximum likelihood for omega(matter) is given as 0.249.

The values derived from the above solution to Einsteins equations, are k = 0, omega(matter) = 0.25, using H_0 in the denominator of (11), and ω = -1 .
It therefore seems that a dark energy has been wrongly assumed, where in reality no such phenomenon exists. The conclusion of the existence of dark energy, is due to a longstanding misunderstanding of the relationship between scale factor and redshift.

The ‘coincidence problem’ that the values of omega(lambda) and omega(matter) are similar only at the time we live in, is avoided with this approach. At all times omega(matter) is 1 and omega(lambda) is zero. Deductions of matter density from X-ray analysis of galaxy clusters also rely on the value of omega(baryons) from WMAP and are similarly affected by the value for H.

4. THE SUPERNOVAE DATA

The flux F due to distant supernovae is given by

$$F = \frac{L}{4\pi d_L{}^2} = \frac{L}{4\pi(1+z)^2 d_p^2} \tag{20}$$

d_L is the luminosity distance, L is luminosity and d_p is the 'proper distance', now

$$d_p = \int_0^z \frac{c}{2H}(1+z)^{-\frac{1}{2}} dz \tag{21}$$

instead of the traditional equation, (there is a derivation in Appendix A), so

$$d_p = \frac{c}{H}(\sqrt{1+z} - 1) \tag{22}$$

with Hubbles constant half the traditional value, about 36km/s/Mpc.

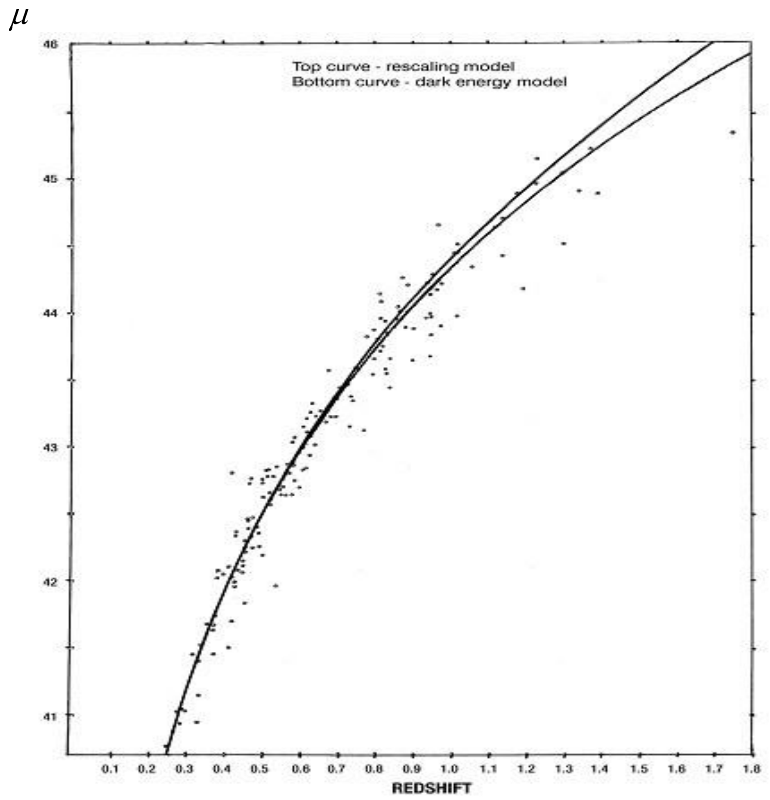
$$d_L = \frac{c}{H}(1+z)(\sqrt{1+z} - 1) \tag{23}$$

the distance modulus is

$$\mu = 25 + 5\log d_L \tag{24}$$

Using (23) in (24), there is a good match to the supernovae data (Riess 2007), gold set. Figure 3 shows a comparison between the rescaling model and the dark energy model for the supernova data. The curves are very similar.

Figure 3 Supernova moduli with redshift, for rescaling and dark energy models.



The chi-squared fit is 183.8 for 182 degrees of freedom. This close match is with H_0 constant, with no requirement for a dark energy component of the universe. The dark energy model has a variable parameter, the matter density, for the curve shown omega(matter) = 0.27. The match from the rescaling interpretation uses no such extra variable parameter. For the rescaling interpretation, the deceleration parameter q(z) = -1 (constant), whereas for dark energy theory q(z) varies, in a way that is not understood (Shapiro & Turner, 2006).

4. CONCLUSIONS AND PREDICTIONS.

There has been a serious and long-standing misinterpretation of the 'expansion' of the universe, and of the relationship between scale factor of the universe and redshift. A new cosmology is required in which 'expansion' is replaced with 'rescaling'. The new interpretation predicts an inferred value for omega(matter) of exactly 0.25 (although really 1.0), and supernovae moduli from equations (23) and (24). A reduction of gravitational mass for compact objects is also predicted.

APPENDIX A DERIVATION OF (21)

Starting from an amended Robertson-Walker metric

$$ds^2 = -a^2(t)c^2dt^2 + a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2(d\theta^2 + \sin^2\theta d\varphi^2)\right] \qquad \text{(A1)}$$

in terms of the co-moving co-ordinates, χ has the role of the radial co-ordinate

$r = \sin\chi$ if k = +1
$r = \chi$ if k = 0
$r = \sinh\chi$ if k = -1

For ray of light moving along a radial path with θ and φ constant , for a flat universe,

$$ds^2 = -a^2(t)c^2dt^2 + a(t)^2 d\chi^2 = 0 \qquad \text{(A2)}$$

so

$$d\chi = -cdt = -c\frac{dt}{da}da = -c\frac{da}{\dot{a}} = -c\frac{da}{aH} \qquad \text{(A3)}$$

for the new relationship between scale factor and redshift (5) and (6)

$$1 + z = \left[\frac{a_0}{a_t}\right]^2 \qquad \text{(A4)}$$

$$dz = -2\frac{a_0^2}{a^3}da \qquad \text{(A5)}$$

so from (A3)

$$d\chi = \frac{c}{2H}\frac{a^2}{a_0^2}dz \qquad \text{(A6)}$$

$$ad\chi = \frac{c}{2H}\frac{a^3}{a_0^2}dz \qquad \text{(A7)}$$

But due to the observers scale, and that of any measuring equipment, increasing too, the apparent value of

$$ad\chi = \frac{c}{2H}\frac{a^2}{a_0^2}dz \qquad \text{(A8)}$$

so

$$a_0 d\chi = \frac{c}{2H}\frac{a}{a_0}dz \qquad \text{(A9)}$$

from (6)

$$a_0 d\chi = \frac{c}{2H}\frac{1}{\sqrt{1+z}}dz \qquad \text{(A10)}$$

$$d_p = a_0\chi = \int_0^z \frac{c}{2H}(1+z)^{-\frac{1}{2}}dz \qquad \text{(A11)}$$

which is (21).

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