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Realistic Non-Singular Cosmology with Negative Vacuum Density

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Abstract

We present a version of "realistic non-singular cosmology" in which the upper turning point of expansion is provided by negative mass density of vacuum rather than by gravitational radiation. The lower turning point is still provided by the negative pressure of electromagnetic energy. Again, assuming that the temperature of microwave radiation is a true measure of the electromagnetic energy density of the universe, and that the supernovae data of magnitudes and redshifts are reliable, we can determine (tentatively) the parameters of this version of our model, with an appropriate Hubble fraction of 0.475, and a deceleration parameter of 0.65, and estimate the time that passed, about 13.3 Gyr, since the initiation of the expansion phase, and the time that remains, about 55 Gyr, before the return to contraction. The maximum radiational temperature was only about 27,344 K, and the maximum mass density was low enough to give each typical star an ample space of about 5% of a lightyear to proceed with its own activity without disruption.

1 Introduction

As the current model for expanding cosmology[1], [2], including the version with an early inflationary era[3], [4], [5], is beset with many difficulties, notably the *initial singularity*, and as the proposal of positive density vacuum-driven expansion, suggested by supernovae data of magnitudes and redshifts[6], [7], [8], leads to an unnatural picture of an *ever-accelerating scenario*, we have proposed a *realistic non-singular cosmology*[9] where the basic idea is that the contraction and the expansion of the universe must be governed by two turning points, corresponding to the roles of negative photon pressure and positive graviton pressure, respectively. It is the negative pressure of electromagnetic radiation produced by stellar bodies which prevents the collapse in a contracting phase, and it is the positive pressure of gravitational radiation produced by stellar bodies, as well, which prevents eternal expansion. We identify the cosmic microwave radiation as a remnant of the *negative photonic density produced by stellar matter*, rather than a positive density relic of a remote singular past[10], [11].

Our purpose in this article is to show that the role played by the positive pressure of gravitational radiation in turning the expansion into contraction, sometime in the future, can also be played, and even more effectively, by a *negative density vacuum* contribution to the Friedmann equation[12].

2 The Non-Singular Model with Negative Vacuum Density

The Friedmann equation in the new scheme takes the form

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

Here we have included a term corresponding to the vacuum (cosmological constant) with coefficient $(1-m-r)$, a matter term, and electromagnetic radiation term. It turns out that we should take a value of the Hubble constant $H = 47.5$ km/sec/Mpc, or $H = 1.53937 \times 10^{-18}$ sec^{-1}. Corresponding to this value, the total mass density is

$$\rho = \frac{3H^2}{8\pi G} \approx 4.23909 \times 10^{-27}\,\mathrm{kg/m^{-3}} \tag{2}$$

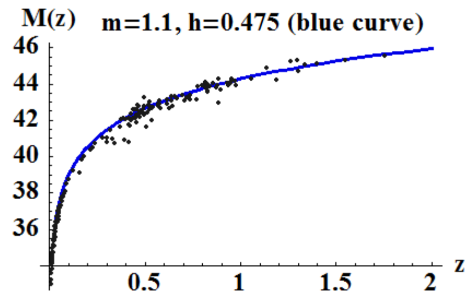
For the photon background fraction r of the total density, we shall take the ratio of the measured mass density value (using the temperature of the microwave radiation $T = 2.726$ K)

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

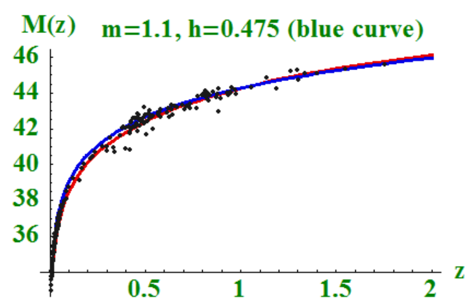
to the total density ρ, however, with a negative sign $r = -0.00010966$. As we have discussed before[9], we choose a negative value, in contrast with ordinary theory, in order to prevent a singularity as $a \to 0$. This choice is dictated by *energy conservation*, since the photons are produced by stellar matter, rather than existing on their own right since creation, as in a singular theory. For the matter fraction m of the total density, we take the tentative value $m \approx 1.1$. This choice gives a coefficient of the vacuum term $(1-m-r) \approx -0.0998903$. Such a negative value will prevent continual expansion. We can easily evaluate the present value of the deceleration parameter to be $q = 0.65$. Again, as we have remarked before[9], the above choice of the Hubble constant, and the fractions of matter and radiational densities, is only tentative and illustrative at this stage, and are taken to be *in pleasant accord with the supernovae magnitudes*, awaiting more accurate measurements of the matter density.

Having specified H, r, and m, we can integrate the Friedmann equation numerically, and obtain the time since the expansion was minimum (when $a = 0.0000996914$), and also the time left for it to reach a maximum (when $a = 2.22476$). Notice that the present value of the expansion scale is normalized at $a = 1$. For the time since minimum we obtain the value 4.19506×10^{17} sec, or 13.3243 Gyr. For the time left to maximum, before the return to contraction, we obtain the value 1.73297×10^{18} sec, or 55.0423 Gyr. Notice that the latter value is *much lower* that the 1066 Gyr value, obtained for the theory where gravitational radiation is taken to be the determinant of the upper turning point.

We now move to see how this version of the model compares with the data from supernovae. The reader should consult the earlier work[9] for the list of data points[13] and related plots in conventional theory. The following is a plot of the corresponding magnitude curve (blue color) with the observational data points.



And the following is the same plot, including the curve (red color) for the theory with a positive vacuum energy, cosmological constant:



It is clear that our model with a *negative* vacuum density, however, with a much lower Hubble fraction (0.475 compared to 0.65), and a higher matter fraction (1.1 compared to 0.3) than the theory with a *positive* vacuum density, does compare equally well with supernovae measurements. However the virtue of our model is that it *does not lead to the unnatural picture of an ever-accelerating expansion.*

3 Discussion

The reader should consult our previous discussion of [9] of energy conservation, however, with the negative vacuum energy replacing that of gravitational radiation.

The *maximum temperature* reached by radiation, at minimum scale ($a = 0.0000996914$) can be computed from $2.726/a$ and the result is 27,344.4 K. This low-value temperature is of the same order of magnitude as the surface temperature of massive stars. The corresponding photon energy is $kT \sim 2.35637$ eV. Again, such low-energy photons would not be able to dissociate neither hydrogen atoms ($\sim$13.6 eV), or even to dissociate hydrogen molecules ($\sim$4.2 eV).

Notice that the size of the visible universe, estimated here to be $c/H \approx 1.9475 \times 10^{26}$ m, would become at minimum scale $a = 0.0000996914$ something like 1.94149×10^{22} m. The latter value is about 20 times the diameter of our galaxy. Hence *galaxies are destined to merge together at minimum scale.*

The mass density of matter at minimum scale is $\rho_{\max} = 1.1/a^3 \approx 4.70645 \times 10^{-15}$ kg/m^3. Whereas this value of density is high enough to cause the merging of galaxies, it is, however, *not high enough to cause the merging of stars*. Let us imagine that all the stars in the universe were to be distributed homogeneously, equating $\rho_{\max} \times (4\pi r^3/3)$ to the mass of a typical star like the sun, we obtain $r \approx 4.65527 \times 10^{14}$ m. This value of radial distance, about 5% of a light year, *would give a star an ample space to remain whole, and to proceed in its normal activity, at minimum expansion scale, without disruption*.

In conclusion, the model presented in this paper, like the one presented earlier[9], is based on a very logical framework governed by energy conservation. It is imperative that *nonsingular* models like these, and which *avoid the inclusion of a positive cosmological constant*, should be studied further. However the actual numerical implementation of these models at the moment, as we have remarked earlier, is only tentative and illustrative. It is very important that a perfectly reliable observational determination of the cosmic average density of matter should be available.

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