The Accelerating Universe and Dark Energy

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I. Abstract

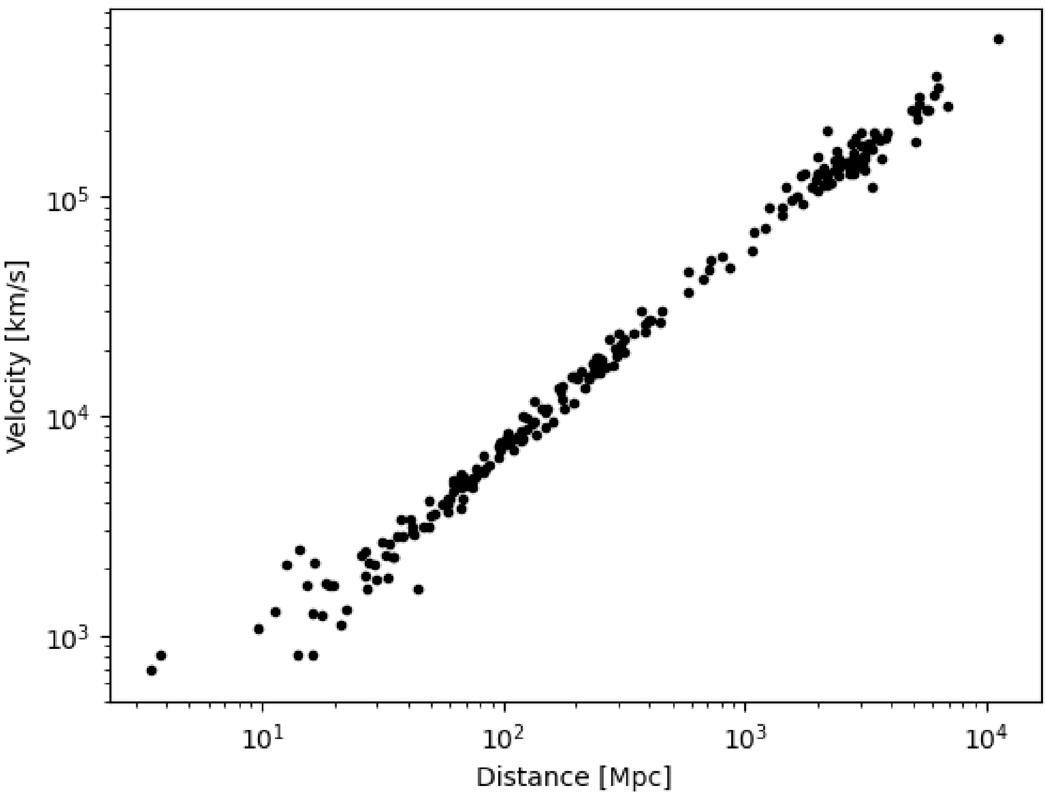
Using data obtained by Tonry et. al, I plotted the distances and velocities of Type Ia supernovae events for two separate distance groups, the local and distant universe. From here I created a line of best fit and took the slope of this line, the Hubble Constant, which measures the expansion of the universe.

II. Motivation

The main goal was to understand the universe and whether it is decelerating, static, or accelerating. From this we can make a guess on the possible fate of the universe, and theorize about what is driving this expansion. I also wanted to determine the age of the universe given the Hubble Constant.

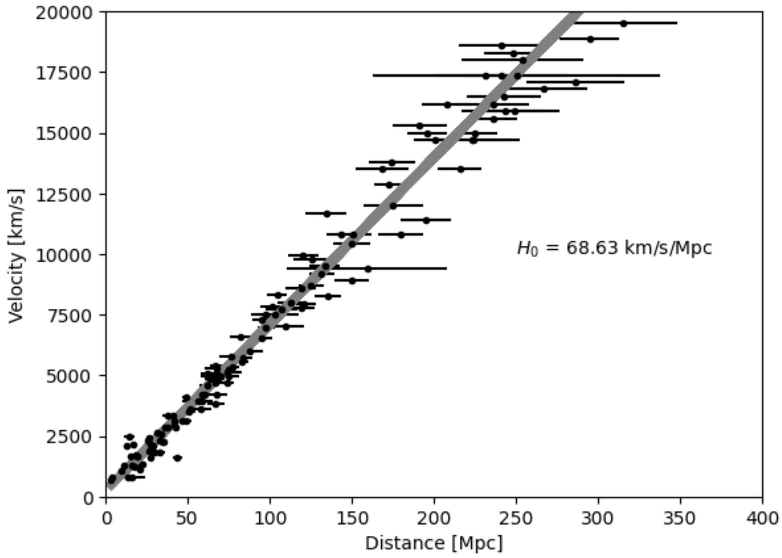
III. Methods

After importing the data obtained by Tonry et. al, I plotted every supernovae's distance and velocity as a logarithmic function as seen in Figure 1.



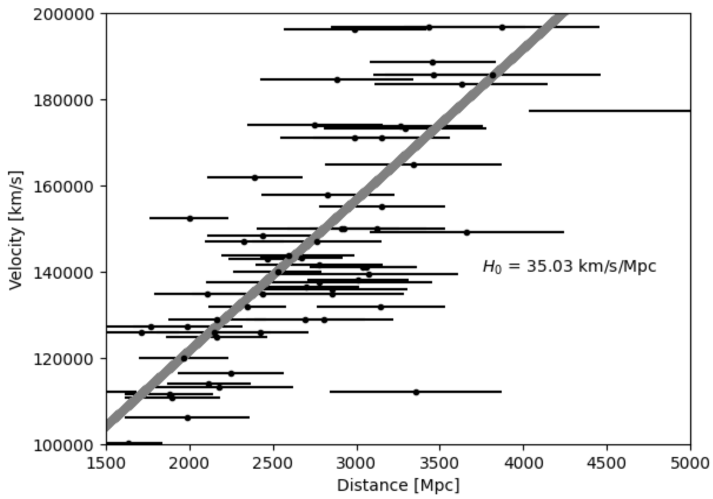
[Figure 1]
Plots supernovae's distances and velocities logarithmically

From here, I took a smaller part of this massive dataset, with distances of these supernovae ranging from 0 to 400 megaparsecs and plotted these with their velocities. This served as the closer universe. I created a least squares polynomial fit for this data between 0 and 400 megaparsecs, and plotted the line of best fit through the data, reporting the value of its slope as seen in Figure 2.



[Figure 2]
The velocity and distance of supernovae in the local universe, as well as the Hubble Constant

I repeated these steps for supernovae ranging from 1500 to 5000 megaparsecs out, which served as the distant universe. This plot is seen in figure 3.



[Figure 3]
The velocity and distance of supernovae in the distant universe, as well as the Hubble Constant

IV. Results

From the data from the local and distant universe, we got values of 68.63 km/s/Mpc and 35.03 km/s/Mpc respectively. These represent the Hubble Constants, or how fast the universe is expanding. However, the data from the distant universe has significantly larger error bars that have not been accounted for, and thus the value of the Hubble Constant I got may not be accurate. We can also determine the age of the universe from the Hubble Constant of the local universe by using $t = \frac{1}{H_0}$, where t is the age of the universe and H_0 is the Hubble Constant. After converting the Hubble Constant into units of $\frac{1}{s}$ with the conversion $68.63\ km/s/Mpc \ \cdot \ \frac{1\ Mpc}{3.08 \cdot 10^{19}\ km}$ I could calculate the age of the universe in seconds and convert it into years.

V. Conclusion

Knowing the Hubble Constants of the local and distant universe, I compared them and found the Hubble Constant of the local universe to be significantly higher at 68.63 km/s/Mpc compared to the distant universe's 35.03 km/s/Mpc. Because these values represent the rate at which the universe is expanding, we can determine the local universe to be expanding at a significantly faster rate than the distant universe, suggesting the universe is accelerating. This may be caused by dark energy. I also found the age of the universe to be about $4.487833309 \cdot 10^{17}$seconds old, or about 14.229021271 billion years old.

References

Tonry, John L., et al. “Cosmological Results from High-zSupernovae.” The Astrophysical Journal, vol. 594, no. 1, American Astronomical Society, Sept. 2003, pp. 1–24. Crossref, doi:10.1086/376865.