Physics 310/610 – Cosmology

Homework Set L

1. A set of Type Ia supernovae has their peak apparent magnitude m and their red shift z measured. The results are collected in the table at right. Assume, for purposes of this problem, that Type Ia supernovae have a peak absolute magnitude of $M_{\max} = -19.3$.
   (a) For each supernova, work out the distance d in Mpc and the radial velocity v in km/s. For the velocity, I recommend using the non-relativistic approximation to save time.
   (b) Plot the velocity versus the distance for this set of points. Why are the points not exactly on a straight line?
   (c) Estimate the value of Hubble's constant H_0, in km/s/Mpc.

$m_{\max}$	z	d (Mpc)	v (km/s)
7.3	–.0003		
11.6	0.0038		
14.3	0.0121		
15.7	0.0247		
16.1	0.0295		
16.6	0.0363		
16.7	0.0383		
17.2	0.0476		

2. Hubble's law gives a simple relationship between distance and velocity. For this problem, you will assume (i) Hubble's Law is exact, and (ii) the velocity does not change; *i.e.*, if something is currently moving at 100 km/s, it always was moving at that speed.
   (a) Assuming constant speed, find a simple formula for how long ago some distant object would have left us t_0, given its current speed. Note that the result does *not* depend on the distance, only on Hubble's constant H_0. This time is called the *Hubble time*, and is a fair estimate of the age of the universe.
   (b) Estimate the Hubble time in Gyr, assuming the Hubble constant you found in problem 1 is correct. How does this compare with our estimate of the age of the oldest stars, 13 ± 1 Gyr?

Graduate problem: Only do this problem if you are in PHY 610

3. In class, we showed that the age of the universe is given in general by the formula

$$t_0 = H_0^{-1} \int_0^1 \frac{dx}{\sqrt{\Omega/x + 1 - \Omega}}$$

   Complete this integral in closed form. You will probably have to do three cases separately: $\Omega < 1$, $\Omega > 1$, and $\Omega = 1$.