Motivation and Introduction

The discovery of the Hubble constant, Hubble’s law, and Hubble time is the turning point of the cosmology study. Hubble’s law states that the radial velocity of galaxies is proportional to their distances, and the slope of the correlation is the Hubble constant, which suggests that the universe is expanding. One way that we could measure the velocity of galaxies is by observing their redshift, since the greater the redshift, the faster the galaxy is moving away from us. The observation of the redshift of galaxies can support Hubble’s discovery that the universe is expanding. However, not only did we find that the universe is expanding, but we also found that the expansion of the universe could be accelerating. Through observing the type Ia supernova, the astronomer observed that supernovae at high redshift appear to be fainter than expected from Hubble's Law, which suggests that the universe is expanding at an accelerated rate than Hubble’s Law suggested and that the Hubble constant should actually be changing with time. The observation of fainter supernovae also suggests the existence of dark energy that we couldn’t observe and a negative pressure that results in the accelerating expansion of the universe. To test whether the expansion of the universe is speeding up and whether dark energy is a component of the universe, one method we could use is to compute the Hubble constant of the supernovae in galaxies of the local universe and compare it with the Hubble constant of the supernovae in the distance universe, since the accelerating expansion of the universe suggests that the Hubble constant of the supernovae in the distance universe should be smaller than that of the local universe. If the result shows that the Hubble constant of the distance of the universe is smaller, then it aligns with the observation that the redshift of distant supernovae appears to be fainter, which is convincing evidence that the expansion of the universe is accelerating and is due to the negative pressure of dark energy1.

Method and Math

To find the evidence of universe is expanding at an accelerating rate due to the negative pressure of dark energy, one way is to observe supernovae since they are bright and easy to measure their redshift. The Hubble’s Law stated that , from which we could get the formula for Hubble constant is . Therefore, we will take the velocities and distances data from the supernovae dataset that Tonry recorded2. We will separate the data into two kind of supernovae based on distance: supernovae in local universe galaxies whose distance to us is smaller than 300 Mpc and supernovae in galaxies of distance universe whose distance to us is larger than 300 Mpc. For each group, we will find the slope of the regression line that results in the least squared residuals. The residual, which means the vertical distance between the observed distance and the expected distance of a supernovae given the velocity, To achieve this, we will utilize the linalg.solve function in the numpy module, which will take two matrix, distances and velocities of the supernovae, and take into consideration the observational error of distance. The inverse of the coefficient of the regression will be the Hubble constant we wanted. If the Hubble constant is lower for the supernovae in distance galaxies, this means that the radical velocities of supernovae in distance universes are lower, and thus they have a fainter redshift than expected, which suggests that the expansion of the universe is accelerating.

Result and Interpretation

A graph of a graph

Description automatically generated with medium confidence

Figure 1. Regression of Velocity and Distance for Supernovae in Local Universe

A graph of a graph

Description automatically generated

Figure 2. Regression of Velocity and Distance for Supernovae in Distance Universe

After using the linalg.solve function to calculate the Hubble constants for local and distance universe, we found that for the local universe, the Hubble constant is 67.746 and the number is 54.144 for the distance universe. It implies that the Hubble constant is changing, and that the universe didn’t expand at a constant rate. We also notice that the Hubble constant is smaller for the distance universe than the local universe, which means that at a given distance, the radical velocity of a supernovae at a galaxy in the distance universe will be smaller than that at the local universe and thus have a fainter redshift, which supports our observations that supernovae appear to be fainter compared to their redshift by Hubble’s law, which proves that our universe is expanding at an accelerated rate. There is no explanation that could explain why the expansion of the universe is accelerating. One of the most common hypotheses is that the existence of dark energy, which we couldn’t observe, has a negative pressure on the universe that results in the accelerating expansion of the universe.

Conclusion

This project aims to show that the universe is expanding at an accelerating rate resulting from the negative pressure from dark energy. We took the distance and velocity data of supernovae from Tonry’s observation and split supernovae into two groups: supernovae in galaxies of the local universe and supernovae in the distance universe. Then utilizing the least-squared residuals method to get the Hubble constants for each group. The result shows that the Hubble constant for the distance universe is smaller than that of the local universe, which implies that the expansion rate of the universe is not constant but increasing, and there must be dark energy that we couldn’t observe, but whose negative pressure results in the speeding up of the universe’s expansion.

References

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2. Tonry, J. L. (2003). Cosmological Results from High-z Supernovae. *The Astrophysical Journal*. https://doi.org/10.48550/arXiv.astro-ph/0305008