Due: Fri Nov 14 2014 12:00 PM EST

Question 1

Instructions

Lab 6: The Great Debate: The Solar System's Place in the Galaxy and the Galaxy's Place in the Universe I

Read the lab before attending lab. You might find it easier to navigate if you expand only one or two sections at a time.

The following summary video is available to you in case you miss lab or want to review it when completing the lab:

The Great Debate (15:22)

You are permitted 100 submissions per question. Use some of these to save your work.

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Enter all calculated values to at least two significant digits.

Do not add units when entering numerical responses. WebAssign will not accept your response.

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1. Question Details UNCAstro101L1 6.IL.001. [2817383]

LAB 6 — THE GREAT DEBATE: THE SOLAR SYSTEM'S PLACE IN THE GALAXY AND THE GALAXY'S PLACE IN THE UNIVERSE I

GOALS

In this lab, you will:

- Use RR Lyrae variable stars in globular clusters to measure our distance from the center of the Milky Way galaxy (i.e., is the solar system at the center of the Milky Way?).
- Use RR Lyrae variable stars in globular clusters to measure the approximate size of the Milky Way.
- Use Cepheid variable stars in nearby galaxies to measure their sizes (i.e., is the Milky Way the primary object in the universe or is it merely one of countless many similar-sized objects in the universe?)

EQUIPMENT

Computer with Internet connection

BACKGROUND: A. THE GREAT DEBATE

On April 26, 1920, astronomers Harlow Shapley (left) and Heber Curtis (right) debated the size of the then-known universe and our place in it at the Smithsonian Museum of Natural History in Washington, DC, in an event that later became known as the Great Debate.

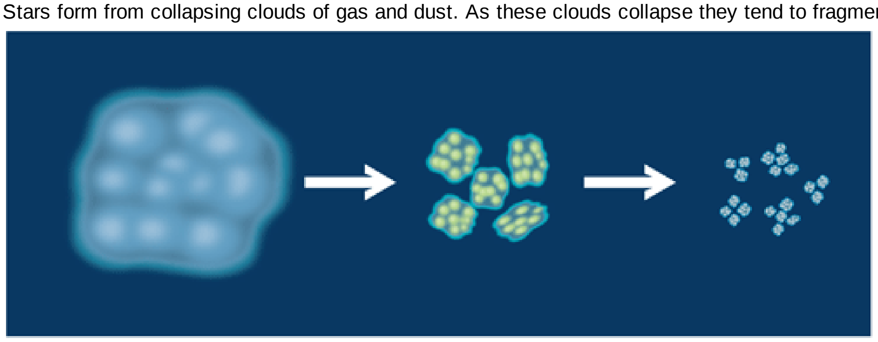
 

Curtis argued that the solar system is near or at the center of the Milky Way galaxy, and that the Milky Way is about 10 kpc across. Shapley, on the other hand, argued that the solar system is not near the center of the Milky Way, and that the Milky Way is about 100 kpc across. In Section A of the procedure, you will use RR Lyrae variable stars in globular clusters to measure (1) our distance from the center of the Milky Way, and (2) the approximate size of the Milky Way.

Shapely also argued that the Milky Way is so big that it is the primary object in the universe, and that what were then called "spiral nebulae", like Andromeda, are nearby and much smaller than the Milky Way. Curtis, on the other hand, argued that the spiral nebulae are far away and similar in size to the Milky Way, making them galaxies in their own right, and making the Milky Way merely one of countless many similar-sized objects in the universe. In Section B of the procedure, you will use Cepheid variable stars in spiral nebulae (1) to measure their distances and (2) to measure their sizes.

⊞ BACKGROUND: B. SIZE OF MILKY WAY AND OUR PLACE IN IT

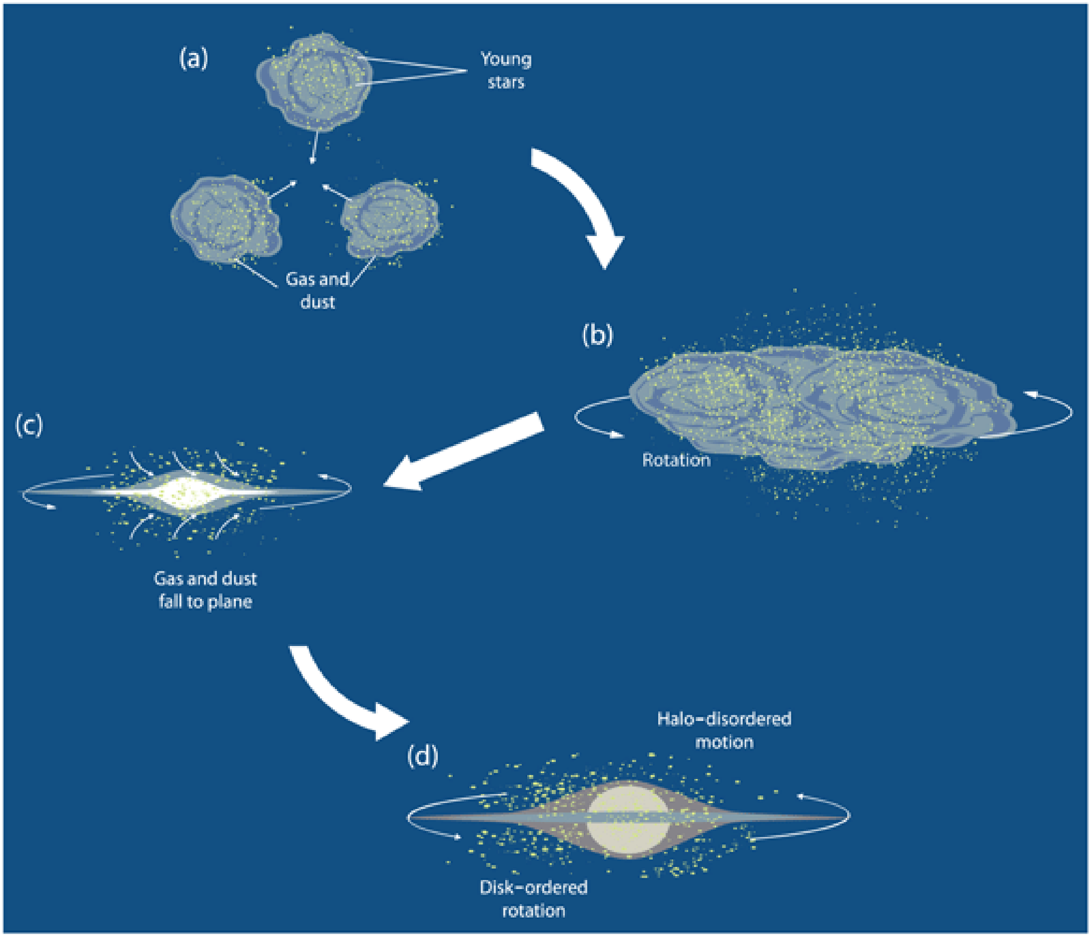
Stars form from collapsing clouds of gas and dust. As these clouds collapse they tend to fragment, over and over.



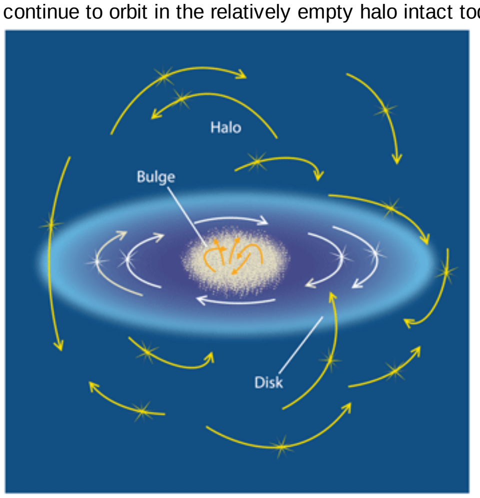
This results in a cluster of sometimes hundreds of thousands of stars that form at the same time.

If a star cluster forms in the disk of the Milky Way, it is (relatively) quickly torn apart into individual star systems by other star systems and clouds of gas.

However, not all star clusters formed in the disk. Consider when the Milky Way was still forming.

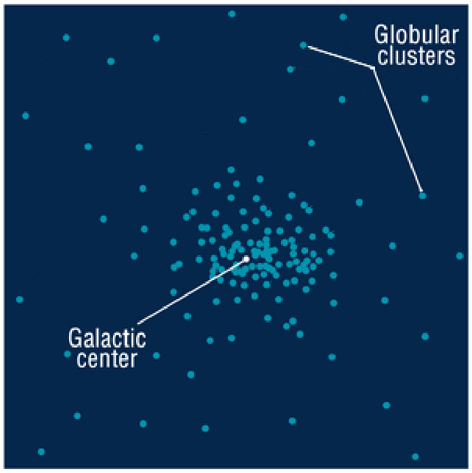


Some star clusters formed above and below the disk, in what we call the halo. We call these star clusters globular clusters and they continue to orbit in the relatively empty halo intact today.



In Lab 5, we learned how to measure the distances to globular clusters by measuring the distances to RR Lyrae variable stars in them. In Section A of the procedure, you will measure the distances to a random sample of globular clusters in the halo of the Milky Way.

With these distances, you will create a map of these globular clusters' locations as if you were above the Milky Way looking down upon them.

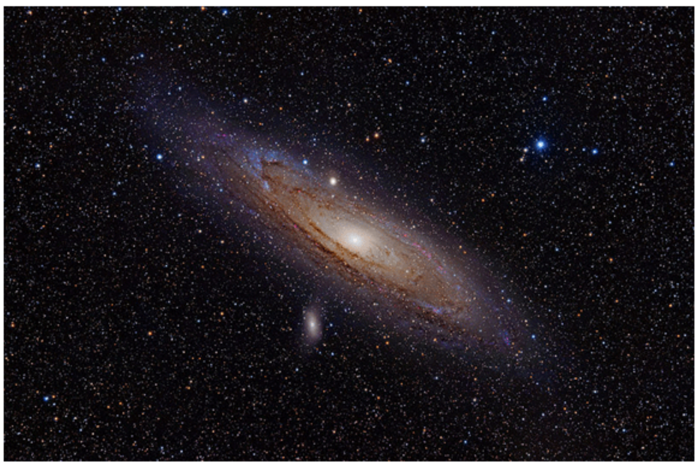


If this distribution is centered on the solar system, then the solar system is at the center of the Milky Way. If not, the distance between the center of this distribution and the solar system is our distance from the center of the Milky Way.

The diameter of this distribution is approximately the diameter of the Milky Way.

BACKGROUND: C. DISTANCE TO AND SIZE OF SPIRAL NEBULAE

In 1920, it was not known if the spiral nebulae, such as Andromeda:

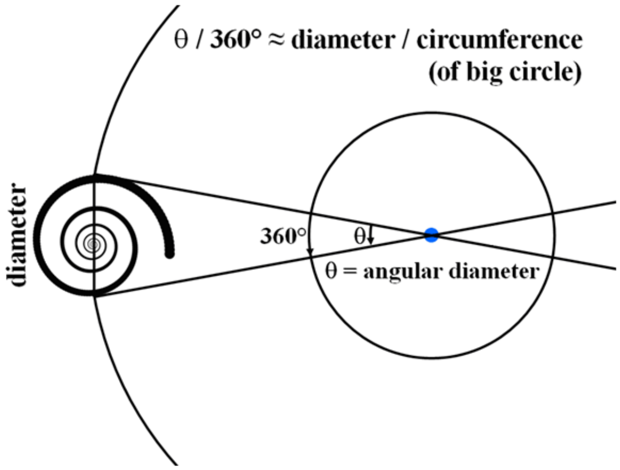


and similar-looking objects:

are nearby, small objects that orbit the Milky Way like the globular clusters, or if they are distant, large objects like the Milky Way itself. If the former, the Milky Way is the primary object in the universe. If the latter, the Milky Way is merely one of countless many similar-sized objects in the universe.

In Lab 5, we learned how to measure the distances to what were then called spiral nebulae by measuring distances to Cepheid variable stars in them.

Once we know the distance to a spiral nebula, we only need to measure its angular diameter to calculate its physical diameter. The following image is adapted from Lab 3.



The physical diameter of a spiral nebula as a fraction of the circumference of the big circle is the same as the angular diameter of the spiral nebula as a fraction of 360°.

$$\frac{\textbf{diameter}}{\textbf{circumference}} = \frac{\theta}{360°}$$

Since circumference = 2π times radius and the radius of the big circle is the distance to the spiral nebula:

$$\frac{\textbf{diameter}}{(2\pi \times \textbf{distance})} = \frac{\theta}{360°}$$

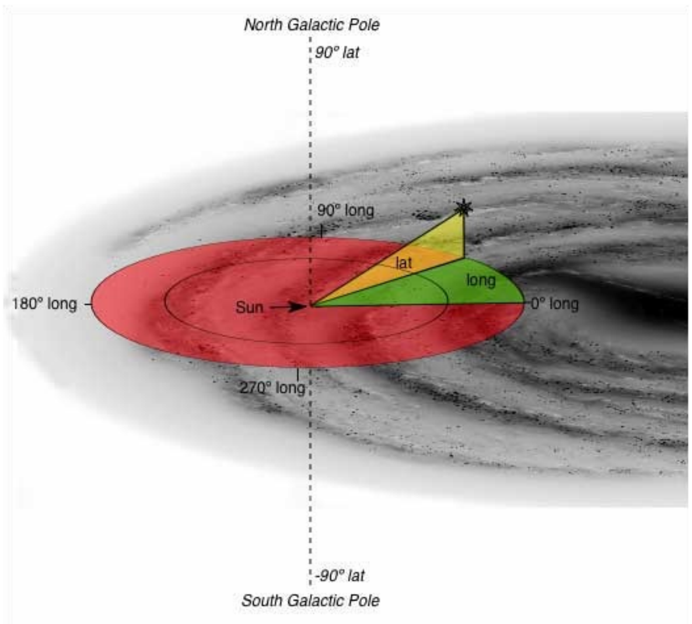
Solving for the physical diameter of the spiral nebula yields:

$$\textbf{diameter} = 2\pi \times \textbf{distance} \times \left(\frac{\theta}{360°}\right)$$

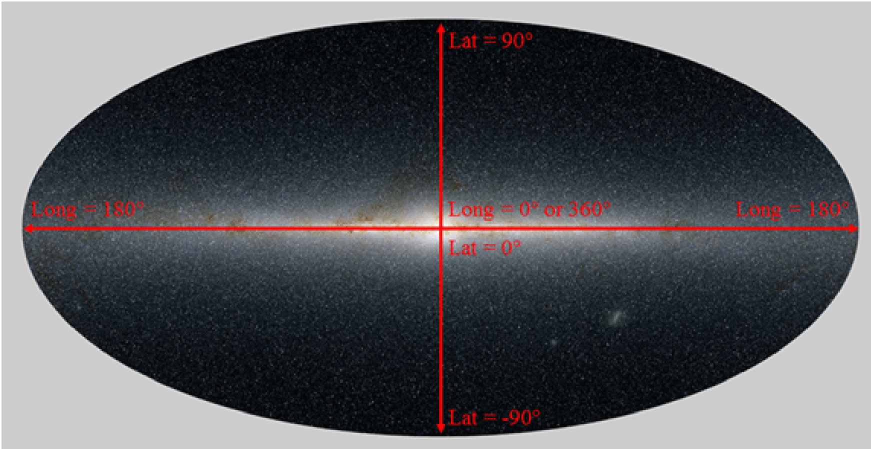
Note: Remember to convert θ to degrees before using this equation!

PROCEDURE: A. SIZE OF MILKY WAY AND OUR PLACE IN IT

Astronomers have identified approximately 150 globular clusters that orbit the Milky Way. We have randomly selected 30 of these and have listed their Galactic longitudes and latitudes in Data Table 1 below. Galactic longitudes and latitudes are similar to Earth longitudes and latitudes (see Lab 2), except that they are framed on the center and disk of the Milky Way, as viewed from Earth:



Here is the view from Earth. Logitude = 0, latitude = 0 corresponds to the center of the Milky Way, which is at the center of this full-sky image. The disk of the Milky Way runs horizontally across the image:



Next we must determine how far away each globular cluster is. We have randomly selected a known RR Lyrae variable star in each globular cluster and have listed its average apparent magnitude (think average brightness) in Data Table 1 below.

Given what you learned about RR Lyrae stars in Lab 5:

Determine the average absolute magnitude (think average luminosity) of each. Record these to the nearest 0.01 magnitudes in Data Table 1 below.

Calculate to distance to each. Record these to the nearest 0.01 kpc Data Table 1 below.

Data Table 1: Globular Clusters (9 points)

Globular Cluster Number	Galactic Longitude (Degrees)	Galactic Latitude (Degrees)	RR Lyrae Average Apparent Magnitude (m)	RR Lyrae Average Absolute Magnitude (M)	Globular Cluster Distance (kpc)
1	353.57	7.32	14.94		
2	282.19	−11.25	15.66		
3	7.9	−7.15	15.66		
4	7.73	3.8	15.37		
5	28.09	16.23	17.33		
6	5.54	10.7	15.24		
7	52.1	−18.89	16.73		
8	1.53	−11.38	15.77		
9	307.35	−20.47	17.13		
10	53.38	−35.78	16.05		
11	332.96	79.76	17.00		
12	328.41	4.34	16.72		
13	328.77	−2.79	15.04		
14	56.74	−4.56	13.76		
15	5.76	−24.56	17.82		
16	342.14	−16.41	16.39		
17	20.3	−25.75	17.33		
18	227.23	−29.35	16.30		
19	27.18	−46.83	15.27		
20	357.56	0.99	14.49		
21	130.07	19.03	15.94		
22	3.86	46.8	15.13		
23	20.8	6.78	15.37		

24	337.02	13.27	15.84		
25	0.85	45.86	17.58		
26	252.85	77.19	17.18		
27	346.9	−12.57	17.43		
28	87.1	−42.7	17.81		
29	19.23	6.76	15.92		
30	14.1	−6.8	16.30		

Question: Present your calculation for the distance to the first globular cluster in Data Table 1. (3 points)

Go to this website.

In this tutorial, you will learn how to plot globular cluster positions *as if you were above the Milky Way looking down upon them.* This is called a *top-down map.* In this top-down map, the sun will be at the origin (*X*, *Y* = 0,0) and both axes will be measured in kpc.

Make a top-down map of your globular clusters' distribution. Save your final graph as a png file.

Question: Upload your final png graph. (5 points)

Choose File No file chosen

Question: Estimate the distance between us and the center of this distribution. This is the distance between us and the center of the Milky Way. (2 points)

kpc

Question: Google and record the true distance to the center of the Milky Way. (1 point)

kpc

Question: Calculate your percent error. (1 point)

%

Question: What is the most significant source of error? (1 point)

Question: Who was correct about the solar system's place in the Milky Way: Shapley or Curtis? (2 points)

- Shapley
- Curtis
- neither

Question: Estimate the distance across this distribution. This is approximately the diameter of the Milky Way. (2 points)

kpc

Question: Google and record the true diameter of the Milky Way. (1 point)

kpc

Question: Calculate your percent error. (1 point)

%

Question: What is the most significant source of error? (1 point)

Question: Who was correct about the size of the Milky Way: Shapley or Curtis? (2 points)

- Shapley
- Curtis
- neither

PROCEDURE: B. DISTANCE TO AND SIZE OF SPIRAL NEBULAE - 1. Observe Spiral Nebulae with Skynet

Observe each spiral nebula that is currently observable from the following list. If observable from CTIO or SSO, use PROMPT.

Spiral Nebulae	Filter	Exposure Duration (seconds)†
M66	Open	80
M96	Open	80
NGC 1365	Open	80
NGC 2935	Open	80
NGC 7331	Open	80

Request only one exposure per observation.

If any of your images are of poor quality for any reason, re-observe them.

PROCEDURE: B. DISTANCE AND SIZE OF SPIRAL NEBULAE - 2. Determine Distances to and Sizes of Spiral Nebulae

In Section B.1, you observed a random sample of spiral nebulae. First we must determine how far away each is. We have randomly selected a known Cepheid variable star in each spiral nebula and have listed its average apparent magnitude (think average brightness) and period in Data Table 2 below.

Given what you learned about Cepheid stars in Lab 5:

Calculate the average absolute magnitude (think average luminosity) of each for the spiral nebulae that you observed. Record these to the nearest 0.01 magnitudes in Data Table 2 below. (If not observed, leave blank.)

Calculate the distance to each for the spiral nebulae that you observed. Record these to the nearest 100 kpc in Data Table 2 below. (If not observed, leave blank.)

Data Table 2: Spiral Nebula Distances (2 points for each observed spiral nebula)

Spiral Nebula	Successfully Observed?	Cepheid Average Apparent Magnitude (m)	Cepheid Period (days)	Cepheid Average Absolute Magnitude (M)	Spiral Nebula Distance (kpc)
M66	---Select---	24.6	22.1		
M96	---Select---	24.2	48.3		

NGC 1365	---Select--- ▼	25.5	35.2		
NGC 2935	---Select--- ▼	26.2	60.8		
NGC 7331	---Select--- ▼	24.5	42.6		

Sign your name to attest to the fact that you collected these data yourself.

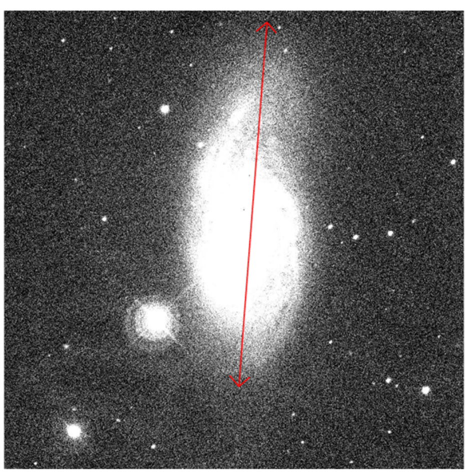
Question: Present your calculation for the average absolute magnitude of the Cepheid in the first spiral nebula that you observed in Data Table 2. (3 points)

Question: Present your calculation for the distance to the first spiral nebula that you observed in Data Table 2. (3 points)

Next we must determine how big each spiral nebula is. Open each of your images in Afterglow. The central regions of spiral nebulae are brighter than their outer regions. To better see the outer regions, in the histogram window, change "Max" to "90". Zoom in until the spiral nebula fills the window.

Measure the angular diameter of each. Record these to the nearest 0.1 arcminutes in Data Table 3 below. (If not observed, leave blank.)

Note: Measure the long axis. If the entire long axis is not in the image, measure the angular radius and multiply by two.



Convert your angular diameter measurements from arcminutes to degrees. Record these to the nearest 0.001 degrees in Data Table 3 below. (If not observed, leave blank.)

Calculate the physical diameter of each. Record these to the nearest 0.1 kpc in Data Table 3 below. (If not observed, leave blank.)

Data Table 3: Spiral Nebula Diameters (3 points for each observed spiral nebula)

Spiral Nebula	Spiral Nebula Angular Diameter (arcminutes)	Spiral Nebula Angular Diameter (degrees)	Spiral Nebula Diameter (kpc)
M66			

M96			
NGC 1365			
NGC 2935			
NGC 7331			

Question: Present your calculation for the diameter of the first spiral nebula that you observed in Data Table 3. (3 points)

Question: What is the most significant source of error? (1 point)

Question: How does the size of the Milky Way compare to the size of the spiral nebulae in your random sample? Is the Milky Way many times larger than, many times smaller than, or typical of the spiral nebulae? (2 points)

- Milky Way is many times larger than spiral nebulae
- Milky Way is many times smaller than spiral nebulae
- Milky Way is typical of spiral nebulae

Question: Who was more correct about the Milky Way's place in the universe: Shapley or Curtis? (2 points)

- Shapley
- Curtis
- neither

Assignment Details

Name (AID): **Lab 6: The Great Debate (T) (2413171)**
Submissions Allowed: **100**
Category: **Homework**
Code:
Locked: **Yes**
Author: **Reichart, Daniel (** reichart@physics.unc.edu **)**
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