Edwin Hubble’s Discovery

Determining the distance d to an observed galaxy like to an observed star involves measuring the ‘magnitude’ m (logarithmically related to luminosity) and comparing that to what it would be if the star or galaxy were at a fixed distance. (The magnitude is compared to what it would be if the object were located a distance 32.6 light years away, its ‘absolute magnitude’ M.) The definition of magnitude and the fact that the flux f of photons from a point source diminishes with an inverse-square relationship to distance corroborates the legitimacy of the metric. This conflated assessment of distance gets confusing, but it is the most direct a measure of the distance at extreme distances that is possible. It is not entangled with theoretical interpretation other than accepted knowledge that the flux of photons of light diminishes as $1/d^2$. This definition is equivalent to:

$$d = 32.6 \sqrt{f(32.6) / f(d)}$$

This is the determination of distance that Hubble used to assess how far away the galaxies were whose spectra he observed. The ‘spectrum’ of a galaxy is simply a chart or a graph that shows the intensity of radiation emitted or absorbed over a range of wavelengths. It is the sum of the spectra of the stars within the galaxy and the preponderance of elements in the stars such as oxygen (O), sodium (Na), etc. that emit radiation. There are recognizable differences between different types of galaxies with similarities in the spectra of galaxies of the same type. The spectra of two similar galaxies are shown in figure 5, a nearby galaxy and a very distant one with a redshift z = 0.1. The two galaxies are obviously of the same type but with one spectrum shifted due to its redshift.

‘Redshift’ z is defined as a proportionate change, $\Delta\lambda = \lambda_o - \lambda_e$, in observed wavelength of observed radiation λ_o divided by the wavelengths of the originally emitted radiation λ_e.

$$z = (\lambda_o - \lambda_e) / \lambda_e$$

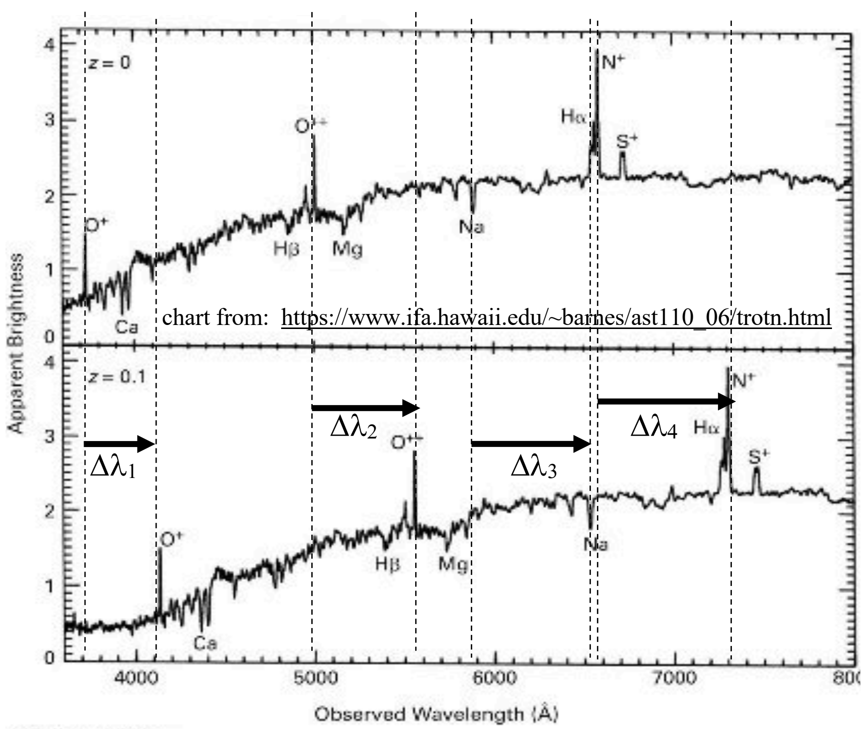

Figure 5: Redshift of galaxy spectra

In this chart, notice that all of the indicated features in the spectra are emission lines except for sodium which is an absorption line due to a temperature of sodium gas in this type of galaxy that results in a predominance of absorption rather than emission at that wavelength. Notice also that the values of changes in wavelength (lengths of the arrows) increase proportionately with the values of the emitted wavelength of the observed feature in the nearby galaxy spectra. That *is* the phenomenon of redshift. It is not just a change in wavelength, but a lengthening of wavelength proportional to the original wavelength. By performing spectra assessments on similar galaxy types, Hubble discovered that the redshift of galaxies increases in proportion to their distance d from our observing position here in the Milky Way galaxy:

$$\not{Z}(d) = H_o\, d$$

with H_o a constant of proportionality. A systematic error in his measurements gave an exaggerated value of H_o that would be corrected later, and even now is known with some uncertainty. But he had produced conclusive proof that redshift increases with distance and vice versa. That is what his measurements proved and that is *all* that they proved. See figure 6 below.

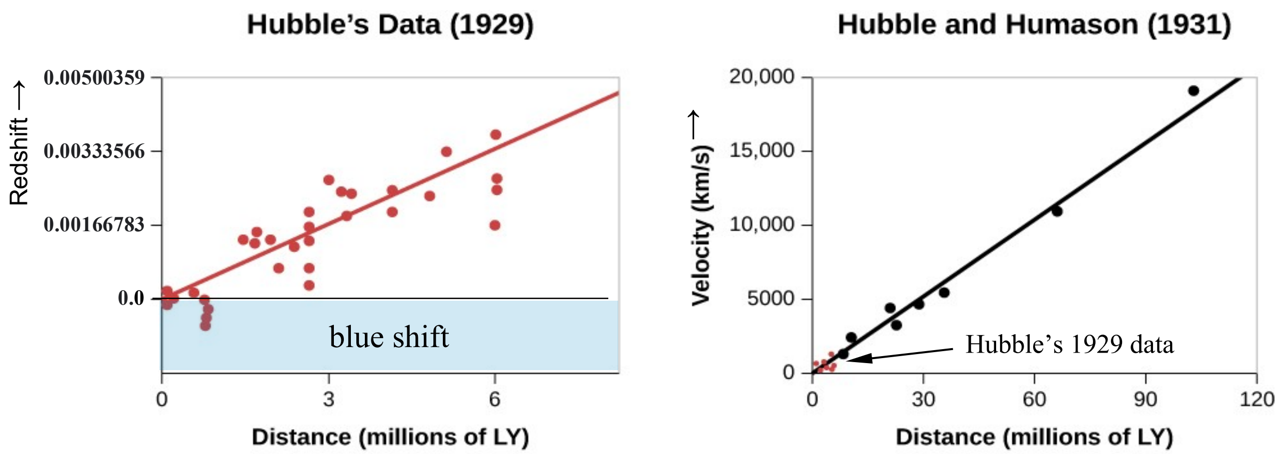

Figure 6: Hubble's discovery of the relationship between the redshift of galaxy spectra and then extended with the help of Humason to distances of over 100 million light years

There is a tolerance that applies to every measurement; they only approximate the phenomena under investigation. In defining a functionality for a set of measurements, the assumption of linearity is rather bold to say the least. To accurately assess functionality one must obtain sufficient data over an extended range to assure a valid expression for representation. There are many functions that are approximately linear over a short range but deviate from it when more accuracy is obtained. For example, the series expansion of an exponential yields the following:

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \cdots$$

If $x = H_o\, d$, then for $r << 1/H_o$, the expression $z(r) = H_o\, d$ is a reasonable misunderstanding of:

$$z(r) + 1 = e^{H_o d}$$

The viability of a direct proportionality between redshift and distance had ultimately to be abandoned once spectroscopic data was obtained from deeper searches into space. Redshift is an indicator of distance; it is not a replacement for distance by any means as shown clearly in figure 7. More importantly, there is no evidence beyond the unitless spectroscopic measurements that there is any involvement whatsoever of galaxy velocities other than orbital motions about the centers of galaxy clusters that have nothing at all to do with the distance to the galaxy in question.

Hubble succumbed to the view that redshift could only be caused by recessional velocity of the source of emitted radiation. That was in response to the question 'Why?' that we tend to ask. A discovery process cannot allow it to corrupt measured data. Recessional Doppler being the only known explanation for *why* spectra are redshifted is precisely 'why' Hubble presented a chart with an axis labeled velocity in km/sec. It is replaced with equivalent redshift values on the 1929 chart above but left with units of velocity on the 1931 chart. Velocity does not belong there. Reinstating spectroscopic measurements instead of velocity has become an onerous task for anyone who is skeptical of recessional velocity as interpretation of galaxy redshift.

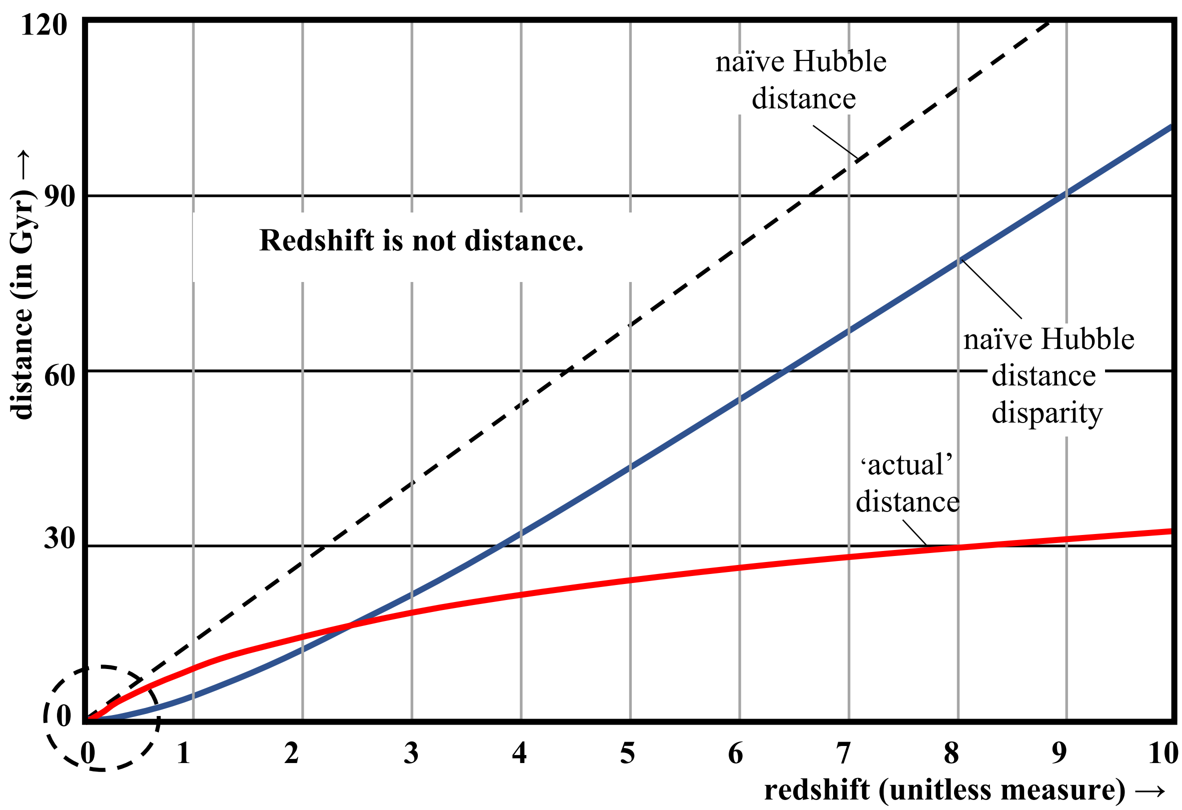

Figure 7: Increasing disparity between redshift and naïve Hubble distance

Redshift is the primary means of determining distance in cosmological investigations. The linearity initially assumed by Hubble beneath the random variations does not continue beyond the Local Group of galaxies of which the Milky Way is a component. A logarithmic scaling on such charts becomes much more appropriate. Astronomical distances quickly become dwarfed by cosmological distances; Hubble realized that the Doppler effects of the vagaries in the motions of galaxies in orbits around the centers of groups of galaxies were significant. He cautioned that the cosmological trend was only a reliable indicator of distances in excess of several hundred million light years. A giga light year (Gyr) is 10^9 light years and a mega parsec (Mpc) is 3.26 x 10^6 light years; these have become the usual units of measure for distance in cosmology.

All versions of the standard cosmological model are based on redshift interpretated as the Doppler effect of recessional velocities of galaxies or the more orthodox phrasing preference of space itself having expanded to the same effect. There are, however, *no* such observed effects – only inferences from photometric and spectroscopic data interpreted as velocity other than miniscule variations in the cosmic microwave background (CMB). All inferences of 'evolution' derive from that interpretation of data – attempts to prove the accepted 'Why'. We know redshift increases with distance; that is what we know for certain. That is *all* we know from observations.

With subscription to a Doppler recessional velocity interpretation of redshift and acceptance of an expanding and therefore necessarily evolving universe, Pandora's box was opened for disparate versions of distance. How would one define distance to something that is moving away at a velocity appreciable with regard to the speed of light by which it is observed? For the model in which redshift is simply a function of distance, it isn't too complicated other than the necessity to extract observed data from the pollution of theoretical interpretation. That requires knowledge of the model that involves a complex of velocity, inflation, deceleration, acceleration, and three component types of matter in the context of general relativity. That is not a trivial matter. There are various definitions of distance used in that context whose values all converge to the same value at small redshifts. These disparate definitions of distance are explicit functions of redshift which is the primary observable; Hubble's constant is prominent in each. We address this complexity briefly because the data we deal with has been saturated with investigators' preferred version of distance appropriate to their agenda.

The standard model involves a Hubble distance $d_H = 1/H_o$, with H_o being merely the present value of what they refer to as the 'Hubble parameter' $H(z(t))$. There are also the assumed contributors to the density of the universe, Ω_R, Ω_m, and Ω_Λ that are normalized values of the present radiation energy density, baryonic matter density, and 'dark energy' density. 'Normalization' of these parameters involves $\Omega_k = 1 - \Omega_R - \Omega_m - \Omega_\Lambda$, with Ω_k defining the 'curvature of space'. If the sum of the three densities equals Einstein's critical density value – normalized to unity in this case – then the universe is said to be 'flat', i.e., Euclidean. Finally, the Hubble parameter $H(z)$ is defined in terms of these densities and redshift by the equation:

$$E(z) = H(z)/H_o = \sqrt{(z+1)^4\,\Omega_R + (z+1)^3\,\Omega_m + (z+1)^2\,\Omega_k + \Omega_\Lambda}$$

$E(z)$ is central to any assessment of distance in the standard model. 'Comoving distance', the most basic of the various distances that are defined, can only be obtained by integrating from a redshift of zero to the redshift of the object whose distance is in question. There are a limited number of density value assignments for which the integral has a closed analytic form, but for most versions of the standard model, solutions can only be obtained by numerical integration. The distance from an observer to an object at redshift z along the line of sight (LOS) is defined as:

LOS comoving distance:

$$d_C(z) = d_H \int_0^z \frac{dz'}{E(z')}$$

Notice that if all three densities are zero, $d_C(z) = \ln(z+1) / H_o$. This is what was plotted in figure 7 with no implication of velocities, curvature, or gravitation. This De Sitter formula is also plotted as the solid red line in figure 8. It is a relation I will derive from first principles for the plasma scattering model for which the preceding velocity- (or universal expansion-) based analyses are irrelevant. This is the metric of distance that we will use throughout in our analyses of galaxy survey data. In recent galaxy survey data, redshifts have been converted to distances assuming the 'cold dark matter' (ΛCDM) consensus version of the standard cosmological model so that

$$d_{\Lambda CDM}(z) = d_H \int_0^z \frac{dz'}{\sqrt{(z'+1)^3\,\Omega_m + \Omega_\Lambda}} \text{, with } \Omega_m = 0.274,\ \Omega_\Lambda = 0.726, \text{ and } \Omega_k \text{ and } \Omega_R = 0.0$$

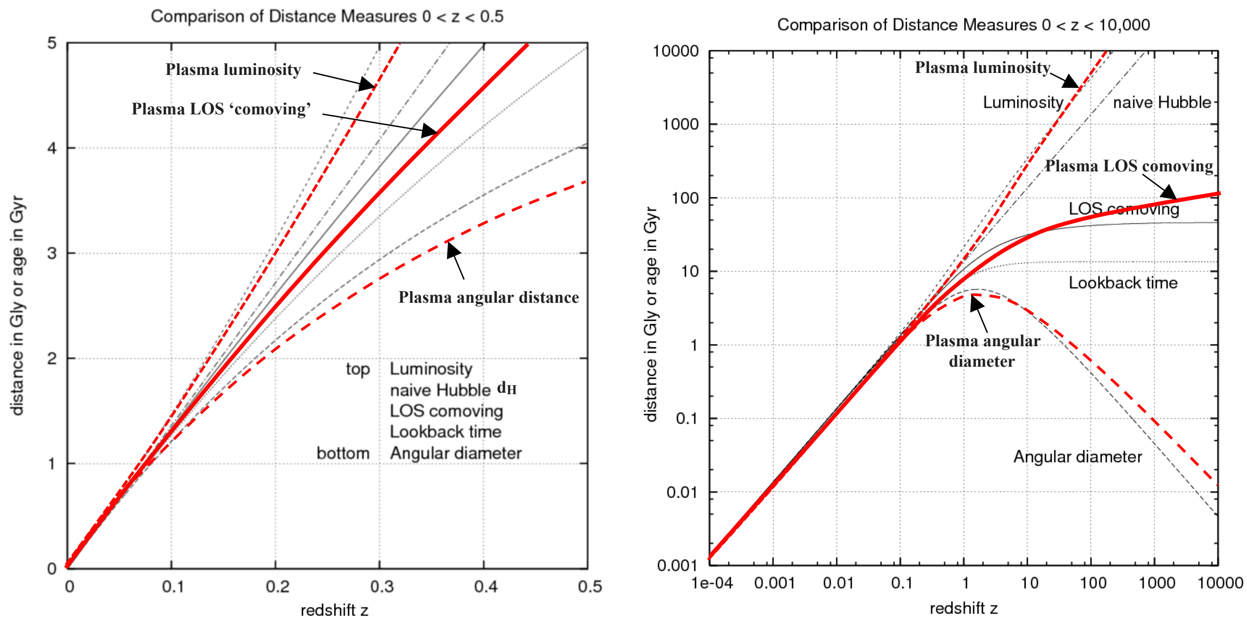

Figure 8: A comparison of cosmological distance measures defined for the 'ΛCDM' version of the standard cosmological model with H_o=72 km/s/Mpc and the plasma scattering cosmological model for a redshift range of zero to 0.5 and then for redshift 10^{-4} to 10^4

In the plasma model, the incremental volume of a subtended conic section of radial angle θ extended to a considerable distance r from the observer, would be expressed as follows:

$$\Delta V(\theta,r) = \frac{\partial}{\partial r}\,(4\pi\theta^2 r^2)\,\Delta r \rightarrow \frac{4\pi\theta^2}{H_o^3}\,\frac{\partial \ln^2(z+1)}{\partial(z+1)}\,\frac{\partial(z+1)}{\partial z}\,\Delta z = \frac{8\pi\theta^2 \ln(z+1)}{H_o^3\,(z+1)}\,\Delta z \approx \frac{8\pi\theta^2 \ln(z+1)}{H_o^2\,(z+1)}\,\Delta r$$

The right-most expression is valid for the plasma redshift model when $\Delta r \ll H_o$ is a constant. The functionality of this expression is shown in figure 8 as analogous to the 'angular distance' of the standard model. It is useful in assessing how many galaxies should appear as a function of distance in a survey if there were enough resolution of the telescopes to observe all galaxies in each interval $\Delta V(\theta,r)$. Counterintuitively, rather than increasing indefinitely with distance, the number becomes virtually constant, diminishing slightly at extremely large redshifts.

All the 'distances' shown in figure 8 for the (ΛCDM) consensus version of the standard model involve formulations that include LOS comoving distance. For each there is a counterpart that maps closely for the plasma redshift model. There is considerable diversity of distances as functions of redshift in the standard model that can be confusing as suggested in figure 8. A consensus on the assignment of a value to H_o and of density values in the expression for E(z) was a long time coming. Some of the diversity of options is illustrated in plots of figure 9 for the single distance construct, $d_{\Lambda CDM}(z)$ with H_o=70 km/s/Mpc, with $d_C(z)$ included for the plasma model.

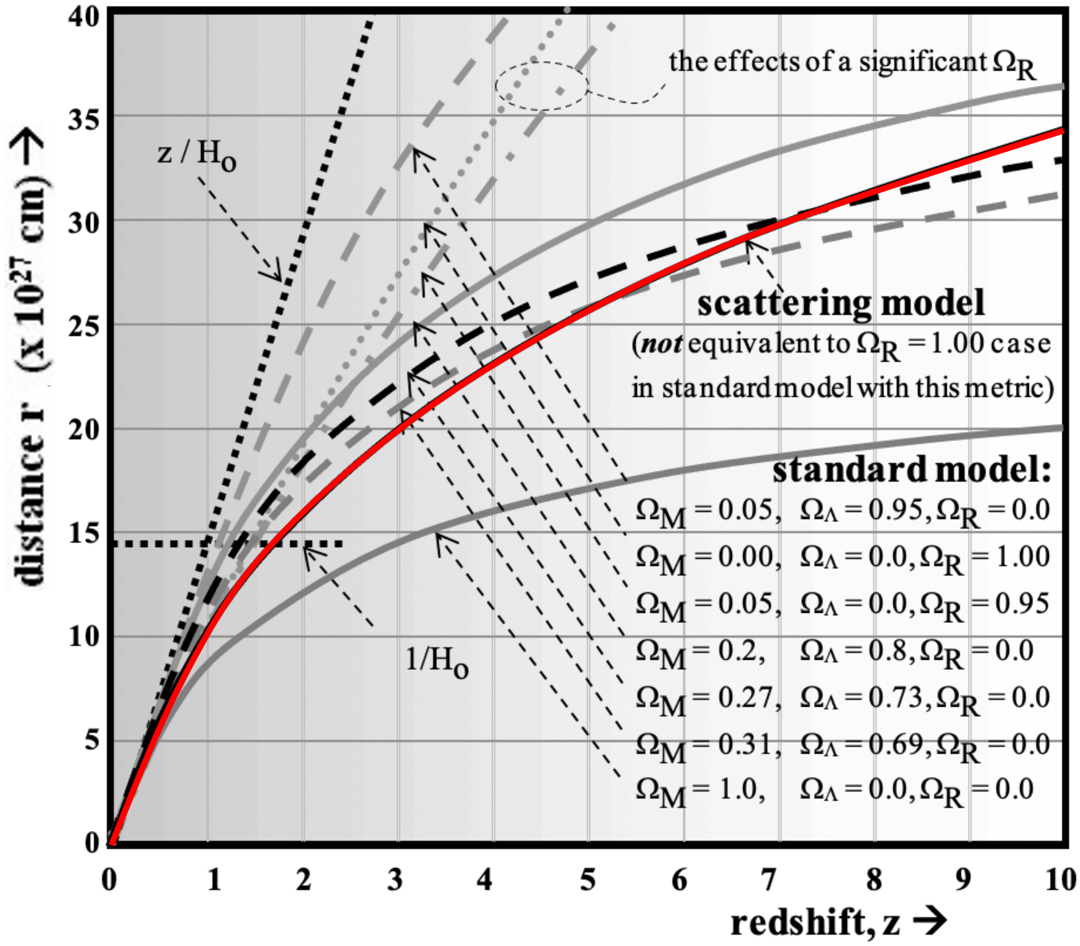

Figure 9: LOS comoving distance d_C versus redshift predictions for the standard model with various density parameter values as well as a plot (heavy red line) for the plasma scattering model – chart taken from Bonn (2009) (Notice that 10^{27} cm ≈ 1 Gly ≅ 307 Mpc.)

Luminosity distance:

Luminosity distance d_L is defined by the relationship between the observable bolometric (i. e., integrated over all wavelengths) of flux S and inherent luminosity L of the observed object as described earlier:

$$d_L \equiv \sqrt{L / 4\pi S}$$

In the standard models this distance parameter is related to LOS comoving distance follows:

$$d_{\Lambda CDL}(z) = (z+1)\, d_{\Lambda CDM}(z)$$

The rationale for the additional factor of (z+1) is in deference to area-dependent brightness determined using an anomalous 'angular diameter' shown in figure 8. The plasma redshift model includes an additional factor as well, but as derived uniquely for the plasma scattering model.

$d_{LSC} = (z+1)\, d_{C_{sc}} = (z+1) \ln(z+1) / H_O$

These ‘luminosity distances’ are plotted for many of the family of possibilities accommodated by the standard model. The consensus version (dark dashed curve) and the plasma redshift model (dark solid curve) are plotted in figure 10 taken from Bonn (2009); they are intriguingly related.

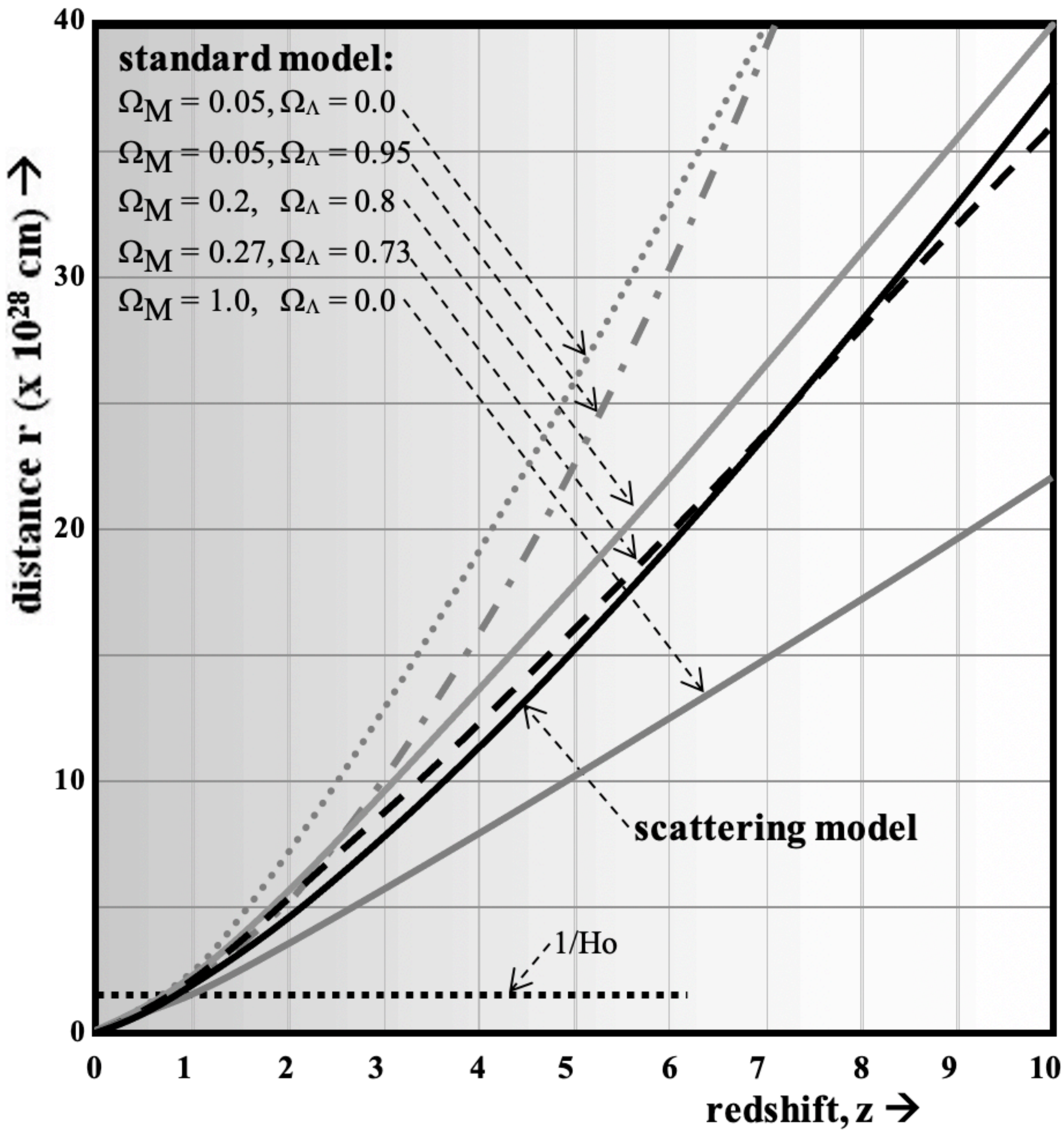

Figure 10: Luminosity distance (d_L in centimeters) with various density parameter values appropriate to the standard model as well as a plot for the scattering model – chart taken from Bonn (2009)

‘Apparent magnitude’ of astronomical sources in photometric bandpass filters is used to define the distance modulus d_M; it is the logarithmic relation:

$d_M \equiv 5 \log (d_L / 10 \text{ parsec})$

It is the magnitude difference between the observed bolometric flux and what it would be if the luminous flux were from that object located at 10 parsecs. This is a frequently employed metric in cosmological investigations; it is plotted for three of the standard model versions including the (ΛCDM) consensus and for the plasma redshift model in figure 11. Data points are included for luminosities of distant SN1A supernova events. The data points in the oval at right are what precipitated Riess et al. declaring that the universal expansion must have undergone acceleration since these points conclusively refute any of the standard model versions otherwise. You will notice that the data is in full agreement with the plasma redshift (scattering) model.

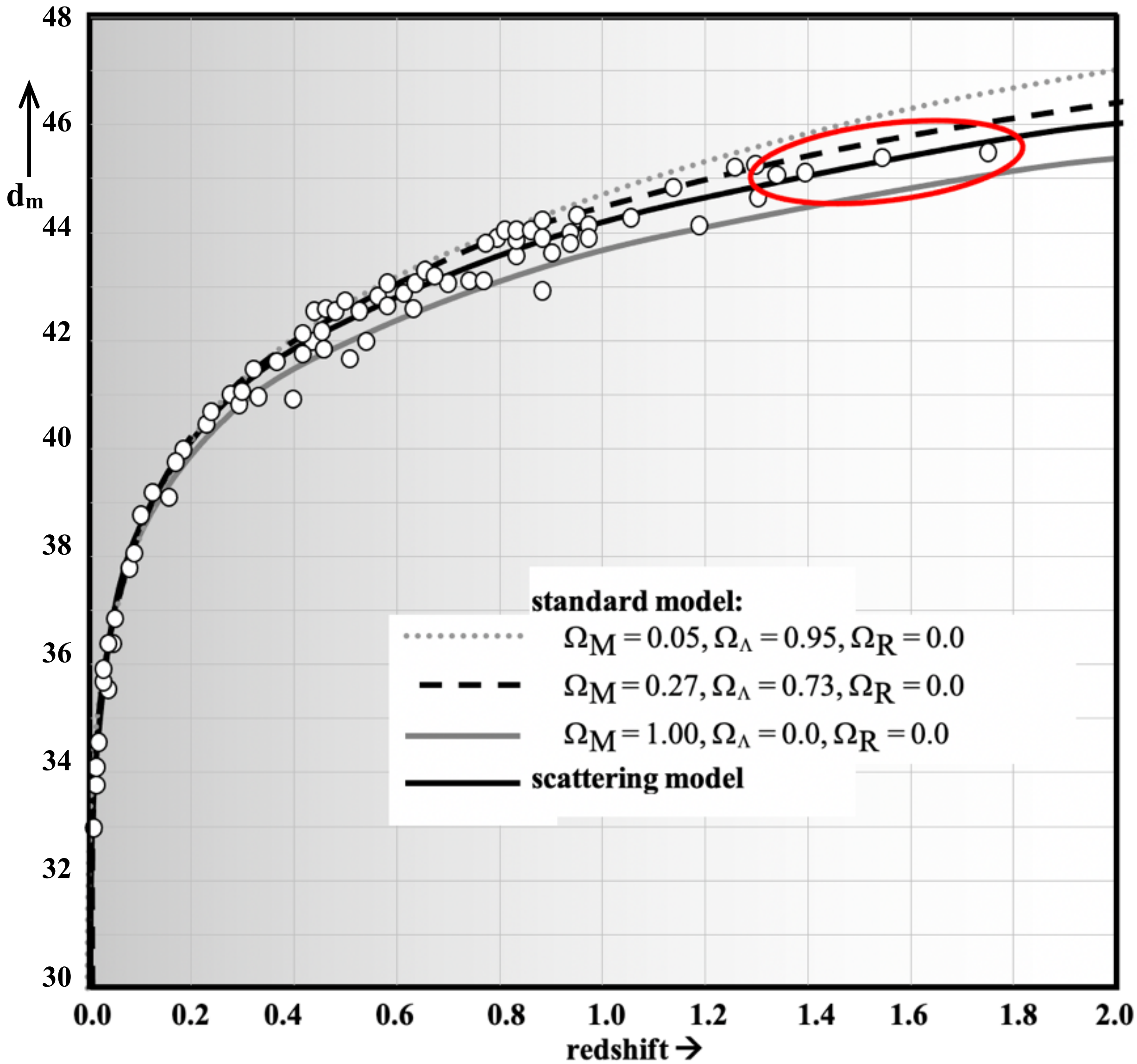

Figure 11: Distance modulus d_m of SNIA supernovae data superimposed on model predictions – chart taken from Bonn (2009)

Should we anticipate a claim for an earlier deceleration when observations of SN1A supernova events out to a redshift of 7 have been obtained?

Probably. The standard model paradigm with all its add-ons will be a tough nut to crack.