How Big is Our Galaxy
ASTR 102

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1 Objective

The objective of this lab report, is to determine the size of the Milky Way Galaxy which we reside in. This object will be achieved through two mean, firs by determining the distance to the M15 globular cluster, and secondly by using a method similar to Shapley's determining of the distance to the center of a globular cluster system.

2 Introduction

We all live inside the Milky Way, the galaxy that contains our solar system. The name Milky Way is derived from it's appearance as a milky glowing band across the night sky on a clear and dark night [1]. Not even 100 years ago, astronomers and common folk believed that the Milky Way was the universe. Nothing was believed to have existed outside of the Mily Way as these types of sizes were deemed impossibly big. Then along came a man named Harlow Shapley and his famous 1918 study of globular clusters, the galaxy, and our Sun's position inside of it [**?**].

Using Cepheid variable stars [3], Shapley was able to correctly estimate the size of the Milky Way Galaxy and the Sun's position within it. From these calculations are came the idea of deep space objects. Objects that lay outside of the Milky Way. These objects eventually became to be seen as other galaxies, black holes, and deep space supernovae [4].

Although Shapley created ground breaking procedures and calculations, this report will focus on merely replicating (with slight variations) some of his measurements and calculations.

3 Equipment

For this report, the following list of equipment was used. A set of 8 images of the globular cluster M15 all taken on a single night. A single sheet of transparent paper with graph lines pre-fabricated onto it. A single felt pen used for writing on the transparent paper. A single sheet of opaque graph paper. A regular pencil for drawing on the opaque graph paper. A SHARP-EL510R calculator. The Linux computer program known as skycat which was used for viewing images of globular clusters and measuring their sizes.

4 Procedure

4.1 Determine the distance to M15

First, a graph was draw to represent a variable star's magnitude in the globular cluster known as M15. To do this, the 8 images of the cluster previously mentioned were used to measure the magnitude of the star at each of the frames. This was done by comparing the star's magnitude from a first frame to a known magnitude of a secondary star in the proceding frame. Some of the frames however did not have known magnitude stars. In these cases, either the variable star was compared to known magnitudes in it's own frame or the next frame in the series. Once the variable star's magnitude was measured for each frame, the graph was ready to be constructed. The results of these measurements can be found in Table 1. The graph was constructed first on the transparent sheet of paper with the felt pen. The graph is drawn as apparent magnitude vs. time in fractions of a day. These fractions of a dat correspond to the given image frames. Once the point were plotted, an error barr of magnitude 0.5 was added to the graph to correct for possible measurement errors.

Next the mean of the single variable star measured was calculated. This calculation can be found in Equation 1. As other participants were taking part in the experiment, the same procedure was conducted with other teams and other variable stars in the globular cluster. These means can be found in Table 2. Next, the mean of the variable stars mean magnitude was taken, as can be seen in Equation 2. This true mean of the variable stars measure was then used for a final calculation to determin the globular cluster's distance away from Earth as seen in Equation 3. A final step was now taken to transfer the graph previously drawn on the transparent paper to the opaque graph paper. This final graph can be found in the back of this report labelled as Figure 1.

4.2 Determine the distance to the galactic center

To determine the distance to the center of the Milky Way Galaxy from Earth, the Linux program skycat was first used. Skycat came pre loaded with images of various globular clusters that are located in the field of view from Earth pointed towards the galactic center. Using skycat, each image was loaded to the screen.

Then, each globular cluster was measure in diameter using arc minutes. These measurements were done by measuring from one side of the "solid light" in the center of the cluster to the other horizontally as the image dictates. The "solid light" for this report is defined as where a single star can no longer be distinguished from the rest of its neighbooring stars. The results of the measurements can be found in Table 3.

Once the cluster were measure, they were inserted in to a web based application supplied by the lab instructor.[1] This program preformed a type of weighting procedure based on the measurement of M15 and all other globular clusters measured. the result of this program's calculation can be found in Equation ??.

4.3 Miscellanious

Lastly, questions proposed by the lab manual for Astronomy 102 at the University of Victoria in the lab "How big is out galaxy" were answered using various calculation. The questions and answers can be found in Section 10 while the calculations themselves can be found in Section 8.

5 Observations

All observations for this report were made on the day of 2013-Mar-04. Since the result of any given observation did not depend on time of day or weather, they have been ommitted from this report. The measurements of the M15 globular cluster and the brightness of its variable stars can be found in Table 1. The measurements of all variable stars mean magnitude preformed by all groups inside the lab at the time of observation can be found in Table 2. The measurements for the diameter of given globular clusters preformed with the skycat program can be found in Table 3 given in arc minutes. Finally, the plotting of the variable star magnitude in the M15 globular cluster can be found at the back of this lab report labelled as Figure 1.

6 Tables and Measurements

The following two table correspond to lab supplied images and measurements taken of that image of M15 the globular cluster. These images consisted of 8 frames taken at variable times apart.

[1] orca.phys.uvic.ca/OLDWEBPAGES/a120/centgal/index.html

Star	Magnitude
B	16.0
B	15.8
B	15.75
B	16.4
B	15.5
B	15.3
B	15.35
B	15.6

Table 1: Measurements B star magnitude in M15.

Star	Mean Magnitude
A	16.2
B	15.7
C	15.7
D	15.8
E	15.8
F	15.6

Table 2: Measurements variable star means in M15.

Cluster	Diameter (arc minutes)
M15	3.20
NGC6624	0.30
NGC6626	0.82
NGC6637	0.57
NGC6638	0.33
NGC6652	0.25
NGC6656	1.13
NGC6681	0.37
NGC6715	0.58
NGC6723	0.47
NGC6809	2.40

Table 3: Globular cluster diameters in skycat.

7 Graphs

The graphs of a given variable star's magnitude variance in globular cluster M15 can be found at the back of this lab report labelled as Figure 1.

8 Calculations

The following calculation creates the mean magnitude value for the measured variable star in the globular cluster M15 where i represents a row in Table 1.

$$mean = \frac{\Sigma m_i}{8} = 15.7125 \quad (1)$$

The following claculation creates the mean magnitude valie for all measured varible star means as calculated by other participants in the lab where i represent a row in Table 2

$$mean = \frac{\Sigma m_i}{6} = 15.8 \quad (2)$$

The following calculation gives the distance in parsec from Earth to the globular cluster M15.

$$D = 10^{\frac{15.8-0.8+5}{5}} = 10,000pc \quad (3)$$

The following calculation gives the results of the orcs web application used to determine the distance from Earth to the galactic center

$$Orca_d = 25,700.24pc \quad (4)$$

The following calculations refer to the miscellanious questions asked at the end of this lab manual lab.

$$LightTime = 8,000pc * 3.26lry/pc \quad (5)$$

$$Distance = 8,000pc * 2\pi \quad (6)$$

$$Time = \frac{50,000pc}{.00021pc/yr} \quad (7)$$

$$Mass = 8.8X10^{15} * \frac{A^3}{P^2} \quad (8)$$

$$Count = \frac{78,000,000,000}{(3 * 10^7)} \quad (9)$$

9 Results

The results of this lab can be found by examining the calculations preformed in Section 8. The results for the question of "how far away is the globular cluster M15" are found through Equation 3 and show the result as being 10,000 parsecs.

The results for the question of "how far away is the galactic center from Earth" are found in the results of Equation 4 and show the reult as being 25,700.24 parsecs.
The results for any question that the lab manual (as previously mentioned) poses can be found in Section 10 while the supporting calculations can be found in Section 8.

10 Questions and Answers

The following questions and answers are asked inside of lab 6, How Big Is Our Galaxy, inside of the lab manual for ASTR102. The questions have been repeated for the reader.

Q. Calculate how long it takes for light to get to the sun from the center of the galaxy. There are 3.26 light years in one parsec.

A. As per Equation 5 the answer is 26,000lyr. This corresponds to the accepted answer of 27,000lyr +- 1,000lyr [5].

Q. Calculate the distance the Sun travel around the center of the galaxy.

A. As per Equation 6 the answer is 50,000pc.

Q. How long does it take the Sun to orbit the center of the galaxy?

A. As per Equation 7 the answer is 240,000,000yr. This corresponds to the accepted answer of 240,000,000 years [6].

Q. Find the mass of the galaxy.

A. As per Equation 8 the answer is 78,000,000,000. This corresponds to the accepted answer of $1.0 - 1.5 * 10^{12}$ [7].

Q. If you are looking for life in our galaxy, and you spend 1 second looking at each star, how many years would it take to check out our galaxy?

A. As per Equation 9 the answer is 2600yr.

11 Threats to Validity

There are three main threats to validity for this lab report. Two come at the hands of self measurement, while the third comes at the hands of reliance of external teams for measurement and calculation. For once, the measurements of the variable star magnitude measured in M15 is a threat to validity. These measurements were prefomed purely with the naked eye and can be subject to much debate as the magnitudes of stars were simply compared visually. Errors in this measurement can lead to errors in the drawing of Firgure 1 and the further calculations preformed on both means and on the distance from Earth to M15.

The second self measurement threat to validity is the measuring of globular cluster sizes on the program skycat. The definition of what constitues the boundaries of a globular cluster causes the basis of this error aside from the actual imprefection of the measurement itself. The boundary used as described early was the "solid light" boundary. However, some globular clusters measure lacked a definite "solid light" boundary. This lead to potential measuring errors from one globular cluster to the next. These measurements effect the error in the calculation of the distance to the galactic center from Earth. This error leads to the rather large final calculation error for this question.

The final threat to validity is the reliance of external teams for their own measurements of variable stars in M15 and following calculations. The numbers passed to myself were not validated by any other external party for validity. One external team admitted to large measurement errors in a variable star magnitude. These types of errors and possible error effect the calculation done in Equation 3.

12 Conclusions

This report has shown how to calcute two items. First, by measuring the magnitude of variable stars, one can determine the distance of a globular cluster from Earth, in this case M15. Second, this report has shown how diameter measurements of globular clusters in a globular cluster system can be used to determine the distance from Earth to the galactic center.

13 Evaluation

I found this lab interesting purely for the demonstration and experiment involving the magnitudes of variable stars inside a globular cluster to determine its distance. I had heard before that variable stars can be used to determine the distances to astronomical objects but had never known the procedure. It would have been interesting if a larger explination was given as to how this procedure works or how the formula used in Equation 3 was derived.

References

[1] "Milky Way Galaxy". Encyclopdia Britannica, Inc.. Retrieved 2012-10-31.

[2] Bart J. Bok. Harlow Shapely 1885-1972 A Biographical Memoir. National Academy of Sciences

[3] Udalski, A.; Soszynski, I.; Szymanski, M.; Kubiak, M.; Pietrzynski, G.; Wozniak, P.; Zebrun, K. (1999). "The Optical Gravitational Lensing Experiment. Cepheids in the Magellanic Clouds. IV. Catalog of Cepheids from the Large Magellanic Cloud". Acta Astronomica 49: 223.

[4] Fred Schaaf, 40 nights to knowing the sky: a night-by-night skywatching primer, page 113

[5] Reid, Mark J. (1993). "The distance to the center of the Galaxy"

[6] Hess, Frances. Earth Science. New York: Glencoe Mc Graw-Hill, 2002: 348.

[7] McMillan, P. J. (July 2011). "Mass models of the Milky Way". Monthly Notices of the Royal Astronomical Society 414 (3): 24462457