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12.4: The Hubble Parameter

The Hubble Parameter

So, how did astronomers and cosmologists determine the Hubble parameter? Edwin Hubble first assigned a value in 1929 of 500 km/s/Mpc, based on his observations of extremely-distant objects at Mt. Wilson Observatory in Southern California. Astronomers continued to collect data to revise the Hubble parameter; Allan Sandage achieved a good estimate of 75 km/s/Mpc in 1958. This was a significant change over Hubble’s initial estimate. The debate became quite acrimonious, with Sandage revising his estimate to around 50 km/s/Mpc and Gerard de Vaucouleurs proposing a value around 90 km/s/Mpc. This Hubble parameter wide range and debates continued until the mid-1990’s, when data from spacecraft such as the Hubble Space Telescope assisted in better values for the Hubble parameter.

Various spacecraft have provided different values for the Hubble parameter. And each of these values are dependent on the type of object being observed or methodology employed. Astronomers and cosmologists have collected data from include Type 1a supernovae, Cepheid variable stars, gravitational lensing, the cosmic microwave background, and most recently gravitational waves.

Let’s look at how the Hubble parameter changes things, specifically the age of the Universe. Recall Hubble’s Law:

v = H_o d

Dividing both sides by d, solves for H_o :

v/d = H_o

Since v = d/t (velocity equals distance divided by time, e.g. 65 miles/hour) substituting for v:

d/t/d = H_o

1/t = H_o

t = 1/H_o

This equation — **t = 1/H_o** — gives one a direct relationship between the age of the Universe and Hubble parameter. So, let’s look at how it works to determine the age of the Universe.

Let’s use a value for the Hubble parameter, H_o , of 70 km/s/Mpc. This gives us:

t = 1/H_o =1/70 km/s/Mpc

Yet these units don’t look like time, except for the seconds. And we need — *want* — the age of the Universe in years. So first cancel the distance units by dividing 3.09 × 10^{19} km/Mpc by the selected Hubble parameter:

(3.09 × 10^{19} km/Mpc) / (70 km/s/Mpc) = 4.41 × 10^{17} s (seconds)

There are 3.16 × 10^{7} seconds in a year. To convert seconds to years, divide the number of seconds above by 3.16 × 10^{7}s/yr:

(4.41 × 10^{17} s) / (3.16 × 10^{7} s/yr) = 1.396 × 10^{10} yr or 13.96 billion years

Let’s see one more example, based on Edwin Hubble’s original estimate of the Hubble parameter, Ho, being 500 km/s/Mpc:

t = 1/H_o =1/500 km/s/Mpc

(3.09 × 10^{19} km/Mpc) / (500 km/s/Mpc) = 6.18 × 10^{16} s (seconds)

(6.18 × 10^{16} s) / (3.16 × 10^{7} s/yr) = 1.92 × 10^{9} yr or 1.92 billion years

So, in comparing the two values for Hubble’s parameter, H_o :

Hubble’s parameter, H_o	Age of the Universe
70 km/s/Mpc	**13.96 billion years**
500 km/s/Mpc	**500 km/s/Mpc**

For a Hubble parameter of 70 km/s/Mpc, close to the range astronomers and cosmologists use today, that is a Universe some 7.27 times older than Hubble’s 1929 estimate.

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