Using Radio Waves to Map the Galaxy

Written by Sofia Sheikh and Vishal Gajjar
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Part 1: Learning about the Milky Way and Radio Astronomy

1. ”Globular clusters” are clumps of stars that are evenly distributed around the center of a galaxy. Here are 10 of the globular clusters in the Milky Way. Plot these points onto the polar plot on the next page, assuming that Sun sits at the center at 0 kiloparsecs (1 kiloparsec is about 3300 light-years!)[1]

Cluster	Galactic longitude, l (degrees)	Distance away from Sun (kiloparsecs)
NGC 104	305.89	4.5
NGC 362	301.53	8.6
NGC 1851	244.51	12.1
NGC 2808	282.19	9.6
NGC 3201	277.23	4.9
NGC 4372	300.99	5.8
NGC 4590	299.63	10.3
NGC 5286	311.61	11.7
NGC 5927	326.6	7.7
NGC 6101	317.74	15.4

2. Once you have plotted the 10 points, place a mark at their approximate center. How far away from the Sun is the mark you made, in kiloparsecs (which concentric circle is it closest to)? Then, multiply that number by 3300 to get the distance in lightyears. How does that number compare to the distance of the galactic center we used in Week 4 (25000 ly)?

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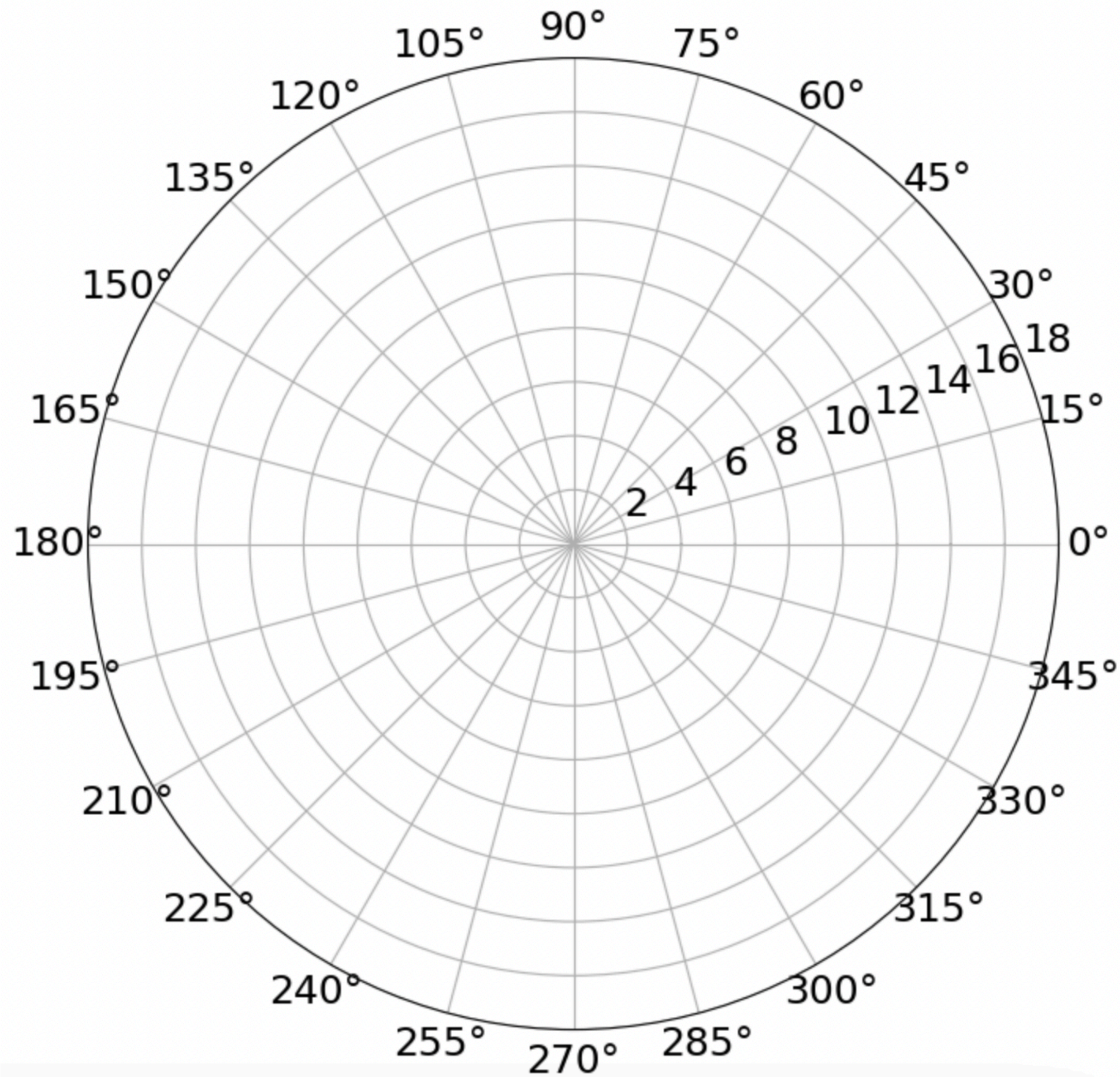
[1] This is exactly what was done by Edward Shapley in 1918, to first map the location of the galactic center!



2. Take a look at the distribution of points you plotted. Someone claims “The Earth is at the center of the Galaxy” - below, use claim-evidence reasoning to support or reject this claim.

3. Now, listen to the presentation about the basic structure about the Milky Way, and watch Sofia do the Doppler demo. Write out in your own words the evidence from the demo that supports the claim: “A signal’s frequency goes up when the source is moving towards you, and it goes down when the source is moving away.”

4. Give it a try! Sofia will give you a card containing a measurement - figure out the *velocity* (or speed towards or away from you) that the source was moving based on the Doppler shift process below. The full equation is as follows, where ***c*** stands for “the speed of light” (because radio waves are light waves, and all light waves travel at the same speed).

$$\text{velocity towards or away} = c \times \frac{(\text{measured frequency} - \text{rest frequency})}{\text{rest frequency}}$$

a) What is the rest frequency of the line?

b) What is the measured frequency of the line?

c) What is the *difference* in the measured frequency and the rest frequency (measured frequency - rest frequency)? Don’t forget to include the negative sign if you have one!

MHz

Divide that number by the rest frequency

Now multiply that number by *c* = 300,000 kilometers per second (the speed of light) to get your velocity

My source was moving at **kilometers per second**

4. Now, listen to the presentation about the principles of radio astronomy, GNU radio, and the ATA. Radio Frequency Interference (RFI) is what we call any radio signals that *don't* come from an astronomical source, and instead come from, for example, human technology like cellphones. Discuss the following questions with your group:

a) When do you use your cellphone the most for calling and texting? Therefore, what time of day might be the best to observe with a radio telescope to avoid RFI from cellphones?

b) Where do you tend to have the worst cell service? Usually, that's because you're further from a cell tower than usual. Therefore, where would you want to put a radio telescope to avoid RFI from cellphones?

c) Satellite-based radio technologies like GPS, Starlink, and satellite radio (Sirius-XM) don't rely on towers on the ground, but instead rely on signals coming down from satellites overhead. What are some challenges that satellites could cause for radio astronomy, that "terrestrial" interference (from devices on Earth's surface) do not?

5. Time to take some data! Whenever we observe in astronomy, we keep an Observation Log which contains all of the important information from the session. Below, you should fill in your own **Observing Log** for this session.

Observing Log

General information

Name of observer:

Telescope:

Weather at the observatory:

Time of observation start:

Length of each observation:

If anything unusual happened, or went wrong, during the session, note it here:

Scan #1:

Galactic Coordinate #1:

Was the 1420 MHz HI line detected?

If so, what was its peak strength?

If so, what was its peak frequency?

Scan #2:

Galactic Coordinate #2:

Was the 1420 MHz HI line detected?

If so, what was its peak strength?

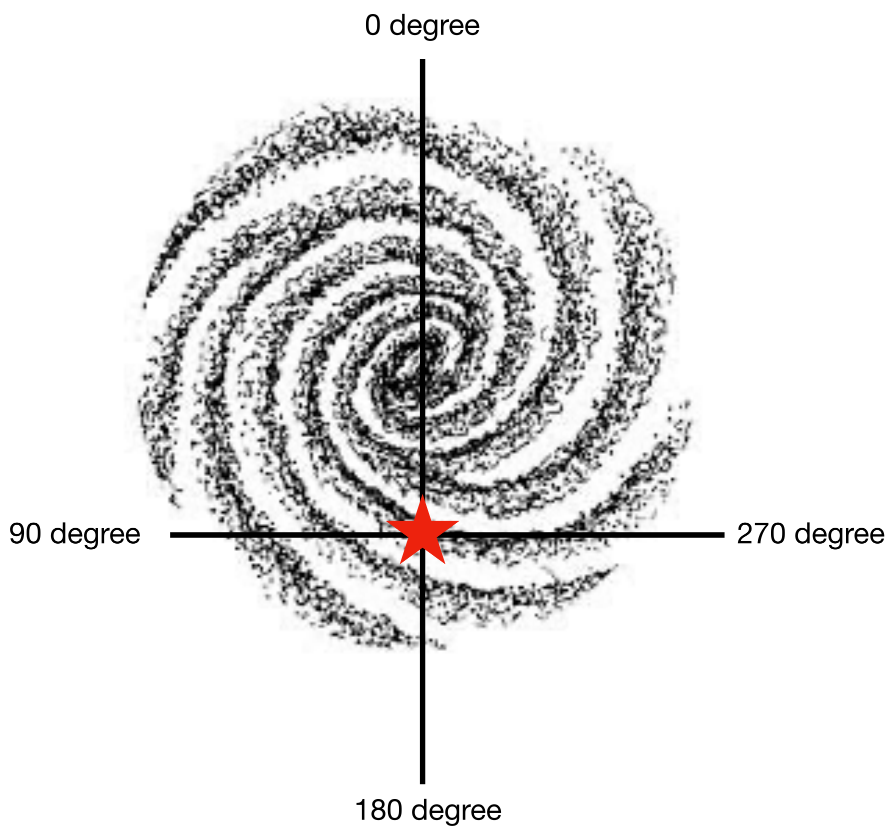
If so, what was its peak frequency?

6. Use the Doppler shift formula to calculate the velocities for each coordinate.

Galactic Coordinate #1:

Galactic Coordinate #2:

7. Can you draw arrow in this plot for these two directions given the position of the Sun marked with a (red) star in following image.



8. We will now have a class discussion about these two measurements. What claims can we make about the galaxy based on these measurements?