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1. Introduction

For this project, we planned to analyze two things:

1. The expansion rate of the universe (Hubble's Constant) for a given set of galaxy clusters.
2. The probability of the galaxies within a galaxy cluster being gravitationally bound depending on a varying diameter.

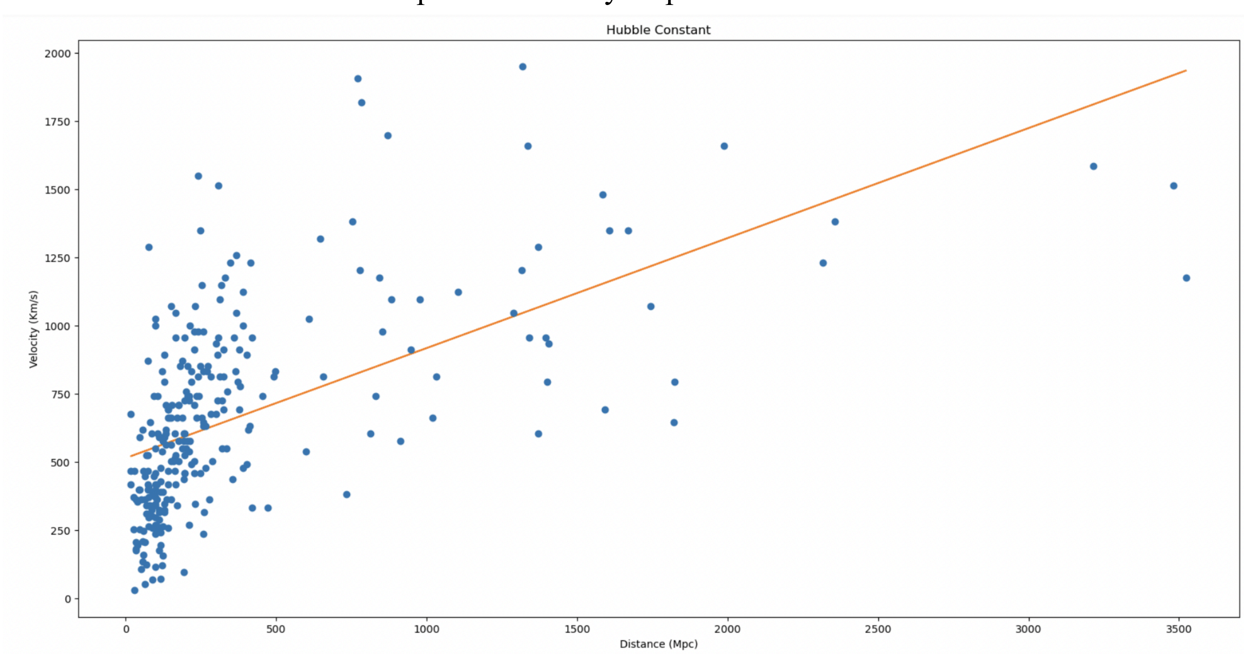
This project involves data analysis and generation, the application of quality filters, and fitting data with error.

2. Chosen Phenomenon and Data Source

The phenomenon chosen for this project were galaxy clusters and their velocity dispersion and redshift measurements. We used data from a survey taken from the Strasbourg Astronomical Data Center (CDS) which has compiled data from the Strasbourg Observatory in France. This data set [https://vizier.cds.unistra.fr/viz-bin/VizieR?-source=J/ApJ/554/L129] is a catalog of galaxy clusters that contains information on the clusters' redshift, velocity dispersion and its statistical error, its bolometric luminosity, and its standardized NED identifier.

3. Data Fitting

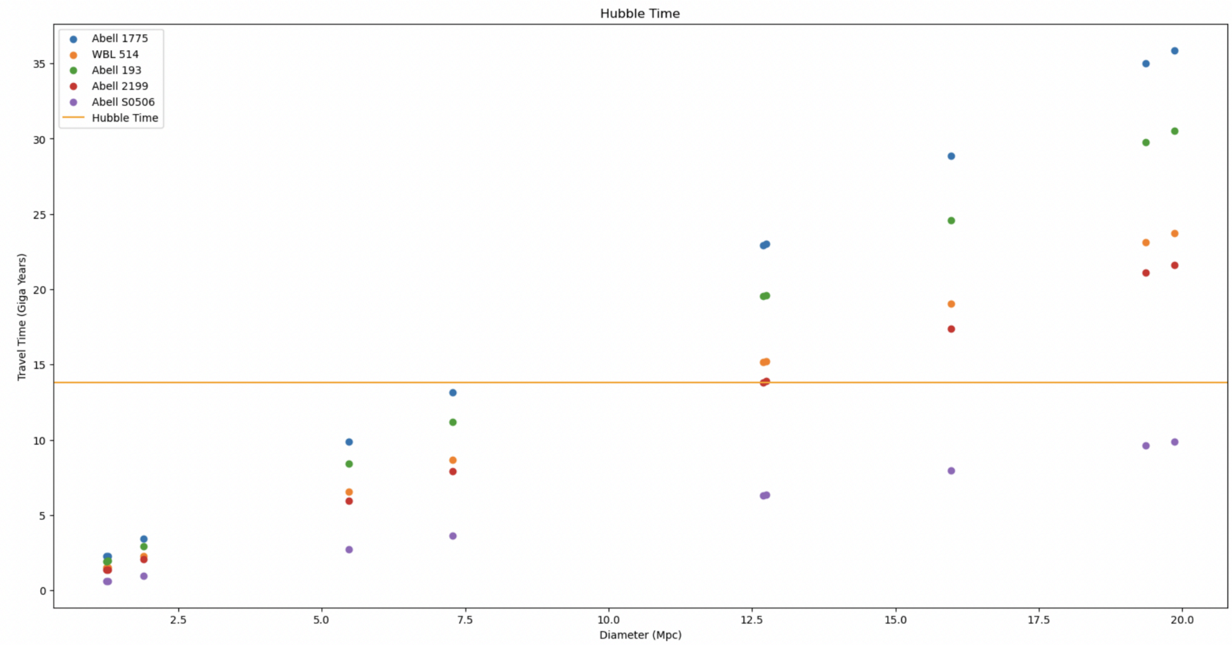
The first relationship we plotted was each cluster's distance from Earth in megaparsecs vs its velocity dispersion so that we could get a sense of the rate of expansion of the universe based on just the clusters measured. We determined that there is a pretty linear relationship between distance from Earth and their respective velocity dispersions.



We performed a linear regression to find the best fit line for the data and we found the slope to be ~0.40. This leads us to conclude that overall, the farther a galaxy cluster is away from us, the faster it will be moving.

4. Data Generation

We generated 10 random diameters from 0-20 megaparsecs as well as choosing 5 galaxy clusters from the list at random. We then found the travel time of a galaxy in that cluster using the dispersion velocity and the travel time equation: $travel\ time\ = \frac{diameter\ (km)}{velocity\ dispersion\ (km/s)}$



5. Data Filtering

To avoid an oversaturation of data, we processed the original columns to a set that only included the names, redshift values, and velocity dispersions of every cluster. Then when actually trying to calculate travel times, we are able to have the code run and choose a random set of 5 clusters each time it runs. This way we are able to get an accurate spread of velocity dispersions across the board.

6. Conclusions

After converting the travel time from seconds into gigayears, we were able to plot these times based off of the diameters we generated for each specific galaxy cluster. The ones we included in this run were Abell 1775, WBL 514, Abell 193, Abell 2199, and Abell S0506. They have decently well distributed velocity dispersion measurements. When travel time is calculated at different diameters for each, we were able to find that past a certain diameter, the clusters would no longer be viable to be classified as a cluster. Plotted alongside the data points is a horizontal line representing Hubble Time, or the approximate age of the universe in gigayears, which is estimated to be about 13.8 Gyrs. If a cluster's travel time was less than that amount of time, meaning its plotted points landed below the horizontal line, then the galaxies in the cluster are *gravitationally bound* to one another. To explain this further, if it takes a galaxy less than Hubble Time to travel the length of the cluster, it would have had ample time to leave its boundaries, yet it still remains contained with the larger group, thus there is a gravitational force keeping these galaxies together. Every analyzed cluster had a diameter where the travel time exceeded the 13.8 Gyrs, so if the clusters were to ever grow past that size, the galaxies within it would no longer be influenced by the effects of that gravitational pull and they would continue to drift away as the universe expands. Overall, this was only a small sampling of galaxy clusters that helped prove a greater concept in the fabric of the universe, and we would likely see similar results with a much larger data set.