

Galaxies and Cosmology Homework #5  
Due February 26

Go to the website and start up the “High-Z Supernova Cosmology Calculator”. This is a graph of two sets of Type I supernova data, one low redshift ( $z$ ), the other high redshift. The data is graphed with  $\log(z)$  versus DM, which is our good old buddy, the Distance Modulus ( $=m-M$ ). You can change the values of Omega, Lambda and  $H_0$  to alter the line that corresponds to how the Universe’s expansion varies with distances/redshift.

To make life easier, we’re going to assume that the Universe is flat, so the values of Omega and Lambda should always add up to 0. This is also indicated by the “Curvature” notation.

With only the “Low Z” or blue data points, answer questions A - D. Please put your answers on a separate sheet.

A. Omega represents a negative gravity effect, so leave that value to 0 for now, and change Lambda and the Hubble constant until you get the best fit through the data for a flat Universe. What are the resulting values?

B. Is it possible to get a better fit through the data with a non-zero value for Omega? Try by adjusting all three values of Omega, Lambda and the Hubble constant until you get the best fit through the data points. What values do you have for the best fit?

C. Which fit appeared better, the one you did with or without a non-zero value for Omega?

D. Does a non-zero value for Omega make any sense? Explain your reasoning.

Now turn on the “High Z” supernova data and now you have the entire data set to work with. Again, we’re going to assume that the Universe is flat so that  $\Omega + \Lambda = 1$ .

E. Is it possible to get the best fit to the data with a value of 0 for Omega? What are the values for Lambda and the Hubble Constant for your best fit for the data?

F. Now adjust all three values again, and this time, let’s keep the Hubble constant near its currently accepted value of 70 (don’t change it too much from that). What values do you get now for the Hubble Constant, Omega and Lambda?

G. How do these values compare to your values in “B”?

H. Which set of values are likely closer to the actual nature of the Universe, your answers from part “B” or from part “F”? Justify your answer.

We’re going to now look at how the Hubble constant changes over time – which sort of goes against the concept of a “constant”. But as the Universe’s expansion changes, the value for the Hubble constant changes. Exactly how it changes depends upon the type of Universe you live

in. For a Universe that is dominated by Matter (sort of the type you used from questions A-D), the relation for the Hubble Constant's variation over distance/redshift is given by

$$H^2 = H_0^2 (\Omega(1+z)^3 + \Lambda)$$

where  $\Omega$ =Omega and  $\Lambda$ =Lambda.

I. Using the most distant blue dot, determine the corresponding value for  $z$ , and the value for  $H$  at that location. You'll want to use the values from part "B". Note, on the graph,  $z$  is given as a log value, so you'll have to convert it to a normal value first (take 10 to the power of the graph value).

For a Universe that has matter and energy density (anti-gravity) dominating, the formula is slightly different. In this case it is

$$H^2 = H_0^2 (\Omega(1+z)^3 + \Lambda(1+z)^{-3(1+w)})$$

where  $w=-0.93$ .

J. For the most distant red point on the graph, determine the value of  $z$ , and the value for  $H$  at that location. This time you'll want to use the values you previously determined in part "F".

K. If a galaxy has a redshift of 7(= $z$ ), what would the value of  $H$  be at that distance? Again, use your values from "F".

L. So just how "constant" is the Hubble constant?