Evaluation and measurements of the age for the universe

Haozhi Liu*

Department of physics, Grinnell College, Grinnell, United States of America

*The corresponding author: liuhaozh@grinnell.edu

Abstract. The universe is expanding, at a very large rate, which attracts a large number of scholars to measure its age and size accurately. In this paper, a possible way to measure the age of the universe is proposed. To be specific, this study employs a CCD and an EMCCD camera to evaluate the redshift of the Hydrogen isotopes in another galaxy. Then, compare values to those on Earth are compared and the escaping velocity of the galaxy are calculated. Afterwards, the distance between us and the galaxy are derived, and the age of the universe will come out from the Hubble's Law. The data collected from a CCD camera and an EMCCD camera set on a 0.61m telescope. According to the analysis, the age of the universe is 9.7 billion years, which has a 29.6% margin of error. The reason why it has such large margin of error is that all the measurement of distance is based on a simple ruler. Naked eyes easily cause error, so in the following experiments more concise measurements will be employed with appropriate equipment. When one knows the age of the universe, a series of investigations and study can be carried out in context of the evolution of the universe. These results shed light on guiding further exploration of unveiling the evolution of the universe.

Keywords: age of universe, EMCCD camera, escape velocity, Hubble's law.

1. Introduction

In physical cosmology, the age of the universe, is the length of time since the Big Bang in which energy, matter, space, and time were created [1-4]. As it known to all that the universe is expanding at an extremely high velocity. It increased the linear size of the universe by more than 60 "e-folds", or a factor of ~10^{26} in only a small fraction of a second [5, 6]. People may ask how large is it or how old is it. In fact, it is a tough project because human beings are within the universe. Meanwhile, it is still expanding really fast.

Luckily, despite the two serious problems above, scientists have found ways to measure its age. If everything started out together if the rate of the expansion has been constant over time, and if another galaxy is now a distance d away from us and has a velocity v away from as a result of this expansion, then the age of the universe would just be $t = d/v$. On this basis, one could then determine the age of the universe simply by measuring d and v.

The description in the introduction is too simplistic. Distant galaxies seem to be receding from us with velocities that are approximately proportional to their distances from us. The history of the subject began with the development in the 19th century of wave mechanics and the exploration of phenomena associated with the Doppler effect. The effect is named after Christian Doppler, who offered the first known physical explanation for the phenomenon in 1842. Contemporarily, there are plenty of novel approaches are proposed to estimate and evaluate the age of universe, including photometric analysis of globular Clusters, etc. [7-10].

The reason why this study is conducted is that some of the experiments data is collected which could offer a new way to estimate the age of universe. Human history is but a blip in the history of the universe. The universe is full of infinite possibilities, driven by curiosity, which has aroused the strong desire to explore the universe. The universe is so big that one might not be alone. This is also the motivation for me to carry out this study. It will start from the most basic characteristics of the universe -- the age of the universe, and then go deeper and deeper, hoping to explore a brand new universe. In this study, the telescope is utilized to obtain data and apply some laws to get the final experimental results. The whole experiment process is not particularly complicated. The only thing that needs to be paid attention to is the measurement part, which is also the most prone to mistakes in the whole experiment process. Subsequently, the laws of physics and experimental methods needed for the experiment will be introduced. A picture of the mysterious universe is shown below as shown in Figure. 1 and the typical detection results are presented in Figure 2.

Figure. 1 A sketch of the Universe.

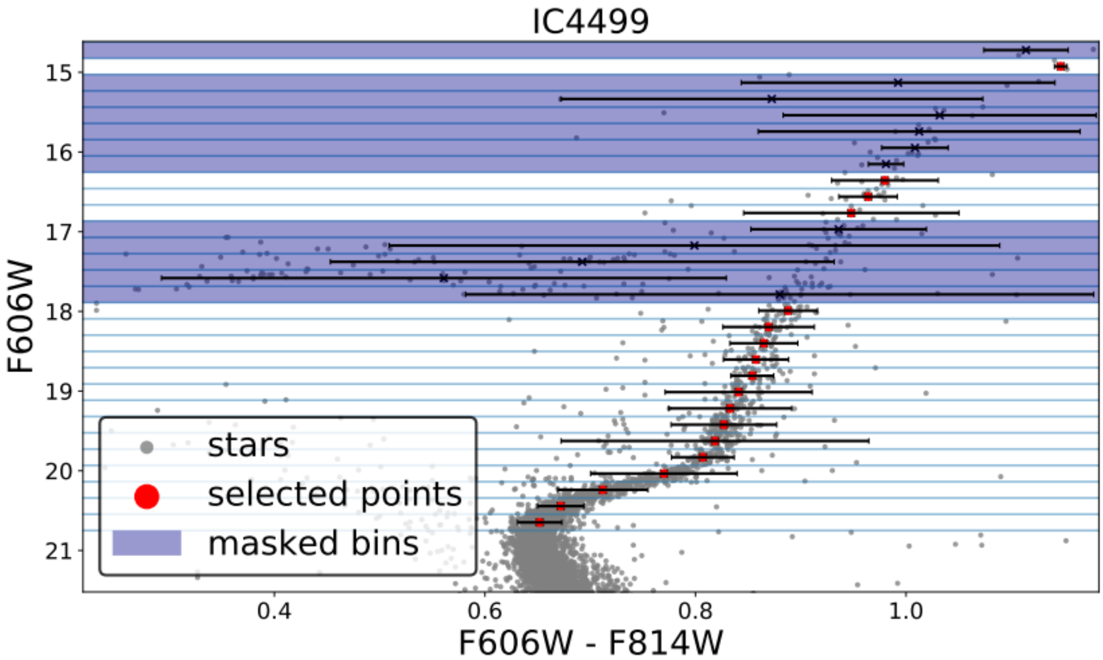

Figure. 2 A sketch of binning of the main sequence, illustrated for the GC IC4499.

2. Method

The description in the introduction is too simplistic. Distant galaxies seem to be receding from us with velocities that are approximately proportional to their distances from the earth. This relationship is one of the primary pillars of observational evidence supporting the Big Bang model and is known as the Hubble Law: $v = H_0 \times d$. The analysis above would suggest that the age of the universe is approximately $t = d/v = 1/H_0$. The actual connection between the age of the universe and the Hubble constant is a bit more complicated and involves some assumptions about exactly how the expansion proceeds. If one accepts the common assumption of a “flat” universe, one in the universe in which the average density is exactly equal to the critical density at which the future of the universe switches from eternal expansion to eventual contraction, then the age of the universe comes out to be $2/3H_0$.

The observational determination of H_0 normally involves measuring the velocities and distances of a sample of galaxies and fitting a straight line to the data points on a plot of v as a function of d. The velocities are obtained from observations of the redshifts of the galaxies' spectra, assuming that these redshifts are indeed associated with the recession of the galaxies from us. Determining the distances to the galaxies is more difficult, especially for those that are more distant and have greater redshifts. The essence of the experiment is to use a telescope, spectrograph, and two CCD cameras at our observatory to record both an image of a galaxy and its spectrum. The galaxy this study focus on is NGC 7469. The goal of spectroscopy is to determine the velocity of recession of the galaxy. The lab offers a lamp with both the H(alpha) and H(beta). First, the redshifts of the isotopes will be evaluated, then the redshift of the galaxy's H(alpha) line. According to the observation results, the velocity of the recessing galaxy will be calculated and obtained.

3. Data

From the first two pictures, as shown in Fig. 3 and Fig. 4, the size of the galaxy and the distance it moves will be measured because the time session of the camera exposure is 30 minutes. These results are collected from the telescope, which will be used for further analysis in subsequent analysis of this paper. The galaxy's H(alpha) line, as shown in Fig. 5, will provide data for the study to calculate the redshift of the Hydrogen isotopes of the galaxy. However, the measurement of the data will be used the ruler, which brings about lots of errors.

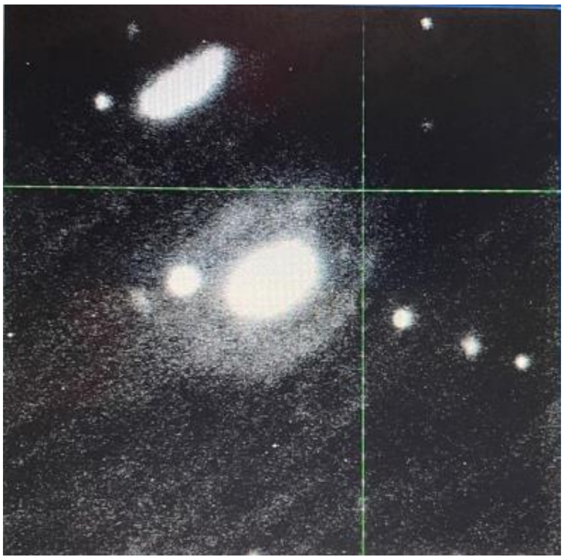

Figure. 3 Galaxy before exposure.

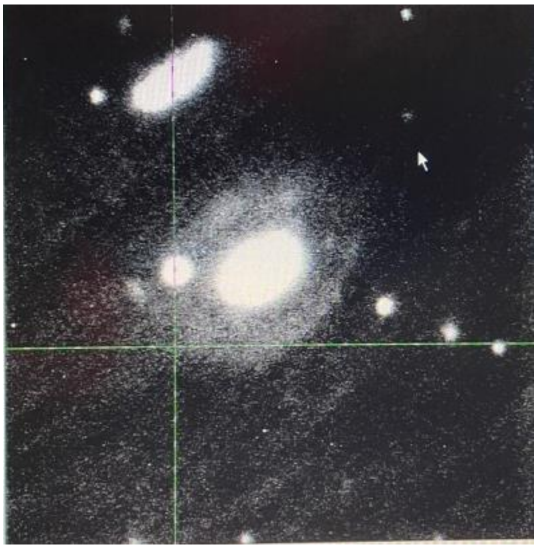

Figure. 4 Galaxy after exposure.

Figure. 5 Galaxy's H(alpha) line.

4. Results & Discussion

Based on the observation, comparing the redshift of the Hydrogen atom in that galaxy and the one here on Earth, the age of the universe would be 9.7 billion years, with a redshift of approximately 0.67. These results are very close to the results listed in Refs. [7-10] as depicted in Fig. 6.

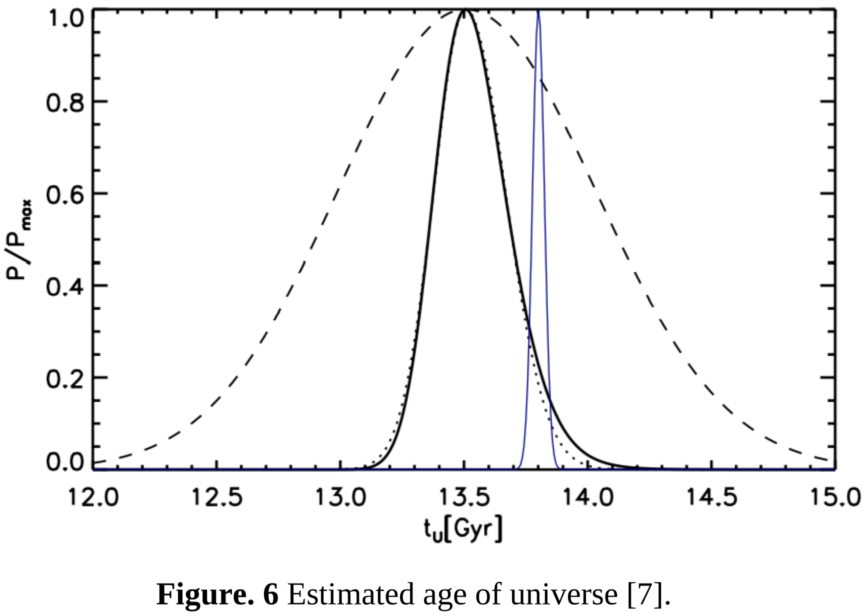

Figure. 6 Estimated age of universe [7].

During the observation, together with my professor, a CCD camera was employed first to capture a 30-minute change in position of a specific galaxy NGC 7469. Then, the size of the galaxy was calculated by using the pixel displayed on the computer. Afterwards, measure the redshift of the galaxy's Hydrogen isotopes before measuring them here on Earth. A comparison was made between the two values, then an approximate distance between us and the galaxy will be calculated.

By employing Hubble's Law, $t = d/v = 1/H_0$, the result of the age of the universe will come out. The whole process went pretty well since the weather was good during the days spent in the observatory, and it had a clear view of the target galaxy. Meanwhile, thanks to the staff member at the observatory, because they were really kind and helpful. According to properly selecting the observation target, the way to measure the distance, and most importantly, the relationship between the observed values and the result, which is the transformation of Hubble’s Law.

After looking up the true age of the universe on the Internet and further comparing it with my results, there was still a large margin error. It is normal for experiments to have a margin of errors, but as long as they are within 5%, it is usually considered the experimental values to be more reliable. More statistically, it is 95% confident to say that the result is the true value.

However, the experimental value the project got was quite different from the actual value, which had reached a surprising 30% or so. This is a very large margin of error. The possible reasons for this are as follows. Firstly, even if the weather is good enough for observation, the atmosphere and other debris in the universe can still interfere with the observation, making the results inaccurate. This is a very objective factor because it is inevitable. This is known as force majeure.

In addition, the measuring tools are too rough. This influencing factor is subjective because people can reduce the influence of this factor by changing the measurement tools. Because when the distance was measured, it was a simple ruler on the computer screen and then it is measured, and the ruler can only be accurate to the millimeter level. A tiny error in astronomical measurements magnified billions of times can make a huge difference because galaxies are so far apart in the universe. Therefore, in order to make the experimental results more accurate, the measurement tools can be replaced with more sophisticated instruments, such as distance measurement directly on the computer.

Unfortunately, the observatory's computers don't have this capability, so more concise measurement could not be carried out. In the subsequent experiment, more precise measurement methods could be done to reduce the error of my experimental results. Finally, the results of this experiment are based on flat universes, as mentioned earlier. This factor is the most lethal since researchers are also unknown if the average density of the universe is equal to the critical density at which the future of the universe switches from eternal expansion to eventual contraction. Therefore, the universe is worth exploring, because the part people can explore is only the tip of the iceberg or even just a few ice crystals on the iceberg.

5. Conclusion

In summary, this paper investigates the age of the universe based on the relationship between the redshift value of the two galaxies. Specifically, several observations were done of the redshift values of the Hydrogen line of NGC 7469 and here on Earth; several calculations were done through Hubble’s Law. According to the analysis, the study comes out a result that the age of the universe is 9.7 billion years and the redshift of the galaxy is 0.67. Moreover, some evaluations of the project were made to justify the reliability of the results.

Nevertheless, it should be noted that the results in this paper have some limitations and shortcomings. During the evaluation, the most difficult part is the measurement. Only a simple ruler is used, which might have a margin of error and whether it is higher than the true value or below. To improve the measurement, more accurate approaches for measurement ought to be implemented to run the experiment. Meanwhile, this observation opens up a whole new world for researchers and it is a great opportunity to study astronomy, astrophysics, and computer science. In the future, other scholars may continue to explore the universe and never stop because it is a such huge region and probably the exploration will never finish. Overall, these results offer a guideline for later research on the universe on a deeper level, e.g., the cause of The Big Bang.

References

[1] Chaboyer Brian. The age of the universe. Physics Reports 307.1-4 (1998): 23-30.

[2] M. Bolte, and Craig J. Hogan. Conflict over the age of the Universe. Nature 376.6539 (1995): 399-402.

[3] David N. Spergel, Michael Bolte, and Wendy Freedman. The age of the universe. Proceedings of the National Academy of Sciences 94.13 (1997): 6579-6584.

[4] Lloyd Knox, Nelson Christensen, and Constantinos Skordis. The age of the universe and the cosmological constant determined from cosmic microwave background anisotropy measurements. The Astrophysical Journal 563.2 (2001): L95.

[5] Brian Chaboyer, et al. A Lower Limit on the Age of the Universe. Science 271.5251 (1996): 957-961.

[6] Richard C. Tolman. The age of the universe. Reviews of Modern Physics 21.3 (1949): 374-378.

[7] Eleonora Di Valentino, et al. Snowmass2021-Letter of interest cosmology intertwined IV: The age of the universe and its curvature. Astroparticle Physics 131 (2021): 102607.

[8] David Valcin, et al. Inferring the age of the universe with globular clusters. Journal of Cosmology and Astroparticle Physics 2020.12 (2020): 002.

[9] Robin Singh, Vipul Mani, and Kirti Vishwakarma. Evaluating Age of Universe by Photo-metric Analysis of Globular Clusters. 42nd COSPAR Scientific Assembly 42 (2018): E1-16.

[10] Mercier, Claude. Calculation of the Mass of the Universe, the Radius of the Universe, the Age of the Universe and the Quantum of Speed. Journal of Modern Physics 10.8 (2019): 980-1001.