Smiley Radio Telescope
Lab 4
Radio Waves from the Galaxy

Competency Goals

This activity addresses the following competency goals *Middle Grades 6 – 8:*

Grade 6

- *1.01 Identify and create questions and hypotheses that can be answered through scientific investigations.*
- *1.02 Develop appropriate experimental procedures for:*
    - *Given questions.*
    - *Student generated questions.*
- *1.03 Apply safety procedures in the laboratory and in field studies:*
    - *Recognize potential hazards.*
    - *Manipulate materials and equipment.*
    - *Conduct appropriate procedures.*
- *1/05 Analyze evidence to:*
    - *Explain observations.*
    - *Make inferences and predictions.*
    - *Develop the relationship between evidence and explanation.*
- *1.08 Use oral and written language to:*
    - *Communicate findings.*
    - *Defend conclusions of scientific investigations.*
- *1.09 Use technologies and information systems to:*
    - *Research.*
    - *Gather and analyze data.*
    - *Visualize data.*
    - *Disseminate findings to others.*
- *5.05 Describe the setting of the solar system in the universe including:*
    - *Galaxy.*
    - *Size.*
    - *The uniqueness of Earth.*

High School

Physical Sciences

- *3.04 Investigate and analyze the transfer of energy by waves:*
    - *General characteristics of waves: amplitude, frequency, period, wavelength, velocity of propagation.*
    - *Mechanical waves.*
    - *Sound waves.*
    - *Electromagnetic waves (radiation).*

Earth/Environmental Science

- *6.05 Evaluate astronomers' use of various technologies to extend their senses:*
    - *Optical telescopes.*
    - *Cameras.*
    - *Radio telescopes.*
    - *Spectroscope.*

Introduction:

The Milky Way galaxy which we inhabit consists of stars, gas and dust. The majority of the material in the Galaxy lies in a flattened disk, surrounded by a halo that is about twice the diameter of the disk. The general structure is shown in Figure 1.

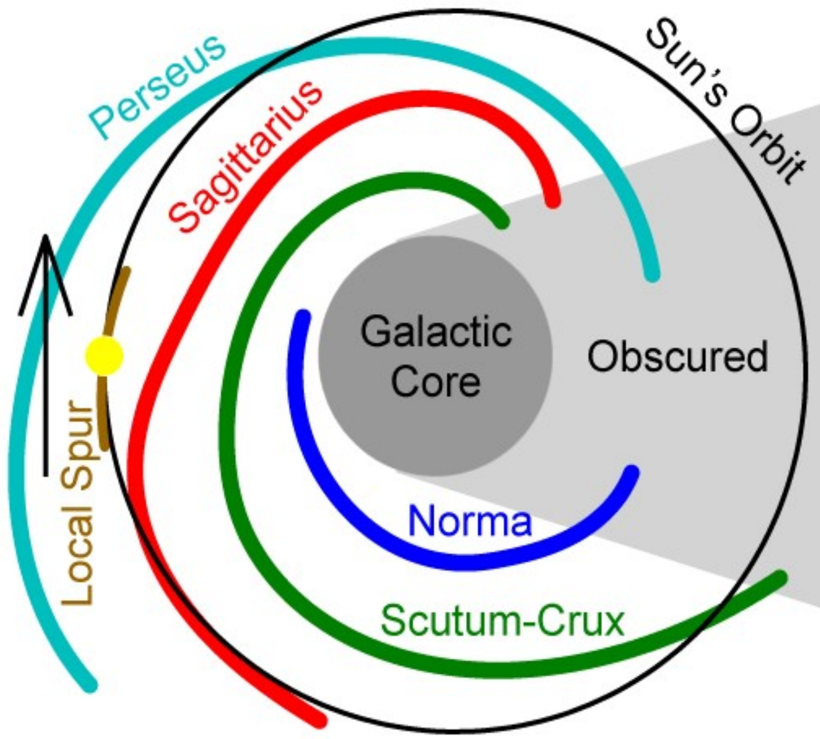

Figure 1. The structure of the Galaxy as viewed from the top
Courtesy Wikipedia

We can easily see the stars that lie in the disk and halo of the Galaxy due to the light they emit. We can see evidence for the dust in the galaxy because the Milky Way in the sky is patchy and has gaps in it caused by the dust obscuring our view. We wish to try to prove that the Milky Way also contains gas as well. The gas and dust that lie in the Galaxy are called collectively the interstellar medium. About 13% of the interstellar medium is dust, while the other 87% is gas. The gas is about 75% hydrogen gas and 24% helium and 1% everything else. This is not surprising since hydrogen is the simplest element there is, containing one electron orbiting one proton. Since we lie inside the disk which contains the interstellar medium, we do not see the gas in all directions; but instead we see the hydrogen mainly in the direction of the plane of the Galaxy. The diffuse band of light that we see in dark sites away from cities that gives the Milky Way its names lie in such a band.

The Smiley Radio telescope

The process by which hydrogen in the interstellar medium generates radio waves is described in Lab 1. The Smiley radio telescope detects radio waves from space by first focusing the light from space to a point using its parabolic mirror (Figure 2)

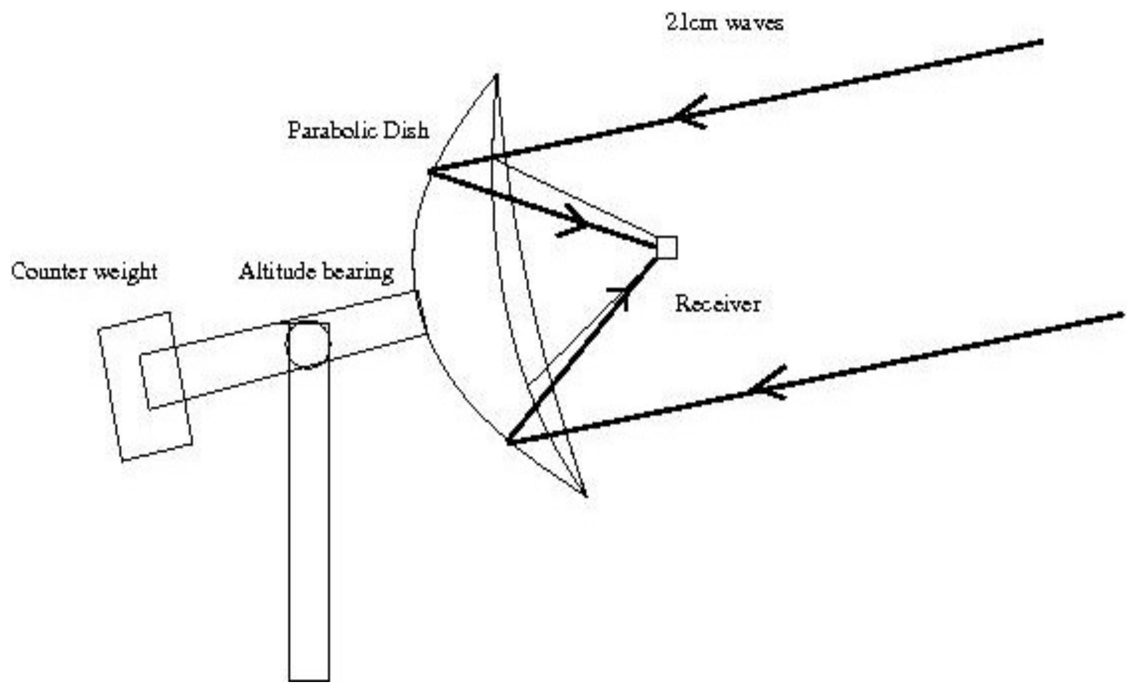

Figure 2. The optical design of the Smiley Radio Telescope

At the focus is an antenna wire cut to a length one quarter the wavelength of the 21 cm radiation. This results in a small current being generated in the wire when the 21 cm radio waves reach it. The signal is then amplified and sent to electronics which produce a plot of the amount of radio energy versus radio frequency (see a discussion of frequency below). This is called a radio spectrum and can be used to measure radio waves from the Galaxy.

The Smiley radio telescope detects hydrogen gas in the spiral arms of the Galaxy as we have mentioned. The data from Smiley is in the form of a graph which shows the amount of radio energy detected versus frequency. Frequency is a number that gives the number of waves that pass by the observer each second from a given source. You may be familiar with tuning a radio in a car. You turn the dial changing the frequency, hearing mostly static until you are near a radio station's broadcast frequency. The sound gets louder until you get to the radio station's exact frequency. If you keep tuning past it then you will hear the sound go down again until you get just static again. The sound never goes to zero loudness because of the static. If we were to plot a graph of our measurements with the loudness on the vertical axis and the frequency on the horizontal axis, then we would be constructing a spectrum of the amount of radio energy received measured by the amount of sound we hear.

Activity: On the graph below, sketch what it would look like if you had a FM radio stations at the frequencies of 96 MHz and 106 MHz. The horizontal axis is frequency and the vertical axis is the loudness of the sound coming from the speakers of a radio.
There should be two peaks coinciding with each radio station.

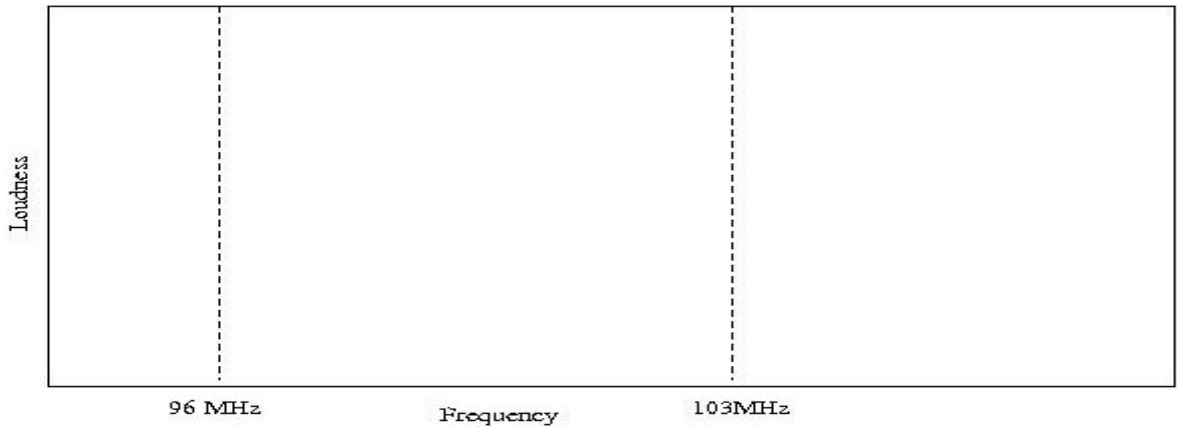

Figure 3. A FM radio region sound spectrum

The Smiley telescope has an instrument called a spectrometer that does this procedure for us. The spectrometer starts a given frequency, measures the amount of energy from radio waves, records it, and then changes the frequency and repeats the measurement. This gives us the amount of radio energy from space through a given range of frequencies. The interstellar gas that Smiley detects sends radio waves at a frequency of 1420 MHz. The spiral arms of the Galaxy emit these waves and result in a "line" or peak in radio energy at this frequency. However, due to the Sun's motion and the rotation of the spiral arms themselves, the 1420 MHz line is Doppler shifted towards higher frequencies for spiral arms that are getting closer to us, and lower frequencies for those moving away. We are now informed enough to design an experiment to prove the Galaxy has hydrogen in its interstellar medium.

Group/Class Discussion: How might we use the Smiley radio telescope to prove there is hydrogen gas in the interstellar medium?

The best procedure is to simply point the telescope at a spot on the plane of the Galaxy and then at a spot away from the plane of the Galaxy. If there is more emission from hydrogen on the plane than away, you have proved the Galaxy emits radio waves from hydrogen. One observation is not enough because the radio waves could be coming from terrestrial or celestial sources that happen to lie towards the part of the Galaxy at which you are pointed. So you need to prove not just detection, but detection from the Galaxy.

Prediction:

On the chart below sketch the expected results.

There should be a flat line for the observation away from the Galaxy while there should be a bump or peak of emission from the emission line of hydrogen.

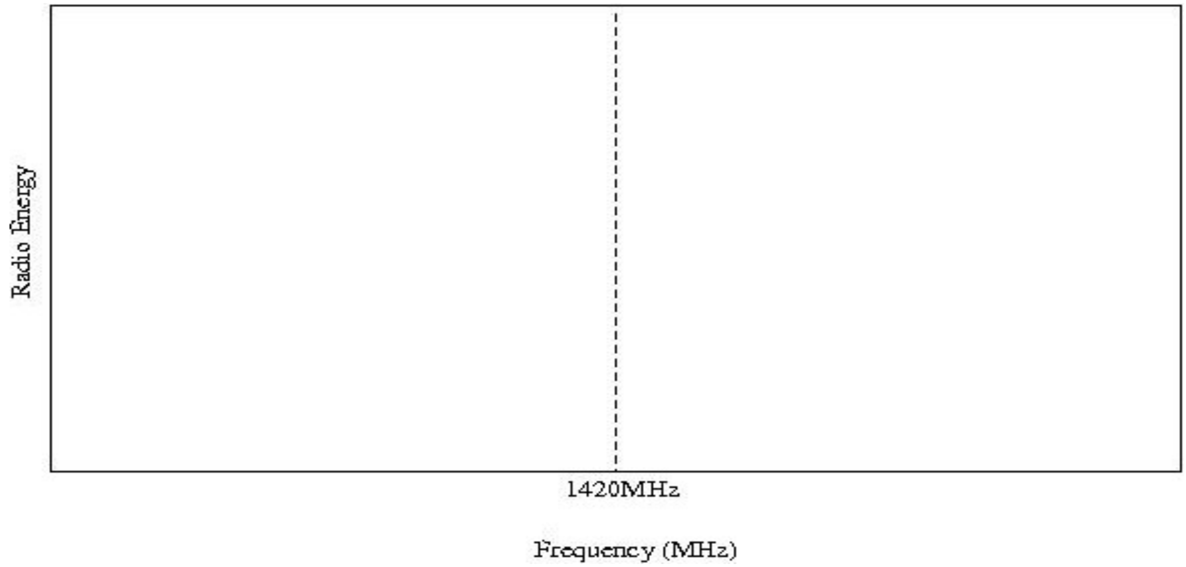

Figure 4. Predicted results

Procedure.

1. Log into the [**Smiley**]() radio telescope.

2. Go to the Smiley control window. The band of light blue running across the map is the plane of the disk of the Milky Way galaxy. This is our area of interest. Smiley's position on the sky is the white cross, the Sun is the yellow circle and the Moon is the white circle. A few bright radio sources are shown as well.

3. We want to select a prominent region along the Milky Way and take a spectrum of it. Select a region and move the telescope to point at it.

4. Use the spectrometer on Smiley to take a spectrum of that part of the Galaxy. Save your spectrum.

5. Point the telescope at a point as far away from the Milky Way as you can. This region will be dark on the all-sky map.

6. Use the spectrometer on Smiley to take a spectrum of that part of the Galaxy. Save your spectrum.

7. Use an Excel spreadsheet or the Smiley analysis package to plot all your data on one graph.

Analysis

1. Compare your predicted behavior with what was actually seen in the observations. Did the predicted results occur?

2. What do you conclude from the experiment?

3. How could we improve the experiment? Have we left anything out that might be important?