Realistic Decelerating Cosmology and the Return to Contraction

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Abstract

For cosmological theory without the bizarre vacuum-driven acceleration, and in the spirit of "realistic non-singular cosmology", we examine the effect of adjusting the value of the Hubble fraction in order to obtain a reasonable fit with the large data set of supernovae magnitudes and redshifts. Adopting a value of the Hubble fraction equal to 0.53, we obtain a pleasing fit for a theory with a negative graviton density, with a matter fraction of 1.12, a decelerating parameter of 0.56, and the remaining time before the return to contraction of about 770 Gyr. For a theory with a negative vacuum density, we obtain a pleasing fit with a matter fraction of 1.02, a decelerating parameter of 0.53, and a remaining time of about 125 Gyr.

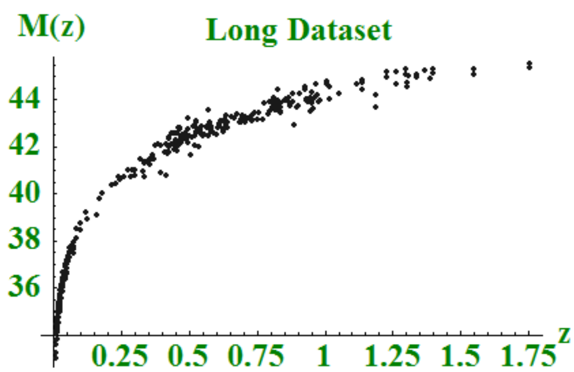
1 Introduction

The basic idea behind the theory[1] of "realistic non-singular cosmology" is that the expansion of the universe was driven, in the past, by the negative pressure of photons emitted by the stars, and would be stopped, in the future, by the positive pressure of gravitons, or by the positive pressure of negative vacuum density[2]. We have identified the cosmic microwave radiation[3], [4], [5], [6] as a relic emitted by the stars rather than created in a singular beginning. A non-singular beginning of the expansion, being a lower turning point for a prior contraction, would have taken place when the radiational density and the matter density were equal. Likewise, an upper turning point of the expansion would have to take place when the gravitational radiation density, or alternatively the vacuum density, would be equal to matter density. That the expansion cannot continue forever is a reasonable expectation in such a theory. Subsequently, if the supernovae magnitudes and redshifts[7], [8], [9] can be taken as reliable observational data[10], we do not see any other possibility but to make them fit our picture of the *decelerating* expansion instead of the the unnatural vacuum-driven ever-accelerating scenario. This can only be done by fitting the Hubble constant to the data together with the fraction of matter density. Our purpose in this article is to examine the parameters that govern the upper turning point of the expansion by fitting them to a supernovae data set, much larger than the one used before[11], [12], [13].

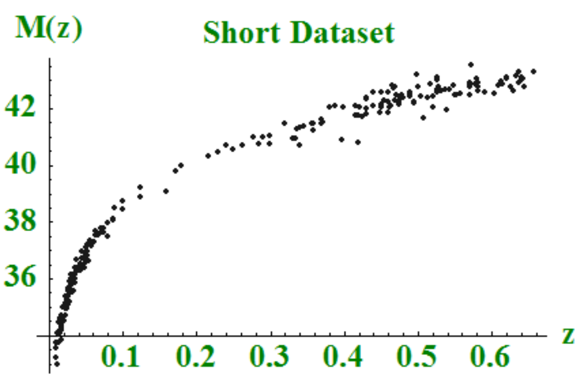
We shall begin by treating the case of a Friedmann equation[14], [15] with a density contribution given by matter alone. We shall show how adjusting the Hubble fraction can bring about a reasonable fit, demonstrated via graphics, with the supernovae data. Choosing a reasonable value for the Hubble fraction, this will be followed by a treatment of the theory of matter together with negative graviton density. Subsequently, we shall treat the theory of matter together with negative vacuum density. In the latter two cases, we give the graphics that demonstrate agreeable fits with supernovae data, specify the values of the matter fractions, compute the values of the deceleration parameters, and estimate the remaining times for the expansion to halt and return to contraction.

2 Supernovae Data, Ordinary Matter, and the Hubble Constant

A large list giving supernovae magnitudes against redshifts is given in the appendix. The corresponding graphic is given below:



This is another graphic with a better resolution for the points with lower redhifts:



Let us consider the Friedmann equation with the only contribution to the mass density is that of ordinary matter:

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{H^2}{a^3} \tag{1}$$

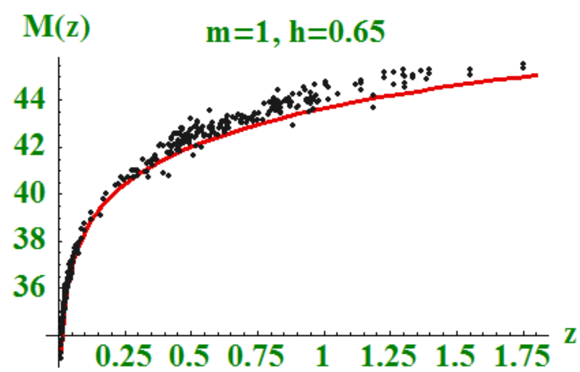
Here, $a(t)$ is the cosmic scale function of time, normalized so that it takes on the value $a = 1$ at the present time, and H is the Hubble constant. Notice that the matter density ρ is related to the H by $\rho = (3H^2/8\pi G)$, where G is the gravitational constant. Now in order to relate the above equation to preceding supernovae data, we recall that stellar magnitudes are given by the expression

$$\mathcal{M} = 25 + 5\log_{10}(d_L) \tag{2}$$

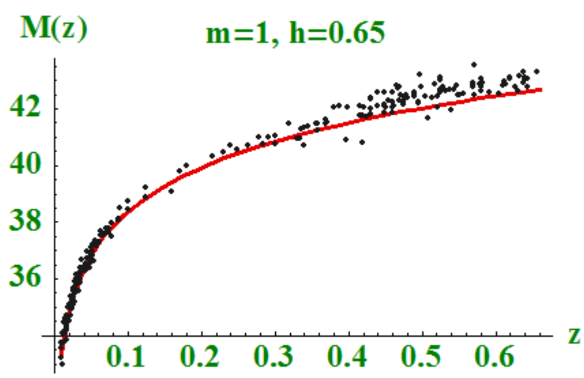
where d_L is the luminosity distance in Mpc, or mega parsec ($\approx 3.08568 \times 10^{22}$ m). With the scale parameter a related to the redshift z by the expression $a = 1/(1+z)$, we obtain from the foregoing Friedmann equation,

$$d_L = \frac{2c}{H}(1+z)\left(1 - \frac{1}{\sqrt{1+z}}\right) \tag{3}$$

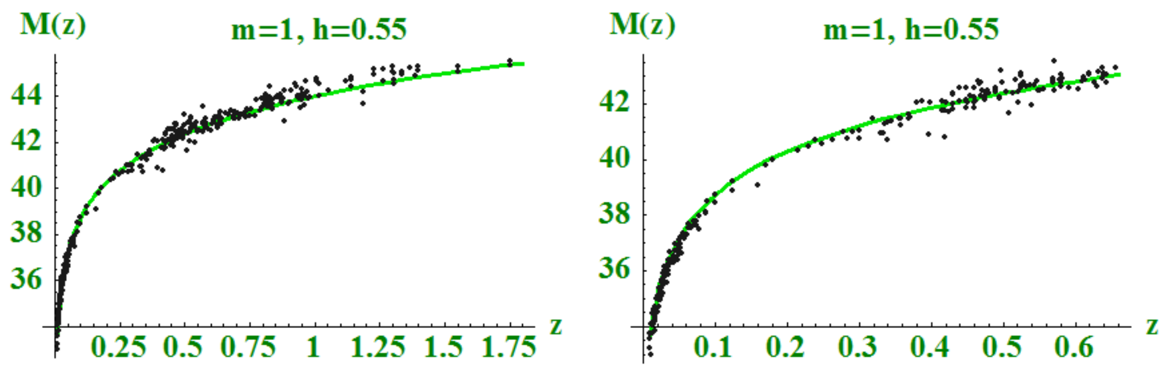
with c being the speed of light. Using the foregoing two formulas, we can plot the curve magnitudes against redshift on the same graphic, given before, for supernovae data:



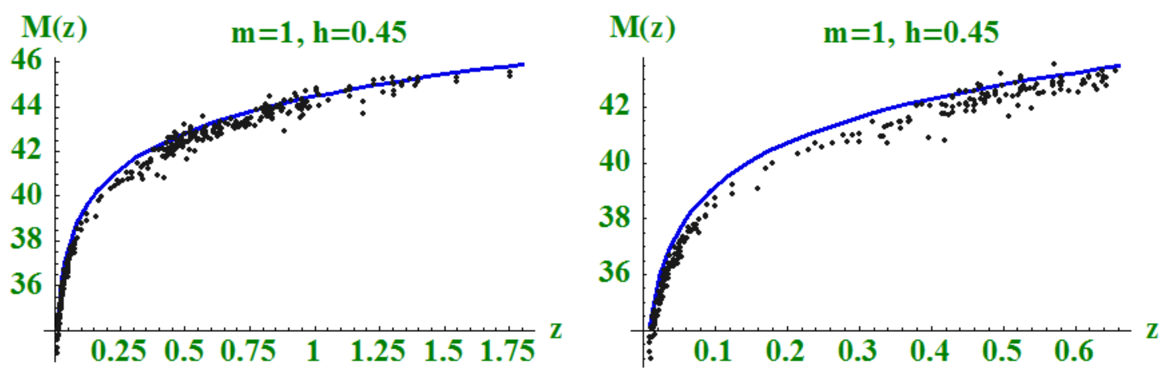
And this gives the same curve in the lower redshift range:



In the above depictions, we have used the usually quoted current value of the Hubble fraction $h = 0.65$, and it is clear that the curve falls short of the observational points, especially for higher redshifts. However, rather than subscribing to the theory with a positive vacuum density (or cosmological constant) which leads to an accelerating expansion, let us see the effect of lowering the value of the Hubble fraction. Here is the curve for $h = 0.55$,



And here is the curve for $h = 0.45$,



It should be clear that a value of the Hubble fraction in the middle (green) range, around 0.55, would give us some pleasant agreement with the supernovae data.

In the following section, we shall consider the case of adding negative graviton density to the Friedmann equation, and examine the effect of changing the matter density on the magnitude curve.

3 Matter with Negative-Density Gravitons

Consider now the following Friedmann equation,

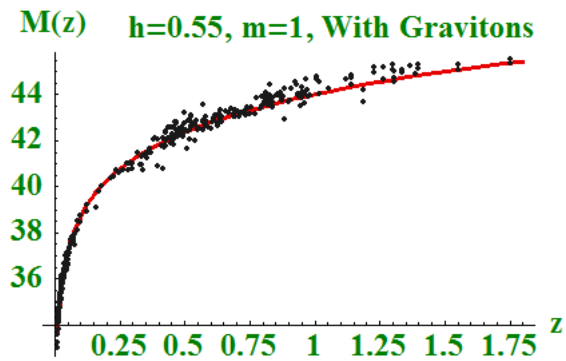
$$\left(\frac{\dot{a}}{a}\right)^2 = H^2 \left\{ \frac{m}{a^3} + \frac{(1-m)}{a^2} \right\} \tag{4}$$

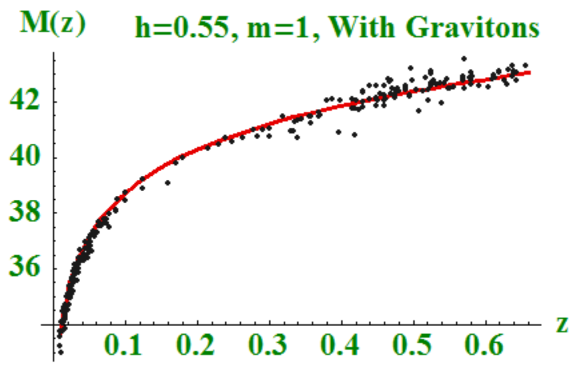
Here we have included a term for matter density with a fractional coefficient m, and a term corresponding to the graviton (or curvature) density with fractional coefficient $(1-m)$. Notice that, for the graviton density to be negative, the value of m must be greater than 1. In the present discussion, we shall use a Hubble fraction of $h = 0.55$, which corresponds to $H = 55$ kilometer/sec/Mpc.

We shall examine the effect of varying the matter density coefficient m on the magnitude curve. From the above equation, we obtain the following expression for the luminosity distance as a function of the redshift z,

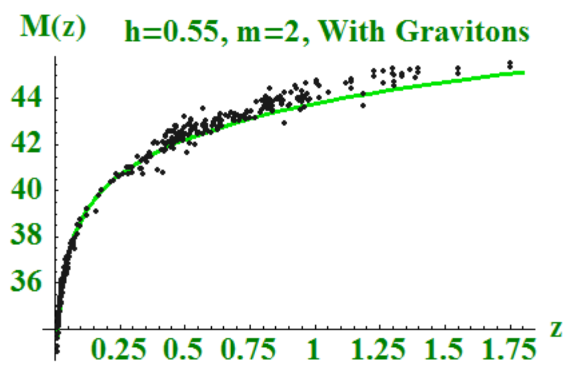
$$d_L = \frac{c}{H}(1+z)\int_0^z \frac{\mathrm{d}\xi}{\sqrt{m(1+\xi)^3+(1-m)(1+\xi)^2}} \tag{5}$$

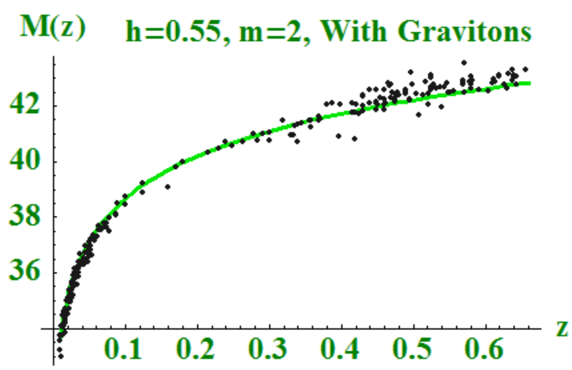
For any specified value of m, the above definite integral can be evaluated to obtain d_L, and the corresponding magnitude computed. We shall demonstrate the graphic results for three values $m = 1, 2, 3$. Here, we have the magnitude curve for the case $m = 1$:



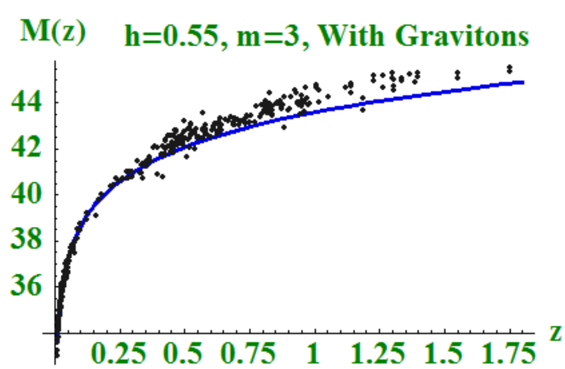


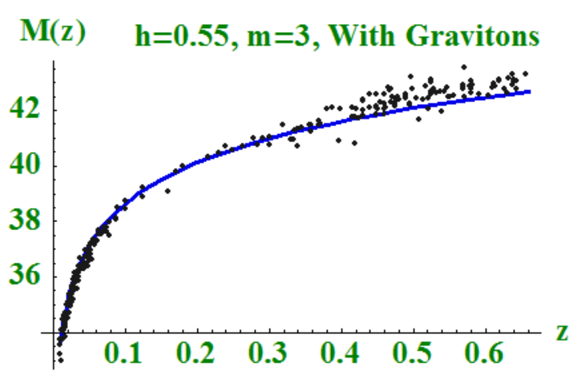
Here, we have the magnitude curve for the case $m = 2$:



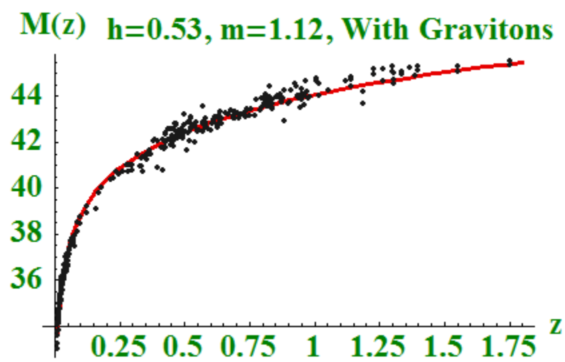


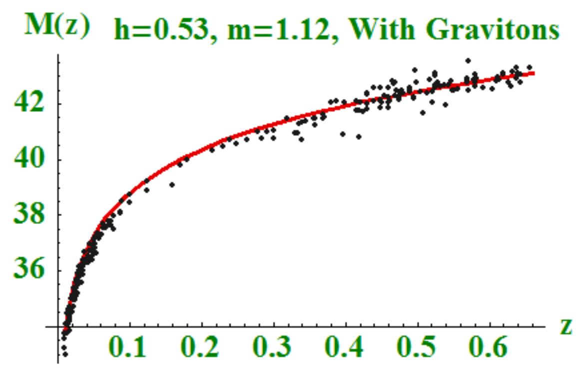
And here, we have the magnitude curve for the case $m = 3$:





It is clear from the above depictions that increasing the value of m would take the curve downwards, especially for higher redshifts, with respect to the observational points. As a matter of fact, we have used large variations to the value of m in order to make the effect quite visible on the graphics. However, if m has to be greater than 1, it has to be so by a small amount. We have experimented with the values of the Hubble fraction h and the matter density fraction m and found that the most agreeable fit, in this model with negative density gravitons, would come about with $h \approx 0.53$ and $m \approx 1.12$. Here are the corresponding graphics:





Let us adopt the value $h = 0.53$, and the value $m = 1.12$, and proceed to compute the deceleration parameter, as well as, the time remaining for the expansion to stop and begin the next contraction phase.

The *deceleration* parameter q can be computed from the right side of the Friedmann equation (using the negative of $\ddot{a} = (d\dot{a}/da)\dot{a}$ evaluated at $a = 1$), and we obtain $q = m/2 = 0.56$. This is a substantial amount of deceleration, to be contrasted with the claimed *acceleration* ($\sim$0.55) of the universe in a theory with a positive cosmological constant.

Notice that, in the present model, the universe would expand until the density of matter $\sim(m/a^3)$ becomes equal to the graviton density $\sim(1-m)/a^2$. Hence the maximum value of the scale parameter is $a = m/(1-m) \approx 9.33$. The *remaining time* for the expansion phase is obtained by integrating the Friedmann equation,

$$\frac{1}{H} \int_{1}^{9.33} \frac{\mathrm{d}a}{\sqrt{\frac{m}{a} + (1-m)}} \tag{6}$$

With the value of the matter density fraction $m = 1.12$, we obtain for the remaining time 2.42607×10^{19} sec, or 770.565 Gyr.

4 Matter with Negative-Density Vacuum

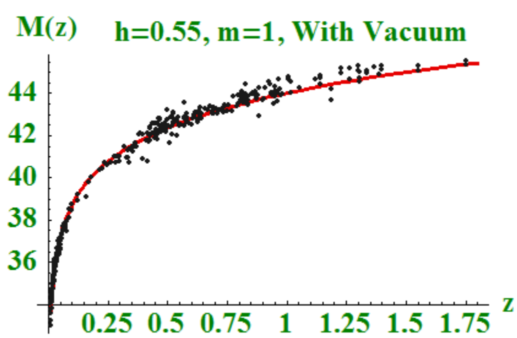
Consider now the following Friedmann equation,

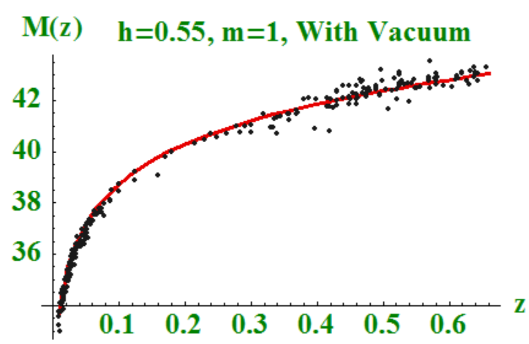
$$\left(\frac{\dot{a}}{a}\right)^2 = H^2 \left\{\frac{m}{a^3} + (1-m)\right\} \tag{7}$$

Here we have included a term for matter density with a fractional coefficient m, and a term corresponding to the vacuum density (negative cosmological constant) with fractional coefficient $(1-m)$. Notice again that, for the vacuum density to be negative, the value of m must be greater than 1. In the present discussion, we shall again begin by using a Hubble fraction of $h = 0.55$, and again, we shall examine the effect of varying the matter density coefficient m on the magnitude curve. Here is the corresponding expression for the luminosity distance as a function of the redshift z,

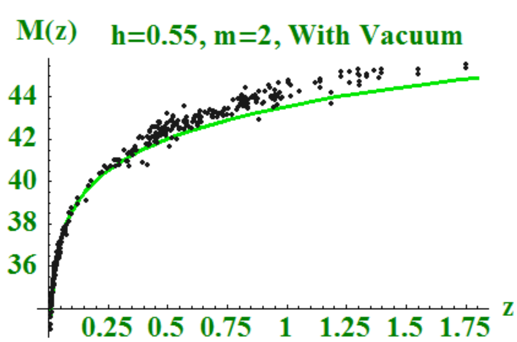
$$d_L = \frac{c}{H}(1+z)\int_0^z \frac{\mathrm{d}\xi}{\sqrt{m(1+\xi)^3 + (1-m)}} \tag{8}$$

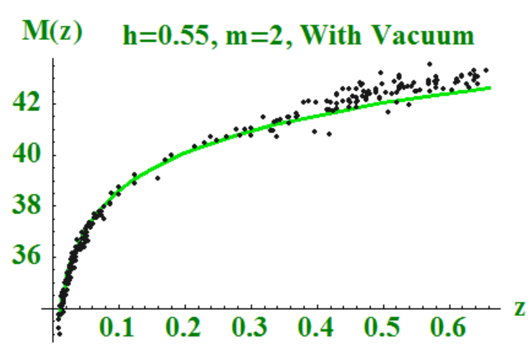
Again, we shall work with the three values $m = 1, 2, 3$. Here, we have the magnitude curve for the case $m = 1$:



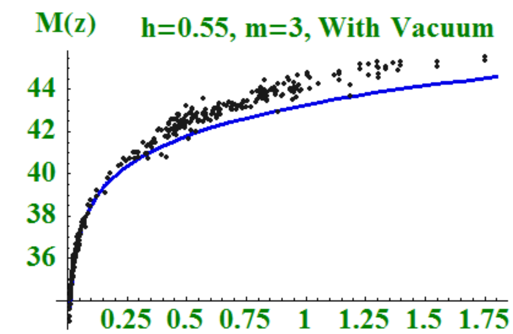


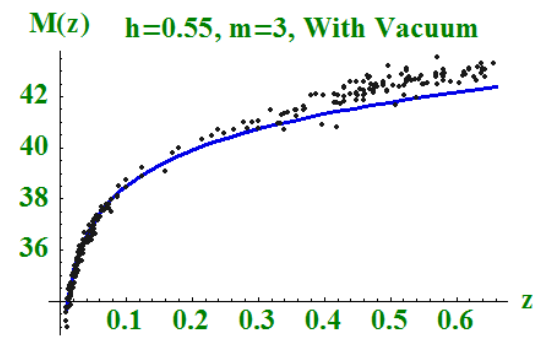
Here, we have the magnitude curve for the case $m = 2$:



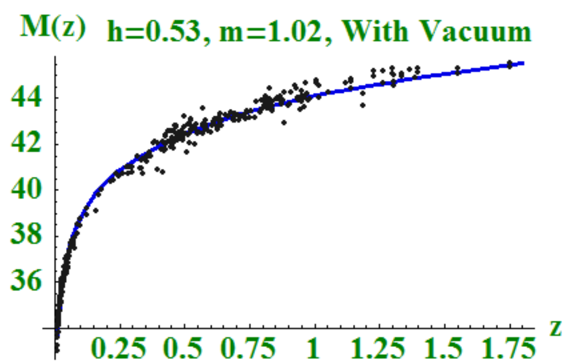


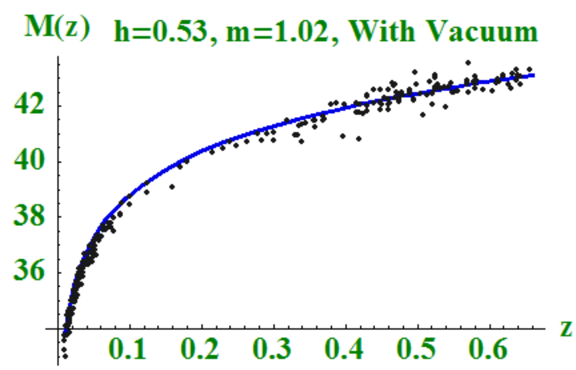
And here, we have the magnitude curve for the case $m = 3$:





Again, it is clear from the above depictions that increasing the value of m would take the curve downwards with respect to the observational points. Again, we have experimented with the values of the Hubble fraction h and the matter density fraction m and found that the most agreeable fit, in this model with negative density vacuum, would come about with $h = 0.53$ and $m = 1.02$. Here are the corresponding graphics:





Let us adopt the values $h = 0.53$ and $m = 1.02$ and compute the deceleration parameter, and the time remaining before the beginning of the next contraction phase.

The deceleration parameter q can again be computed from the right side of the pertinent Friedmann equation, and we obtain $q = (-1+3m/2) = 0.53$. Again, this is a substantial amount of *deceleration*, to be contrasted with the claimed *acceleration* ($\sim$0.55) of the universe, obtained with $m \approx 0.3$, in a theory with a positive cosmological constant.

Notice that, in the present model, the universe would expand until the density of matter $\sim(m/a^3)$ becomes equal to the vacuum density $\sim(1-m)$. Hence the maximum value of the scale parameter is $a = \{m/(1-m)\}^{1/3} \approx 3.71$. The remaining time for the expansion phase is obtained by integrating the Friedmann equation,

$$\frac{1}{H}\int_{1}^{3.71} \frac{\mathrm{d}a}{\sqrt{\frac{m}{a} + (1-m)a^2}} \tag{9}$$

With the value of the matter density fraction $m = 1.12$, we obtain for the remaining time 3.92552×10^{18} sec, or 124.682 Gyr.

5 Discussion

Complementing previous work[1], [2], the present article shows again that it is possible to obtain a satisfactory agreement with the supernovae data, of magnitudes versus redshifts, in cosmological theories characterized by *deceleration rather than acceleration*. This is possible on account of *adjusting the value of the Hubble fraction as well as the value of the matter density fraction*. This is a much more acceptable alternative to the *bizarre scenario of an ever-accelerating cosmic expansion*.

That the universe should be decelerating rather than accelerating is a very realistic possibility that have been the *natural expectation* for cosmologists for many years after the discovery of cosmic expansion. The role of negative graviton density, or alternatively negative vacuum density, in halting the expansion, provides a complementary picture to the role of negative photon density in halting the collapse of the universe in an earlier (or subsequent) contracting phase. Both types of radiations, whether electromagnetic of gravitational, are emitted by the stars. The latter are the *main constituents of an oscillating universe* in the framework of a “realistic non-singular cosmology”. The latter framework is the reasonable *alternative to the grotesque singular and ever-accelerating paradigms*. The origin of a possible negative vacuum density is not clear at the present time. Perhaps our studies of quantum field theory and quantum gravity might clarify the situation.

A Appendix: Supernovae Magnitudes Data List

The following is a collected list[11], [12], [13] of items of the form $\{z, M\}$, where z is the redshift and M is the corresponding supernova magnitude: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{{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},
{0.015,34.118},{0.0152,34.11},{0.0157,34.58},{0.016,34.071},{0.016,34.083},
{0.016,34.129},{0.016,34.405},{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},{0.017,34.162},
{0.017,34.216},{0.017,34.319},{0.017,34.452},{0.017,34.18},{0.017,34.47},
{0.0171,34.68},{0.0175,34.52},{0.0178,34.7},{0.018,34.489},{0.018,34.576},
{0.018,34.29},{0.0186,34.96},{0.0193,34.59},{0.02,34.494},{0.0218,35.06},
{0.0219,34.7},{0.022,34.941},{0.023,35.146},{0.0233,35.14},{0.0234,35.36},
{0.024,35.228},{0.024,35.25},{0.0244,35.09},{0.0247,35.33},{0.025,34.931},
{0.025,35.192},{0.0251,35.09},{0.0257,35.41},{0.026,35.342},{0.026,35.353},
{0.026,35.565},{0.026,35.62},{0.0262,35.06},{0.0265,35.64},{0.0266,35.36},
{0.0276,35.9},{0.028,35.15},{0.0286,35.53},{0.029,35.7},{0.0297,36.12},
{0.03,35.822},{0.03,35.994},{0.0307,35.9},{0.031,35.532},{0.031,35.558},
{0.0316,35.85},{0.032,35.789},{0.0327,36.08},{0.0331,35.54},{0.0348,36.17},
{0.035,35.837},{0.036,36.113},{0.036,36.17},{0.036,36.01},{0.036,36.39},
{0.038,36.67},{0.039,36.284},{0.04,36.38},{0.043,36.276},{0.043,36.53},
{0.045,36.728},{0.045,36.97},{0.046,36.35},{0.049,36.383},{0.049,36.52},
{0.049,36.9},{0.05,36.632},{0.05,36.827},{0.05,36.84},{0.05,37.08},
{0.051,36.67},{0.052,37.16},{0.053,36.794},{0.053,36.97},{0.053,37.17},
```

{0.054,36.606},{0.056,37.31},{0.058,37.13},{0.061,37.3},{0.063,37.54},
{0.063,37.67},{0.067,37.54},{0.071,37.604},{0.071,37.78},{0.075,37.642},
{0.075,37.77},{0.079,37.465},{0.079,37.94},{0.088,38.07},{0.088,38.121},
{0.089,38.5},{0.101,38.437},{0.101,38.73},{0.124,39.2},{0.125,38.885},
{0.16,39.08},{0.172,39.79},{0.18,39.98},{0.216,40.33},{0.216,40.33},
{0.23,40.44},{0.24,40.68},{0.249,40.571},{0.263,40.682},{0.278,41.},
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{0.346,41.367},{0.357,41.441},{0.358,41.474},{0.359,41.23},{0.369,41.485},
{0.369,41.62},{0.371,41.488},{0.38,42.02},{0.388,42.07},{0.397,40.89},
{0.4,42.04},{0.415,41.772},{0.416,42.1},{0.42,40.79},{0.42,41.76},
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{0.475,42.14},{0.475,42.24},{0.477,42.38},{0.478,42.48},{0.48,42.37},
{0.49,42.41},{0.49,42.54},{0.49,42.58},{0.495,42.25},{0.496,42.18},
{0.498,43.21},{0.5,42.74},{0.5,42.75},{0.5,42.75},{0.504,42.429},
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{0.532,42.592},{0.538,42.66},{0.54,41.96},{0.543,42.68},{0.548,42.825},
{0.55,42.487},{0.552,42.461},{0.557,42.511},{0.57,42.77},{0.57,42.81},
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{0.581,42.63},{0.581,42.761},{0.582,42.881},{0.592,42.562},{0.604,42.515},
{0.61,42.796},{0.613,42.961},{0.615,42.85},{0.62,43.03},{0.62,43.11},
{0.627,42.746},{0.63,42.62},{0.633,43.133},{0.638,42.89},{0.638,43.3},
{0.64,43.07},{0.64,43.01},{0.643,43.023},{0.644,42.78},{0.657,43.27},
{0.67,43.19},{0.67,43.19},{0.679,43.398},{0.688,43.046},{0.691,43.144},
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{0.719,43.22},{0.721,43.209},{0.73,43.287},{0.735,43.09},{0.735,43.14},
{0.74,43.35},{0.74,43.38},{0.741,43.427},{0.752,43.17},{0.756,43.453},
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{0.817,43.652},{0.818,43.532},{0.822,43.544},{0.828,43.61},{0.828,43.96},
{0.83,43.85},{0.83,44.414},{0.832,43.55},{0.839,43.45},{0.839,43.86},
{0.84,43.475},{0.84,43.67},{0.854,43.96},{0.86,44.03},{0.868,43.871},
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{0.93,44.43},{0.935,43.97},{0.935,43.99},{0.94,43.87},{0.949,43.507},
{0.949,43.99},{0.95,44.06},{0.95,43.954},{0.95,43.98},{0.954,43.85},
{0.954,44.28},{0.954,44.3},{0.96,43.622},{0.961,44.},{0.97,44.13},
{0.97,44.67},{0.975,44.21},{0.977,43.91},{0.983,43.941},{1.01,44.673},
{1.01,44.77},{1.02,43.99},{1.02,44.52},{1.056,44.25},{1.12,44.67},
{1.14,44.44},{1.14,44.71},{1.14,44.84},{1.19,44.19},{1.19,43.64},
{1.23,44.97},{1.23,45.17},{1.265,44.64},{1.265,45.2},{1.3,45.27},
{1.3,45.06},{1.305,44.51},{1.305,44.7},{1.307,44.99},{1.34,44.92},
{1.34,45.05},{1.37,45.23},{1.39,44.9},{1.4,45.09},{1.4,45.28},
{1.551,45.07},{1.551,45.3},{1.755,45.35},{1.755,45.53}}

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