Realistic Non-Singular Cosmology

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Abstract

The radiational contributions, electromagnetic and gravitational, to energy density in the cosmological equation must be negative. This creates natural turning points for a cyclic cosmological model. The negative pressure of the electromagnetic radiation would prevent the collapse of the universe in a prior contracting phase, while the positive pressure of the gravitational radiation would prevent it from expanding forever. Such a cosmological model avoids the problems of a singular past, and evades an ever-accelerating future. The picture is that of an oscillating universe full of stars, that eternally build and destroy the various forms of matter and life, all in a framework of energy conservation. Assuming that the temperature of microwave radiation is a true measure of the electromagnetic energy density of the universe, and that the supernovae data and redshifts are reliable, we can determine (tentatively) the parameters of our model, with an appropriate Hubble fraction of 0.50, and a deceleration parameter of 0.55, and estimate the time that passed, about 12.8 Gyr, since the initiation of the expansion phase, and the time that remains, about 1066 Gyr, before the return to contraction.

1 Introduction

The current model for expanding cosmology[1], [2] which intended to explain the Hubble redshifts of distant galaxies[3] is based on Einstein's theory of general relativity[4], [5] and the associated Friedmann equation[6]. This model is beset with many difficulties, notably the *initial singularity*. The extension of the model to include a very early phase of exponential inflation[7], [8], [9] generated by vacuum energy does not help in solving the singularity issue. On the other hand, the inclusion of vacuum energy to explain the accelerated expansion[10], [11], [12], that is supposed to be implied by measurements of supernovae redshift data, adds a new problem that presents the unnatural picture of *an ever accelerating vacuum cosmology*. Our purpose in this article is to present a radically new framework for cosmology, still based on general relativity, and on the Friedmann equation. However, a new point of view is adopted, regarding the *role of radiation*, whether electromagnetic or gravitational, in controlling the cosmic dynamics.

The microwave cosmic background, discovered[13] and explained[14] in 1965 as a relic of the initial radiation that dominated the very early state of the cosmic expansion, and whose Planckian spectrum was confirmed[15], [16], [17] by the COBE satellite, will be considered in our approach as *a relic of radiation generated and absorbed by stellar bodies* throughout the cyclical cosmic history. Accordingly, the manner in which the energy density of electromagnetic radiation (or photons) should enter the Friedmann equation must be negative, so that the *negative pressure* associated with it would be so strong to prevent the collapse of matter by gravitational attraction, when in a contracting phase. On the other hand, we give a similar role to gravitational radiation (or gravitons) in preventing an ever expanding dynamics. This is achieved by the *positive pressure* associated with the negative energy density of gravitational radiation. We should note that what we call gravitational radiation density is the equivalent, in a flat space metric, to the density of curvature in a curved space metric. Gravitational radiation with negative energy density simulates positive curvature. We shall give a picture in which energy is conserved, contrary to the conventional approach, where the energy of radiation and matter was produced by an event of *creation*, and contrary to the recent acceleration scenario where energy is produced by the *vacuum*.

In the following paragraphs, we shall introduce the Friedmann equation, and discuss the various contributions to the energy density. In the following sections, we shall discuss the conventional scenarios, before proceeding to present our model and its implications.

The general form of Friedmann's equation takes the form

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho \tag{1}$$

Here $a(t)$ is a function of time which describes the relative size of an expanding or contracting space, the dot represents the derivative with respect to time, G is the Newtonian constant of gravitation, and ρ is the mass density which can receive contributions from various sources. The above equation corresponds to the temporal component of Einstein's equations, with the energy-momentum tensor of a perfect fluid,

$$T_0^0 = \rho\, c^2 \qquad T_i^j = -p\, \delta_i^j \tag{2}$$

and with a spacetime metric whose line element takes the form

$$ds^2 = c^2 dt^2 - a^2(t) d\sigma^2 \tag{3}$$

Here c is the constant speed of light of flat spacetime, and $d\sigma^2$ is the space metric which can have positive, negative, or zero curvature[1]. However, we think the flat metric with $d\sigma^2 = dx^2 + dy^2 + dz^2$ is good enough to describe all situations, because the socalled curvature term which enters the Friedmann equation can be simulated by graviton densities, as we shall see. The other components of Einstein's equations give

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

The above equation and Friedmann's equation give the continuity relation:

$$\dot{\rho} = -3(\rho + p/c^2)\frac{\dot{a}}{a} \tag{5}$$

This corresponds to energy conservation in Einstein's theory. The above relation combined with an equation of state, relating p and ρ, would relate ρ to the scale function

a, which would make the Friedmann equation solvable. For example, ordinary cold matter, may be regarded as pressureless ($p = 0$) leading $\rho \propto 1/a^3$. Electromagnetic radiation has $p = \rho\, c^2/3$, hence from the above relation, the mass density of radiation takes the form $\rho \propto 1/a^4$. A massless scalar field has $p = \rho\, c^2$ leading to $\rho \propto 1/a^6$. We can show[2] that gravitational radiation (or a massless graviton field) has $p = -\rho\, c^2/3$ leading to $\rho \propto 1/a^2$. A cosmological constant in Einstein's equations corresponds to $p = -\rho\, c^2$.

Notice that for electromagnetic radiation ρ and p are of the same sign, while for gravitational radiation ρ and p are of the opposite sign. Hence, negative density photons would generate negative pressure, while negative density gravitons would generate positive pressure.

In the following section, we shall review the current theory with contributions to energy density coming from cold matter, electromagnetic radiation, and a cosmological term, including a discussion of supernovae magnitudes and redshift data. Subsequently, we shall introduce our model and associated implications.

2 Current Theory

The Friedmann equation in current theory takes the form

$$\left(\frac{\dot{a}}{a}\right)^2 = H^2 \left\{(1 - m - r) + \frac{m}{a^3} + \frac{r}{a^4}\right\} \tag{6}$$

Here H is the Hubble constant, the parameter m is the density fraction of cold matter, while r the density fraction of electromagnetic radiation, with $(1-m-r)$ the remaining fraction that corresponds to the cosmological constant. We normalize the scale function so that $a = 1$ at our present epoch. Notice that with $a = 1$ the right side of the above equation is equal to H^2. Hence $H^2 = (8\pi G\rho/3)$ with ρ the total mass density. Taking the current value of H to be 65 kilometer/sec/Mpc or $H \approx 2.10651 \times 10^{-18}$ sec^{-1}, we obtain for the total density

$$\rho = \frac{3H^2}{8\pi G} \approx 7.93803 \times 10^{-27}\,\text{kg/m}^3 \tag{7}$$

and we use $G = 6.67259 \times 10^{-11}$ in MKS units. In order to determine the photon fraction r of the total density, we must use the following expression for the mass density of the photon background radiation

$$\rho_r = \frac{\pi^2}{15}\frac{k^4 T^4}{\hbar^3 c^5} \approx 4.64861 \times 10^{-31}\,\text{kg/m}^3 \tag{8}$$

and we take $k = 1.38066 \times 10^{-23}$ joule/K for the Boltzmann constant, $T = 2.726$ K for the temperature of the microwave radiation, $c = 2.99792458 \times 10^8$ m/sec for the speed of light constant, and $\hbar = 1.05457 \times 10^{-34}$ joule·sec for the reduced Planck constant. Now dividing ρ_r by the total density ρ we find for the photon fraction $r \approx 0.0000585613$.

Before the alleged discovery of accelerated expansion, the value of the matter fraction m of the total density was just equal to $(1-r)$. The computed age of the universe (time since the singularity when $a = 0$) was obtained by integrating the Friedmann equation,

$$\text{Age} = \frac{1}{H}\int_0^1 \frac{\mathrm{d}a}{\sqrt{\frac{(1-r)}{a} + \frac{r}{a^2}}} \approx 10.0512\,\text{Gyr} \tag{9}$$

This low value of the 'age of the universe' was in utter conflict with the ages of old stars. However, the inclusion of a cosmological constant that takes the greatest fractional part of the total density, and with $m \approx 0.3$ for cold matter, we have

$$\text{Age} = \frac{1}{H}\int_0^1 \frac{\mathrm{d}a}{\sqrt{\frac{m}{a} + \frac{r}{a^2} + (1-m-r)a^2}} \approx 14.5327\,\text{Gyr} \tag{10}$$

which gives a more relaxed age value. However, a more decisive argument in favor of the introduction of a cosmological constant into the Friedmann equation came from the interpretation of supernovae magnitudes as functions of redshifts.

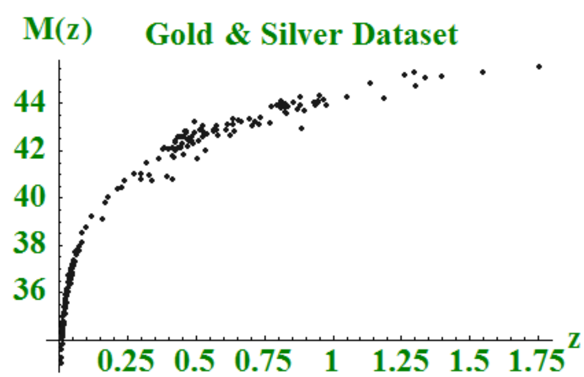
A stellar, or a supernova, magnitude used by astronomers is given by the expression

$$\mathcal{M} = 25 + 5\log_{10}(d_L) \tag{11}$$

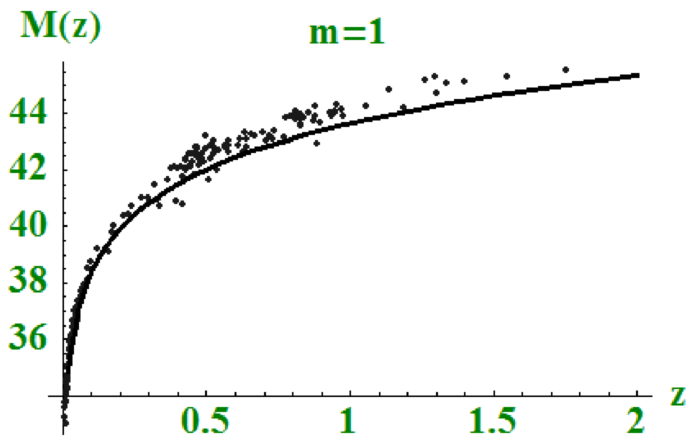
where d_L is the socalled *luminosity distance* in units of Mpc ($\approx 3.08568 \times 10^{22}$ m), or mega parsec. Relating the expansion scale a to the redshift z by the expression $a = 1/(1+z)$, we can deduce from the Friedmann equation, ignoring the radiational contribution, the following expression for d_L defined below:

$$d_L = c(1+z)\int \frac{\mathrm{d}t}{a(t)} = \frac{c}{H}(1+z)\int_0^z \frac{\mathrm{d}\xi}{\sqrt{m(1+\xi)^3 + (1-m)}} \tag{12}$$

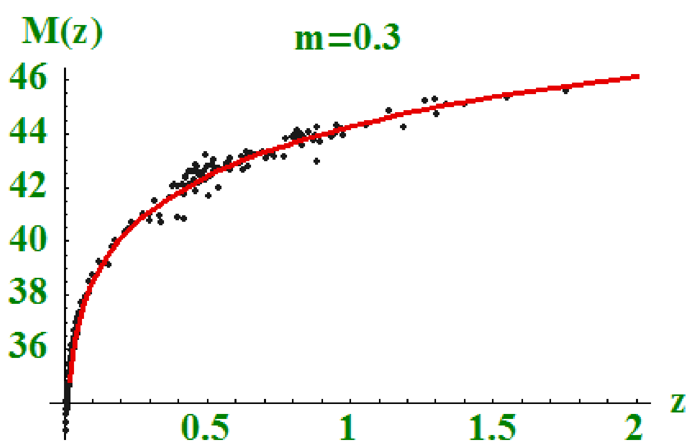
Now we shall compare the observational magnitudes with the magnitudes obtained from the above expressions. A list of supernovae magnitudes and corresponding redshifts (the socalled gold and silver dataset[18]) is given in the appendix. The following is a plot of magnitudes against redshifts:



Now this is a plot of the curve of theoretical magnitudes corresponding to an ordinary theory *without the cosmological term*, $m \approx 1$, together with the observational points:

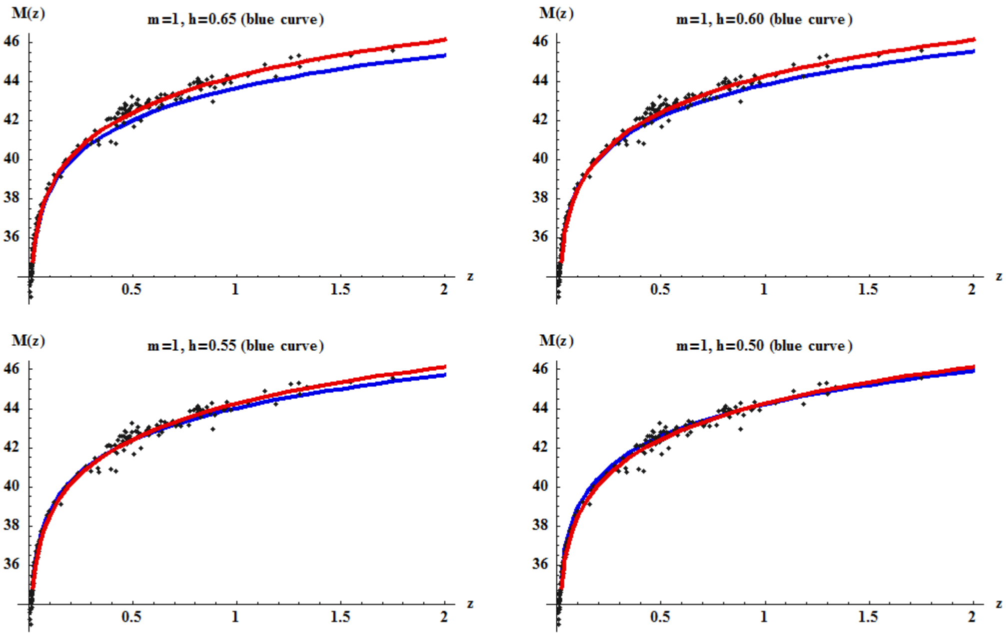


It is clear that the curve does not pass through the observational points as desired. With the introduction of the cosmological term, and with $m \approx 0.3$, we have been shown[11], [12], [18] such a more striking agreement:



That the above nice display of curve and data points should prompt theoreticians to embrace the cosmological constant with all its implications is something of an enigma.

As a matter of fact, removing the cosmological constant altogether ($m \approx 1$), however, *modifying the Hubble constant a little* would give us curves that approach the above result quite well. The following four curves (colored in blue) correspond to four values of the Hubble fraction $\{0.65, 0.60, 0.55, 0.50\}$. It is clear that with values of the Hubble constant that are lower than conventional, the fit can be obtained, without the need for a cosmological constant and its dark vacuum energy. We should remember Disney's warnings regarding cosmological observations before jumping into such an enigmatic theoretical scenario:[19]



> *"Objects at cosmologically interesting distance are exceedingly faint, small and heavily affected by factors such as redshift-dimming and k-corrections, so it will obviously be very difficult, if not impossible, to extract clear information about geometry, or evolution, or astrophysics – all of which are tangled up together."*[19]

In the following section, we shall present our new theory.

3 The New Non-Singular Model

The Friedmann equation in our new model takes the form

$$\left(\frac{\dot{a}}{a}\right)^2 = H^2 \left\{ \frac{1-m-r}{a^2} + \frac{m}{a^3} + \frac{r}{a^4} \right\} \tag{13}$$

Notice that we have included a term corresponding to gravitational radiation with coefficient $(1-m-r)$ as well as a matter term, and an electromagnetic radiation term. Here we take a value of the Hubble constant $H = 50$ km/sec/Mpc, or $H = 1.62039 \times 10^{-18}$ sec^{-1}, which is lower than the previous value of current theory. Corresponding to this value, the total mass density is

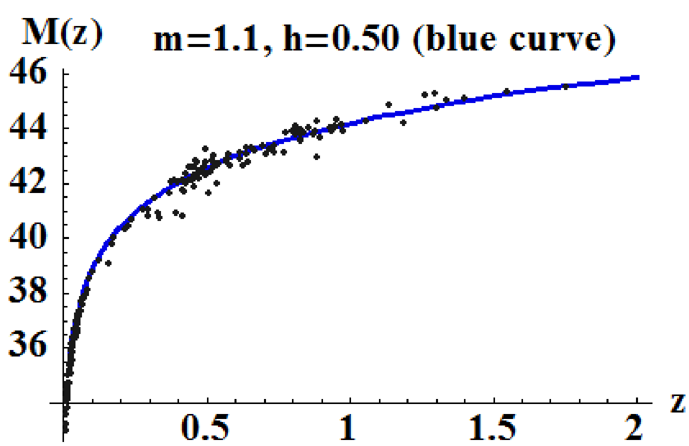
$$\rho = \frac{3H^2}{8\pi G} \approx 4.69706 \times 10^{-27}\,\text{kg/m}^3 \tag{14}$$

which value is smaller by a factor of $(50/65)^2 \approx 0.591716$ than the conventional value. With regard to the photon background fraction r of the total density, we shall take the ratio of the measured density value to the new total density, however, with an opposite sign $r = -0.0000989686$. We choose a negative value, in contrast with ordinary theory, in order to prevent a singularity as $a \to 0$. With this choice there will be a minimum value of the scale factor (a lower turning point), *when the matter density equates the photon density*. For the matter fraction m of the total density, we shall take a value slightly greater than 1 so that the coefficient of the gravitational radiation term is negative (corresponding to positive curvature). We shall take $m \approx 1.1$, which can be shown to give a *deceleration* rather than acceleration, with a decelerating parameter of $q \approx 0.55$. This choice gives a coefficient of the graviton term $(1 - m - r \approx -0.099901)$. Such a negative value will prevent continual expansion and there will be a maximum value of the expansion scale (an upper turning point) *when the matter density equates the graviton density*.

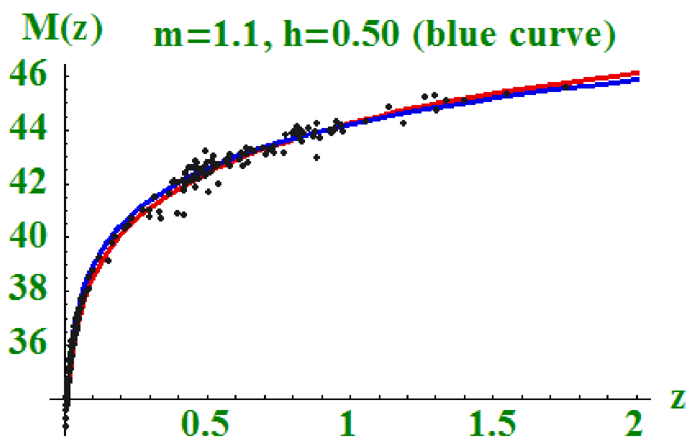
It should be remarked that our choice of the Hubble constant, and of matter density, is only *tentative and illustrative* at this stage, taken to be in pleasant accord with the supernovae magnitudes, awaiting more accurate measurements of the matter density, for it is clear to us that *all observational determinations of matter density are highly influenced by theoretical prejudice.*

With the aboves choices of the Hubble constant, and the fractions of matter and radiational densities, we can integrate the equation numerically, and obtain the time since the expansion was minimum, and also the time left for it to be maximum. For the time since minimum we obtain the value 4.03573×10^{17} sec, or 12.8182 Gyr. For the time left to maximum, before contraction returns, we obtain the value 3.3367×10^{19} sec, or 1059.8 Gyr.

We now move to see how this model compares with the data from supernovae. The following is a plot of the corresponding magnitude curve (blue color) with the data points:



And this includes the famous curve (red color) for the theory with a cosmological constant:



It is clear that our model *would not be a bad choice if it can make us get rid of the cosmological constant*.

We now turn to discuss our model and its implications.

4 Discussion

Before discussing numerical implications of our model, let us present clearly the underlying notion of *energy conservation*, comparing with Newtonian dynamics. If we write the terms of the Friedmann equation of our model all on one side, multiplying by $a^2/2$, we have

$$\frac{1}{2}\dot{a}^2 - \frac{\mu}{a} + \frac{\epsilon}{a^2} + \gamma = 0 \tag{15}$$

Here μ, ϵ, and γ are positive constants related to the respective matter, electromagnetic radiation, and gravitational radiation, contributions. Whereas the 1st term in the above equation represents the kinetic energy of expansion, the 2nd term represents the gravitational potential energy (*negative* and attractive), the 3rd term is the *positive* energy of electromagnetic radiation, and the 4th term is the *positive* energy of gravitational radiation. The above equation tells us that *the total cosmic energy is always zero*, hence conserved. In the course of expansion and contraction, energy *changes form* among its kinetic, gravitational, and radiational components such that the above sum is always zero. Stellar bodies are always attracted by the gravitational force. However, they also emit, and absorb, electromagnetic radiation as well as gravitational radiation, during their lifetimes, due to internal processes, notably atomic, nuclear, as well as gravitational. The electromagnetic and gravitational radiations have important roles in driving and halting the expansion and the contraction phases, through their associated negative and positive pressures, respectively. Notice that moving the above non-kinetic energy components to the other side of the equation leads to the positive matter density in the standard Friedmann equation, and *explains* our introduction of negative radiational densities in that equation. All that scenario follows from an energy conservation principle. Unfortunately for the common model of cosmology, the principle of energy conservation is violated, first by postulating the *creation* of all radiational energy and matter in a singular beginning, and by *vacuum-driving* the expansion towards eternal acceleration.

Let us proceed to some numerical estimates. Whereas the current cosmological model is singular as $a \to 0$, by the fact that the density of matter $\propto 1/a^3$, the electromagnetic radiation density $\propto 1/a^4$, and the temperature of the relativistic background $T \propto 1/a$, all go to infinity, our model has a minimum value $a = 0.0000899722$ with corresponding *finite initial densities* of matter and radiation, both equal to $\sim 7.094 \times 10^{-15}$ kg/m^3, to be contrasted with their current values of 5.16676×10^{-27} kg/m^3 and 4.64861×10^{-31} kg/m^3, respectively.

Whereas the size of the visible universe, estimated to be $c/H \approx 1.85013 \times 10^{26}$ m, would be reduced to zero at the singular beginning, it would be, in our model, something like 1.6646×10^{22} m at the lower scale of its cycle. Notice that the *minimum size* of our visible universe would be just about 17.6 times the diameter of our galaxy. If galaxies had expanded with the cosmic scale, then the size of a typical galaxy like ours, $\sim 9.461 \times 10^{20}$ m or 10^5 light years, would have been at minimum contraction $\sim 8.51227 \times 10^{16}$ m, or ~ 9 light years. This is of the order of interstellar distances.

The temperature associated with the background radiation, which is ~ 2.726 K now, would be at minimum contraction $\sim 30,298$ K only, rather than infinite. In terms of energy, this temperature is equivalent to ~ 2.6 eV, *not enough* to ionize hydrogen atoms (~ 13.6 eV) or even to dissociate hydrogen molecules (~ 4.2 eV).

The above analysis gives a picture that space, at maximum density, was packed with stars, that may have been *whole and active*. It was the negative pressure of their electromagnetic radiation that drove them away from each other. Stars, that build and destroy the various forms of matter and life, are the *basic constituents of an oscillating cosmos*, in our model.

Much work is still needed in order to understand the *formation of galaxies*, the study of *galactic and stellar life cycles*, and possibly their relation to the cosmic life cycle. We are at the dawn of a new nonsingular cosmological model, which hopefully is *much more realistic* than the existing socalled standard model.

My conception of a nonsingular model based on negative energy density found expression in an article[20] many years ago. The picture that I had contemplated then was intended for the standard Big Bang picture, where the initial state is characterized by Planckian density. The model took shape in the framework of an interacting *scalar field with negative energy density*. However, I decided not to publish that article, and stop pursuing the matter for a good while, especially after the contemporaneous introduction of the theory of inflation[7], for I had the feeling that pushing cosmology to Planckian energies may well be a faulty step.

In conclusion, the model presented in this paper is based on a very logical framework governed by energy conservation. It is imperative that a nonsingular model like ours, and which avoids the inclusion of a cosmological constant, should be studied further. However the actual numerical implementation of our model at the moment, as we have remarked earlier, is only tentative and illustrative. It is very important that a reliable observational determination of the cosmic average density of matter should be available. All present determinations are seemingly biased towards standard theoretical constraints.

A Appendix: The Gold & Silver Dataset

The following is an ordered list[18] whose items are in the form $\{z, M\}$, with z the redshift of a supernova and M its magnitude:[1]

```
{{0.0104,33.21},{0.0104,33.56},{0.0104,33.73},{0.0116,32.96},{0.0121,34.05},
{0.0132,34.02},{0.0136,33.73},{0.0141,34.12},{0.0141,34.13},{0.0141,34.43},
{0.0152,34.11},{0.0157,34.58},{0.0161,34.5},{0.0162,34.13},{0.0164,34.41},
{0.0164,34.47},{0.0165,33.82},{0.0166,34.54},{0.0167,34.21},{0.017,34.18},
{0.017,34.47},{0.0171,34.68},{0.0175,34.52},{0.0178,34.7},{0.018,34.29},
{0.0186,34.96},{0.0193,34.59},{0.0218,35.06},{0.0219,34.7},{0.0233,35.14},
{0.0234,35.36},{0.0244,35.09},{0.0247,35.33},{0.0251,35.09},{0.0257,35.41},
{0.026,35.62},{0.0262,35.06},{0.0265,35.64},{0.0266,35.36},{0.0276,35.9},
{0.0286,35.53},{0.029,35.7},{0.0297,36.12},{0.0307,35.9},{0.0316,35.85},
{0.0327,36.08},{0.0331,35.54},{0.0348,36.17},{0.036,36.17},{0.036,36.01},
{0.036,36.39},{0.038,36.67},{0.04,36.38},{0.043,36.53},{0.045,36.97},
{0.046,36.35},{0.049,36.52},{0.049,36.9},{0.05,36.84},{0.05,37.08},
{0.051,36.67},{0.052,37.16},{0.053,36.97},{0.053,37.17},{0.056,37.31},
{0.058,37.13},{0.061,37.3},{0.063,37.67},{0.067,37.54},{0.071,37.78},
{0.075,37.77},{0.079,37.94},{0.088,38.07},{0.089,38.5},{0.101,38.73},
{0.124,39.2},{0.16,39.08},{0.172,39.79},{0.18,39.98},{0.216,40.33},
{0.23,40.44},{0.24,40.68},{0.278,41.},{0.3,40.76},{0.3,41.01},
{0.32,41.45},{0.334,40.92},{0.34,40.71},{0.369,41.62},{0.38,42.02},
{0.388,42.07},{0.397,40.89},{0.4,42.04},{0.416,42.1},{0.42,40.79},
{0.42,41.76},{0.422,42.02},{0.425,41.7},{0.43,41.99},{0.43,42.33},
{0.43,42.36},{0.44,42.08},{0.44,42.57},{0.45,42.1},{0.45,42.13},
{0.45,42.58},{0.455,42.29},{0.46,41.83},{0.46,42.56},{0.465,42.81},
{0.47,42.74},{0.47,42.77},{0.472,42.46},{0.475,42.14},{0.477,42.38},
{0.478,42.48},{0.48,42.37},{0.49,42.41},{0.49,42.58},{0.495,42.25},
{0.498,43.21},{0.5,42.74},{0.5,42.75},{0.5,42.75},{0.508,41.64},
{0.514,42.39},{0.518,42.83},{0.526,42.56},{0.526,43.01},{0.528,42.77},
{0.538,42.66},{0.54,41.96},{0.543,42.68},{0.57,42.77},{0.57,42.81},
{0.57,42.88},{0.579,42.86},{0.58,43.04},{0.581,42.63},{0.615,42.85},
{0.62,43.11},{0.63,42.62},{0.638,43.3},{0.64,43.07},{0.644,42.78},
{0.657,43.27},{0.67,43.19},{0.698,43.33},{0.71,43.05},{0.719,43.22},
{0.735,43.09},{0.74,43.35},{0.771,43.12},{0.778,43.81},{0.798,43.88},
{0.811,43.97},{0.815,43.76},{0.815,44.09},{0.828,43.61},{0.828,43.96},
{0.83,43.85},{0.832,43.55},{0.839,43.86},{0.86,44.03},{0.873,43.75},
{0.882,43.9},{0.884,44.23},{0.886,42.91},{0.899,43.64},{0.935,43.99},
{0.94,43.87},{0.949,43.99},{0.95,44.06},{0.954,44.28},{0.97,44.13},
{0.977,43.91},{1.056,44.25},{1.14,44.84},{1.19,44.19},{1.265,45.2},
{1.3,45.27},{1.305,44.7},{1.34,45.05},{1.4,45.09},{1.551,45.3},{1.755,45.53}}
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[1] I give the list in this form rather than in a table, so that researchers who are using computational packages can copy and compute directly.

References

[1] J.V. Narlikar, *Introduction to Cosmology*, (Cambridge University Press, Cambridge, 1993)

[2] N.S. Baaklini, "Introduction to Relativisitic Cosmology", *N.S.B. Letters*, **NSBL-RC-007**

[3] E. P. Hubble, *Proc. Nat. Acad. Sci.*, **15** (1929) 168

[4] A. Einstein, *Sitz. Preuss. Akad. Wiss. Phys.*, **142** (1917) (x 4)

[5] A. Einstein, *Ann. Phys.*, **69** (1922) 436

[6] A. Friedmann, *Z. Phys.*, **10** (1922) 377

[7] A. Guth, *Phys. Rev.*, **D23** (1981) 347

[8] A.D. Linde, *Phys. Lett.*, **108B** (1982) 389

[9] A. Albrecht & P.J. Steinhardt, *Phys. Rev. Lett.*, **48** (1982) 1220

[10] S. Perlmutter et al, Bull. Am. Astron. Soc., 29 (1997) 1351

[11] A.G. Riess et al, Astron. J., 116 (1998) 1009;

[12] S. Perlmutter et al, Astrophys. J., 517 (1999) 565

[13] A.A. Penzias & R.W. Wilson, *Astrophys. J.*, **142** (1965) 419

[14] R.H. Dicke, P.J.E. Peebles, P.G. Roll and D.T. Wilkinson, *Astrophys. J.*, **142** (1965) 414

[15] J.C. Mather et al, *Astrophys. J.*, **420** (1994) 439

[16] D.J. Fixen et al, *Astrophys. J.*, **473** (1996) 576

[17] J.C. Mather et al, *Astrophys. J.*, **512** (1999) 511

[18] A.G. Riess et al, "Type Ia Supernova Discoveries at $z > 1$ From the Hubble Space Telescope ...", http://arXiv.org/abs/astro-ph/0402512v2, (*Astrophys. J.*, June, 2004)

[19] M. J. Disney, "The Case Against Cosmology", http://arXiv.org/abs/astro-ph/0009020 (1 Sep 2000)

[20] N.S. Baaklini, "A Nonsingular Model of the Big Bang", *Johns Hopkins University Report*, **JHU-HET/8102 (1981)**; (reproduced as *N.S.B. Letters*, **NSBL-RC-003**)

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