

# Unit 3 Lab1

What Lies Between the Stars



**Teacher Version**

# Unit 3 Lab 1:

## What's Between the Stars

**Objective:** In this lab, students will measure and compare the peak intensity of 21 cm radio waves emitted from the gas and dust between five different objects.

### Teacher Notes



PARIPod 3.1 is still in development.

## Background Knowledge

On earth and in space we are immersed in a sea of electromagnetic waves. Electromagnetic waves include gamma rays (very high energy light), X-rays (high energy light), ultraviolet rays (light that gives us tans), visible light (light we can see with our eyes), infrared light (light that we sense as heat), microwaves (light we use in our microwaves), and finally radio waves (light we listen to on the radio and on our cell phones). Almost everything emits, reflects and absorbs electromagnetic waves. For more information on electromagnetic waves see Lab 2. In this lab we will focus on nebula or clouds of dust and gas found between stars.

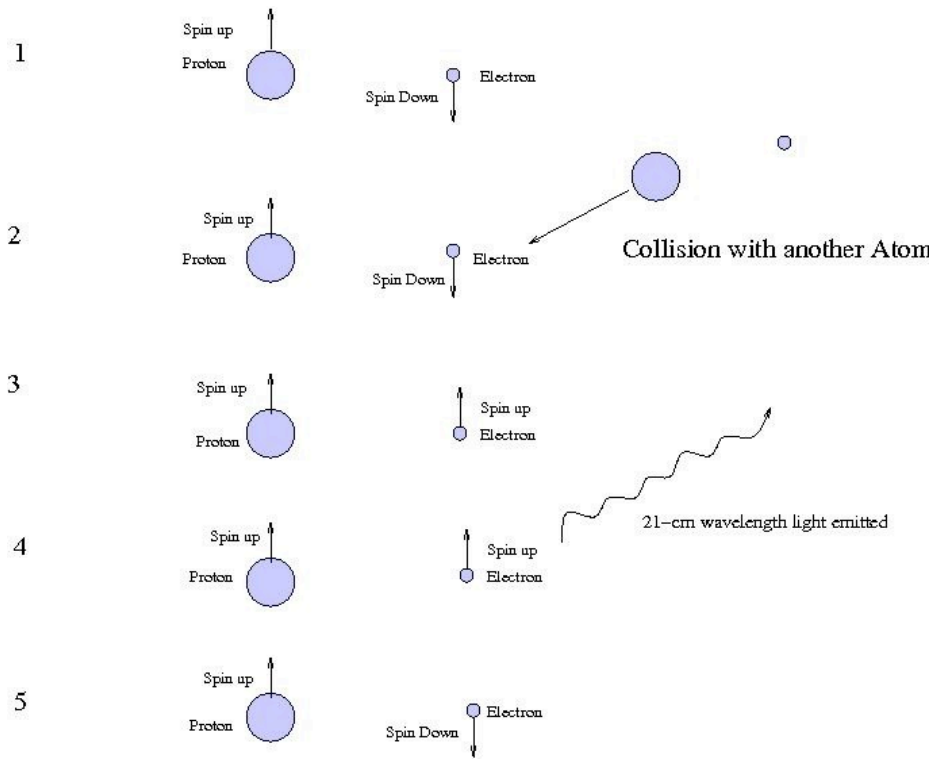
If you go outside with a pair of binoculars and look into the constellation of Orion, you will see more than stars. If you look close enough, you will see a cloud of gas and dust. We call this the Orion Nebula (**Figure 1**). The Orion Nebula is made mostly of hydrogen gas. In fact 70% of our observable universe is made of hydrogen gas. Consequently, the dominant source of radio waves, which we will be observing with Smiley, comes from hydrogen gas.

So how does hydrogen gas emit radio waves? Here's the science: A neutral hydrogen atom consists of a proton surrounded by an electron. One property that both an electron and a proton have is something called spin. (**Figure 2**) Through a crude analogy, spin can be thought of as a spinning earth orbiting a spinning Sun. If we picture spin as this rotation we can place a direction on spin. If the spin of the earth is up, then the earth is spinning counter clockwise as it orbits the sun. If the spin of the earth is down, then it is



**Figure 1. The Great nebula in Orion**

spinning clockwise as it orbits the sun. The same works for the sun. When the spins of an electron and proton are in the same direction, meaning they are both spinning in the same direction, then the spins are said to be **parallel**. When the spins of an electron and a proton are in different directions, meaning they are spinning in different directions, the spins are said to be **antiparallel**. When an electron and a proton have parallel spins, the electron is in a slightly higher energy level than when the electron and proton have antiparallel spins. Nature always prefers to be in the lowest energy possible, so parallel spins usually decay into antiparallel spins. Hydrogen atoms in a nebula can collide or absorb light, causing the electron to flip from its natural state of being antiparallel to the proton to parallel to the spin of the proton. Since the electron wants to be in its lowest energy level it flips back to antiparallel. However, when the electron *spin-flips* it emits a radio wave with wavelength of 21 centimeters and a frequency of 1.42 Gigahertz (1 billion Hertz). Wavelength is simply the length of a cycle and frequency is the number of cycles per second. (See 3.1 for further discussion on wavelength and frequency.) Using Smiley, you will measure 21 cm radio waves from gas and dust that exists between the stars, emitted from the spin-flip transitions from hydrogen. These 21 cm radio waves measure slightly less than the width of an 8 1/2 x 11 sheet of paper. However, these radio waves are much longer than a visible electromagnetic wave (typically visible light has a wavelength of about 550 nanometers which is about 400,000 times smaller than our radio wave).



**Figure 2. The production of 21cm wavelength radio waves from interstellar hydrogen.**

## Procedures:

1. Log into the Smiley Observation Room. For information refer to Unit 2: Smiley Basics.
2. In **Map** mode select an object by either clicking on its red star or by selecting one by pulling down the **Sources** tab.
3. Once you have selected your object, click on the **GO** button. You can follow Smiley's progress by watching the live video in the top center of your screen. Check the status box and notice when Smiley stops.  
*NOTE: Not all objects will be above the horizon. If the Altitude is negative, then the object is below the horizon and cannot be observed. You will get an error message in the status box. (Figure 3)*
4. Once Smiley stops, check the coordinates. The **Target Coordinates** (in the white boxes) should be close to the **CURRENT Coordinates**. To get closer, you can use the **Hand Paddle** to point Smiley closer to the desired coordinates.
5. Next click on the **Spectrum** button, to set Smiley in spectrum mode.
6. In the **Spectrum** window, set your **IF GAIN** to 19 and set your **PLOT RATE** to 1x. Also make sure the **Base Frequency** is set to 1.42 GHz. Click **Begin Scan**.

7. After Smiley has completed the plot and starts to plot again, click on **Stop Scan**. Record the peak intensity on the table below by clicking on **Save Scan** and saving it to some **Output filename**. Next open your saved scan by clicking on **Open Data File**. Then click on **List**, this will list all of your data points.
8. Now find your peak intensity and record your results in the table below.
9. **Repeat steps 2-7** for four more objects making sure you use the same IF gain and plot rate for each object.

## Data Collection

<i>Object</i>	<i>Peak Intensity</i>

## Analysis and Discussion

1. How did your spectrum scans compare from object to object?

*There should be differences in peak intensities for each object.*

2. What could account for the difference?

*The higher the peak intensity, the more spinflip transitions of hydrogen and thus more radio waves.*