7.4: Evidence of Expansion

In 1929, Edwin Hubble combined Vesto Slipher's redshift and velocity measurements of galaxies with Henrietta Swan Leavitt's distance-finding procedure and discovered that there is a roughly linear relationship between a galaxy's distance from us and its recessional velocity (i.e. its velocity away from us), as shown in Figure **7.4.1**.

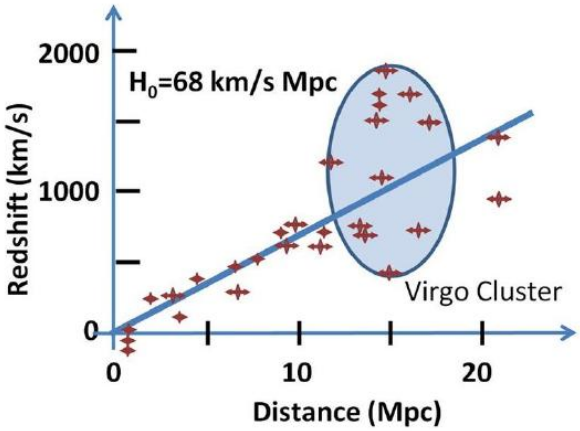

Figure **7.4.1**: Hubble diagram depicting galaxy recessional velocity as a function of distance. (Image credit: Wikipedia)

This can be written as

$$v = H_0 d \tag{7.4.1}$$

where v is the recessional velocity, d is the distance, and H_0 is a constant of proportionality that we call the **Hubble constant**.

Since recessional velocity is measured in km/s and distance is measured in Mpc (megaparsecs), the slope has units of $\frac{\text{km/s}}{\text{Mpc}}$. There is currently disagreement about the value of H_0. Of the various methods of determining the Hubble constant, though, all of them put its value at approximately

$$H_0 = 70\ \frac{\text{km/s}}{\text{Mpc}}. \tag{7.4.2}$$

One potential issue with Equation 7.4.1 is that it makes it seem like we are the center of the universe, which seems to contradict the cosmological principle. One way to resolve this apparent contradiction is with the Raisin Bread Model of the expanding universe. As a loaf of raisin bread bakes, it expands and the raisins all move farther away from every other raisin. The raisins themselves do not expand, and they don't even change their relative locations within the "space" that they exist in. Similarly, if the universe as a whole expands, then clusters of galaxies will all move farther away from every other cluster of galaxies, thus making every point of view look like it is the center of the expansion.

? Exercise 7.4.1

Taken to its extreme, Equation 7.4.1 implies that there is no upper limit to recessional velocity. That is, the speed of light is not an upper limit. How is that possible?

Answer

In an expanding universe, objects can move farther apart from one another while not changing their coordinate positions. So in a sense, they are not technically *moving*. Rather, the space between them expands, and the expansion of space is not limited by the speed of light.