Accelerating Expansion of the Universe: Yes or No?

by Bob Day

Introduction

Over the past decade most cosmologists have come to believe that the universe is expanding at an accelerating rate. Seeming evidence for this acceleration has been provided by brightness measurements of many newly discovered type Ia Supernovae. These supernovae were discovered to be unexpectedly faint for the distance at which they were according to standard cosmology. If their distances were indeed correct, the unexpected faintness of the supernovae would indicate that the universe is larger than thought. This could be explained by postulating an accelerating expansion, which is the way standard cosmology explains it. Another theory, the Dynamic Universe (DU) theory explains the same measurements just as well as standard cosmology, but without the need for the expansion of the universe to be accelerating. In this essay I will describe both approaches.

In this essay I'll be using several terms such as "magnitude", "distance", "flux", "redshift", and "distance modulus". These terms will be introduced as we go along. In cosmology, brightness measurements of stellar objects – stars, galaxies, supernovae, etc. – are normally converted to "magnitudes". The magnitude scale was devised by the ancient Greeks to describe the perceived brightness of stars. They assigned the brightest stars a magnitude of 1, and the faintest a magnitude of 6. The magnitudes we use today are based on that same scale, but we use mathematical equations to convert an object's brightness – its "wattage" which we can measure objectively and accurately – to its magnitude. There are two such equations that will be used in this essay. There is no controversy about these equations; they are direct consequences of the mathematical definition of magnitude. Standard cosmology computes magnitudes based on an object's distance from earth:

$$m = M + 5\ \log_{10} d + 25\,.$$

In this equation, *M* is a reference magnitude whose value in the case of type Ia supernovae (which are the only stellar objects I'll be talking about) is approximately -19.31. '*m*' is an object's magnitude in relation to *M*. 'd' is the distance from earth to the object in megaparsecs. Actually, cosmologists find it more convenient to use the equivalent equation:

$$m - M = 5\ \log_{10} d + 25\,.$$

Cosmologists call the term "m – M" the "distance modulus" and give it the name *μ*. So we have:

$$\mu = m - M = 5\ \log_{10} d + 25\,.$$

Cosmologists call $\mu = m - M$ the “distance modulus” because its principal use is as a measure of distance to stellar objects. However, since M for type Ia supernovae is a constant (about -19.31), μ can be used as a measure of a type Ia supernova’s magnitude or brightness. And that is how it will be used in this essay.

The Dynamic Universe (DU) theory uses a much different approach. It computes magnitudes based on an object’s observed “flux” as measured on earth:

$$m = -2.5\ \log_{10}\left(F_{obs} / F_r\right).$$

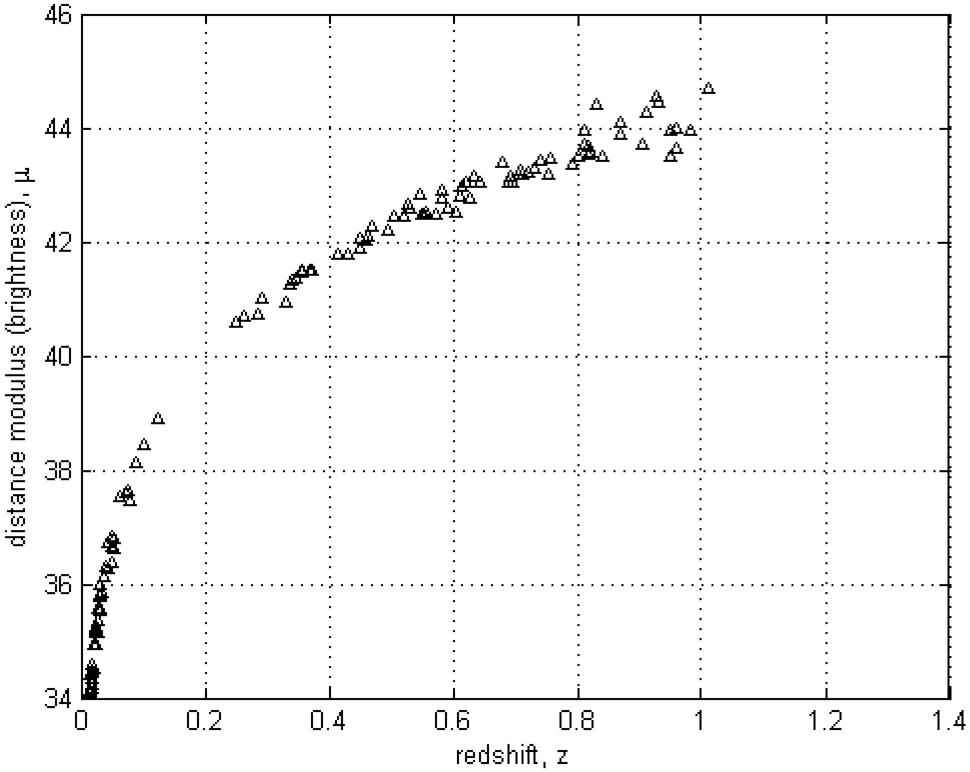
The observed flux, F_{obs}, is a measure of the brightness of illumination over a square meter. F_r is a reference flux whose value is approximately 2.53×10^{-8}. As I will show later in this essay, the DU equation can easily be expressed in terms of the distance modulus μ, so that both models will use the same independent variable, which will be the vertical scale in the figures.

The dependent variable that will be used for both models (the horizontal scale in the figures) is “redshift”. Redshift is the customary variable cosmologists use in plots of cosmological measurements that are dependent on distance. For comparing the standard cosmology and the DU models of type Ia supernova data, redshift is especially convenient because distance in standard cosmology and the observed flux in the DU can both be expressed in terms of redshift. Briefly, redshift, denoted by z, is the fraction by which the wavelength of light an object emits has increased while it has traveled from the object to earth. The wavelength increases because as the light travels, its wavelength increases along with the expansion of the universe.

The Data

The data is where “the rubber meets the road”. Figure 1 shows a plot of what is probably the best data that has so far been obtained from measurements of type Ia supernovae.

Figure 1. The data we want to fit.



The data plotted in Figure 1 was published in 2005 by a group of researchers led by Pierre Astier of the Centre National de la Recherche Scientifique in France. You can find it at http://arxiv.org/PS_cache/astro-ph/pdf/0510/0510447.pdf . The plot shows the distance modulus of 115 type Ia supernovae plotted against their measured redshift. What we would like to do is find models, i.e. equations, that fit this data. The data, having been obtained by real-world measurements, is "shaky" – it contains random fluctuations. Our goal is to find an equation for a smooth curve that goes as close as possible to all of the points and has the same overall shape as the data. The better the curve, the more confidence we can have in the model that produced it. In the following sections, I'll describe the curve that results from standard cosmology and the curve that results from the DU.

Standard Cosmology: the Expansion of the Universe is Accelerating

As stated earlier, standard cosmology uses the equation $\mu = 5\ \log_{10} d + 25$ to relate distance to distance modulus. Since we want to use redshift as the dependent (horizontal axis) variable, we need to relate the distance, d, to redshift, *z*. In standard cosmology this relationship is very complex, but it takes into account how standard cosmology models the shape and expansion of the universe. Here's the equation:

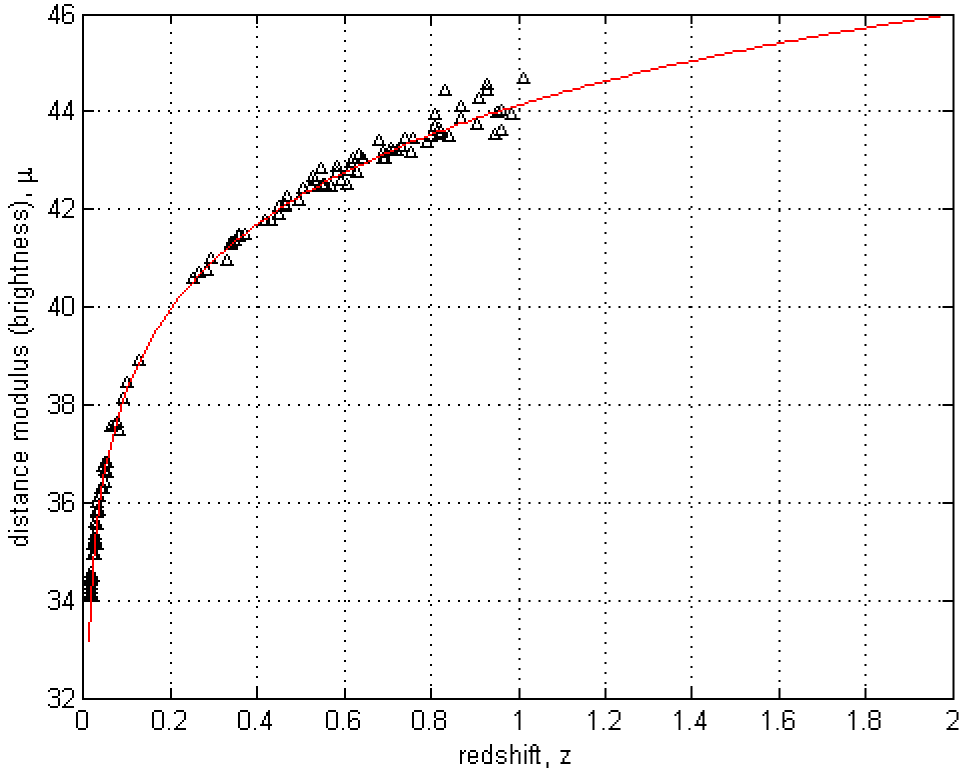
$$d = \frac{c(1+z)}{H_0}\int_0^z \frac{1}{\sqrt{(1+z)^2(1+\Omega_m z) - z(2+z)\Omega_\lambda}}\,dz$$

For a derivation of this equation, see: S. E. Carroll, W. H. Press, and E. L. Turner, 1992. “The Cosmological Constant,” Ann. Rev. Astron. Astrophys., 30, 499. Here’s a link to the article:
http://adsbit.harvard.edu/cgi-bin/nph-iarticle_query?bibcode=1992ARA%26A..30..499C

In this equation, ‘*c*’ is the speed of light and H_0 is the Hubble constant (which represents the expansion rate of the universe), and both have fixed values (c = 299792 km/sec, and H_0 = 70 km/sec/megaparsec). That leaves us with two parameters to play with, Ω_m and Ω_λ. These are “density” parameters. Ω_m is the matter density of the universe and Ω_λ is the “dark energy” density. Dark energy, according to standard cosmology, is an unseen repulsive force that pervades the universe. Enough of it would cause the expansion of the universe to accelerate. The values of Ω_m and Ω_λ are constrained in a couple of ways: Both must be positive (the density of anything can’t be less than zero), and in order to make the universe “flat”, Ω_m and Ω_λ must add to 1. “Flat” means that the universe does not bend in the fourth dimension. So the value of Ω_λ determines Ω_m, or vice-versa. There is another very interesting relationship between Ω_m and Ω_λ. It turns out that if $\frac{1}{2}\Omega_m - \Omega_\lambda < 0$, the expansion of the universe must be accelerating! (See Carroll, Press and Turner, 1992, cited earlier, or “Introduction to Cosmology” by Barbara Sue Ryden, 2003.)

If we play with the values of Ω_m and Ω_λ keeping within the constraints, we can find the values that best fit the data. The optimum fit curve is shown in Figure 2:

Figure 2. The optimum standard cosmology curve.



Obviously it's an excellent fit! Standard cosmology provides a near perfect fit to the data! Any researcher worth their salt would run naked through the streets shouting with excitement with a fit like this! (We need more female researchers.) The optimum values of the parameters are: $\Omega_m = 0.280$ and $\Omega_\Lambda = 0.720$. From these values we can conclude that the universe is indeed accelerating in its expansion since $\frac{1}{2}\Omega_m - \Omega_\Lambda = \frac{1}{2}0.28 - 0.72 = -0.58$, which is less than zero. IF you believe the theory, that is. And that's the trouble. General relativity (on which standard cosmology is based) has been around for close to a century, and it has withstood the test of time. Our confidence in the theory certainly lends credence to the conclusion that the expansion of the universe is accelerating is correct. But it's not the kind of evidence we'd really like – it's not direct evidence. We have no way of independently checking it. We just have to take the say-so of the theory, the theory's word for it. In addition, there's a problem with dark energy, the basis for Ω_Λ – there's no direct evidence for it either. It's just a postulate of the theory! What we'd really like to do is measure the expansion of the universe with a stopwatch and a ruler and see for ourselves whether it's accelerating or not. Unfortunately that's impossible.

Another difficulty is that accelerating expansion of the universe is a totally counterintuitive result. Before the type Ia supernova data was obtained it was rejected as nonsense by most mainstream cosmologists. So perhaps the idea of accelerating expansion shouldn't be accepted quite so easily. Is there an alternative explanation for the unexpected faintness of distant type Ia supernovae that doesn't require an accelerating expansion and dark energy?

The Dynamic Universe theory: No, It Isn't

As stated earlier, the DU calculates magnitudes based on an object's observed flux:

$$m = -2.5\ \log_{10}\left(\frac{F_{obs}}{2.53 \cdot 10^{-8}}\right).$$

Since we want the dependent variable (the horizontal axis in the figures) to be redshift, z, we need an equation that relates the observed flux to redshift, that is, F_{obs} to z. The equation is derived in detail in "Theoretical Basis of the Dynamic Universe" by Tuomo Suntola (2005). In this essay, I'll just summarize the results:

$$F_{obs} = \left(\frac{1}{(z+1)}\right)\left(\frac{1}{(z+1)^2}\right)\left(\frac{z+1}{z}\right)^2 \frac{E_e}{A_e} = \frac{F_e}{z^2(z+1)}.$$

This equation gives the observed flux in term of z and F_e, the Flux emitted by the supernova. F_e is a constant for type Ia supernovae, and, as we'll see later, can be converted to its absolute magnitude. There are four factors in this equation. The first factor is the reduction in energy of a photon emitted by the supernova due to the increase in its wavelength caused by the expansion of space during the photon's travel from the supernova to earth. The second factor represents the reduction in energy due to the increase in the photon's cross sectional area during its travel. The third factor accounts for the expansion during the photon's travel of a unit area (a square meter, say) originating on the surface of the supernova. The last factor converts the total energy, E_e, radiated by the supernova to energy per unit area, i.e., flux.

Substituting the result for F_{obs} in the second equation into the first equation, we get:

$$m = -2.5\ \log_{10}\left(\frac{F_e}{z^2(z+1)} \cdot \frac{1}{2.53 \cdot 10^{-8}}\right).$$

Since F_e is a constant, this reduces to:

$$m = 5\ \log_{10}(z) + 2.5\ \log_{10}(z+1) + \text{constant}.$$

Splitting the constant into two parts, the fixed absolute magnitude for a type Ia supernova, M, and a value to be determined, C, we get:

$$m = M + 5\ \log_{10}(z) + 2.5\ \log_{10}(z+1) + C.$$

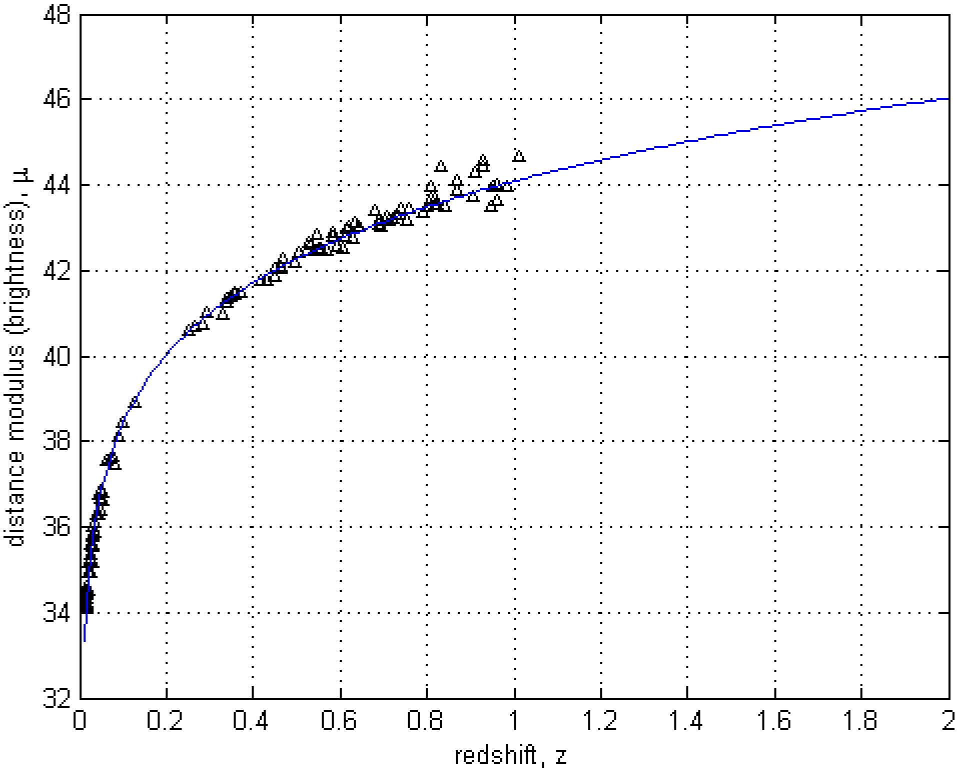
Or equivalently,

$$\mu = m - M = 5\ \log_{10}(z) + 2.5\ \log_{10}(z+1) + C,$$

which, finally, gives the DU equation for the distance modulus in terms of the redshift, *z*.

Figure 3 shows the optimum fit of the DU equation.

Figure 3. The optimum DU curve.



Obviously it’s another near-perfect fit. The value of the constant *C* that optimizes the fit of the curve is 24.020. Both the standard cosmology and the DU curves model the data extremely well. Let’s lay them on top of each other to see how the two curves compare:

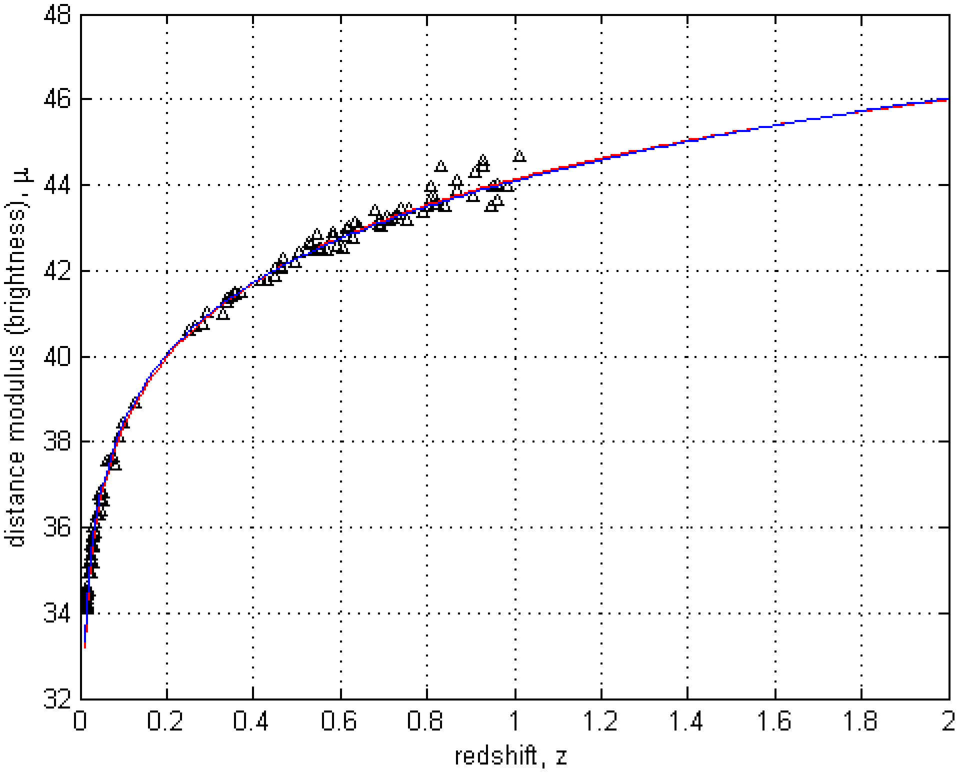


Figure 4. The standard cosmology and DU curves superimposed.

The curves are all but identical. A mathematical “goodness of fit” (GF) value I computed reveals just how close the two curves are. The GF number for the standard cosmology curve is 31.5859; for the DU it was 31.5262. A smidge better for the DU, but the difference is so small that the normal random inaccuracy in the measurement of a single data point could probably account for it.

Conclusion

The big difference is not in the curves but in the theories! In order to explain the data, standard cosmology requires the expansion of the universe to be accelerating. The DU has no such requirement. Which theory is right? On the basis of the type Ia supernova data it’s a complete toss-up. There’s no way to pick one theory over the other. Perhaps an advantage for the DU is that it doesn’t need to postulate a new force, dark energy, to explain the data. On a wider scale, the DU has been found to be in complete agreement with the theory of general relativity (on which standard cosmology is based). As examples, phenomena that general relativity and the DU model equally well include: the tradeoff between mass and energy, the rotation of the perihelion of Mercury, the bending of light around stars, and the slowing of time in a gravitational field.

Here are some Internet links to more information about the DU:

1. “The Dynamic Universe Theory – a Theory of the Universe that Makes Sense!” at http://bobday.vze.com

2. Tuomo Suntola’s website:
   http://www.sci.fi/~suntola

3. ”Theoretical Basis of the Dynamic Universe” by Tuomo Suntola:
   http://www.amazon.com/gp/product/9525502104/sr=1-1/qid=1156529058/ref=sr_1_1/102-3325681-5207315?ie=UTF8&s=books