

Hubble's Law and the Expanding Universe

The astronomer Edwin Hubble first measured the expansion of the universe when measuring how fast galaxies are moving relative to our own Milky Way. He discovered that all galaxies are moving away from us as a result of the Big Bang. This result is expressed mathematically in Hubble's Law which says that the velocity of a galaxy (v) is related to its distance (d) by

$$v = H_0 \times d$$

where H_0 is a constant known as Hubble's constant. We are going to use some real data to check Hubble's result and find a value for H_0 .

On the following pages are spectra of fifteen different galaxies. Your job is to measure the Doppler shift of some lines in each spectrum and then use this to estimate the recession velocity – how fast the galaxy is moving away from us. Their distances are measured for you and are listed in a table at the back. When you have measured their velocities, you can plot a graph of velocity against distance and then calculate Hubble's constant from the above relationship.

- For each galaxy, see if you can identify some of the lines listed in the table on the next page. Some galaxies have emission lines (spikes), some have absorption lines (dips) and some have both.
- For each line, calculate the velocity from the shift between your measured wavelength (λ), the rest wavelength (the wavelength measured in the laboratory, λ_0) and the speed of light (c) using the following relationship:

$$\frac{v}{c} = \frac{\lambda - \lambda_0}{\lambda_0}$$

[Note that this is a simplification which assumes that the galaxies are all moving at speeds low enough that we don't need to worry about relativistic effects.]

- Calculate the average velocity for each galaxy from as many lines as you have measured and enter the value in the table at the back.
- Repeat this method for each galaxy. You can then calculate H_0 for each galaxy using the distance given in the table and your measured value of the velocity using

$$H_0 = v / d$$

- Plot a graph of average velocity (in km/s) on the y-axis against distance (in Mpc) on the x-axis using your results.
- Draw a straight line on your graph which passes through the origin and through most of your points.
- Measure the gradient (the slope) of your line – this is Hubble's constant (in units of km/s/Mpc).
- Find a published value and see how close you are!