FYI Hubble's Law

When Hubble measured distances to galaxies using Cepheids and calculated the speeds at which the galaxies were moving away from us using spectral lines, he noticed an emerging pattern. The farther away a galaxy was, the faster it was moving. He plotted his findings on a scatter graph and found that an approximately straight line was a good fit to the data (Figure 4-14).

From the slope of this line, he calculated the ratio of the speed, or velocity (v), to the distance (d) in a quantity now known as **Hubble's constant** (H_o), which is calculated using **Hubble's Law**:

$$H_o = \frac{v}{d}$$

Over the past several decades, astronomers have struggled to agree on a precise value for Hubble's constant. For years it was believed to be somewhere between 20 and 30 km/s per million light-years. Most recently, consensus has it around 25 km/s per million light-years, although this value can vary depending on the measurements used to calculate it. Note the somewhat unusual units of H_o. These units tell us that if we measure the distance to a distant galaxy in millions of light-years, Hubble's Law will give us a velocity in km/s.

One important use of Hubble's constant is to determine the distances to faraway galaxies. Thanks to Hubble's Law, a galaxy does not need to contain a Cepheid, Type Ia supernova, or any other standard candle in order for us to measure its distance from us. We can measure the redshift of the galaxy's spectral lines in order to infer its speed. From that, we can calculate its distance using Hubble's Law.

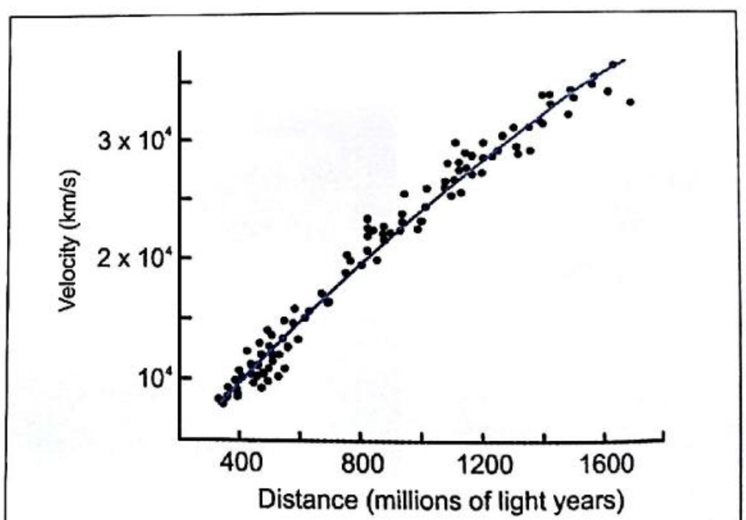

Figure 4-14: The Hubble Diagram, which shows the relationship between velocity and distance for galaxies

Example: Suppose we observe a galaxy that has a redshift, z, of 0.01. This means that the galaxy is moving away from us at a speed (v) of 0.01 times the speed of light or 3×10^3 km/s. Using this value for v and a value for H_o of 25 km/s per million light-years, we can then calculate the distance to the galaxy.

$$d = \frac{v}{H_o}$$

$$d = \frac{3 \times 10^3 \text{ km/s}}{25 \text{ km/s per million ly}} = \frac{3 \times 10^3 \text{ km/s}}{(25 \text{ km/s}) / (10^6 \text{ ly})}$$

$$d = \frac{3 \times 10^3 \text{ km/s}}{(25 \text{ km/s}) / (10^6 \text{ ly})}$$

$$d = \frac{(3 \times 10^3 \cancel{\text{km/s}}) \times (10^6 \text{ ly})}{25 \cancel{\text{km/s}}}$$

$$d = 1.2 \times 10^8 \text{ ly}$$

Step By Step

This is a simple rearrangement of the Hubble's Law equation provided above.

Insert the appropriate values for v and H_o and change "per million light-years" into its numeric value

Take the fraction in the denominator and rearrange the equation

Cancel the units, multiply, and divide.

Checking In

1. How does Hubble's Law help determine distances to the most remote galaxies?
2. If the redshift of a galaxy is observed to be 0.002 and a Hubble constant of 25 km/s per million light-years is used, what is the speed of the galaxy and what is its distance from Earth?

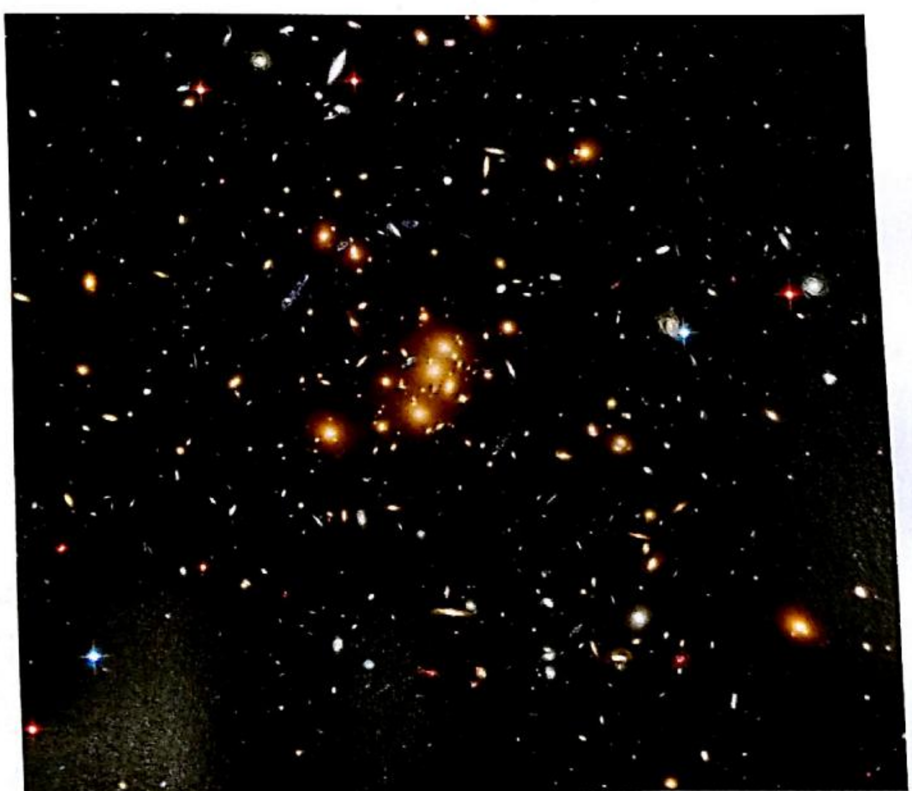

Image of a large cluster of galaxies