

## Lab 5: Smiley Nebula and Proplyd Labs



### Educational Goals/Objectives

Based on the section *Content Standards, Grades 9-12* from the *National Science Education Standard* that pertain to physical sciences, review of the two modules shows that the *Unifying Concepts and Processes*, *Science as an Inquiry*, and *Science and Technology*, are completely met considering the close tie between the technology using the 4.6-m radio telescope and remote astronomical observations made with that telescope. In Physical Science, we address structure of atoms, structure and properties of matter (as a gas), conservation of energy and increase in disorder, and interactions of energy and matter. In Earth and Space Science, we address origin and evolution of the Earth system.

The goal of these module is to present proplyds as objects that represent the Solar System early in its formation. This goal satisfies the *Origin and Evolution of the Earth Content Standard*, Grades 9-12 from the National Science Education Standards.

#### Laboratory 1: Nebula Lab

Students have probably not experienced an out-of-this-world physical science laboratory like the OMC in two different parts of the electromagnetic spectrum. Since observing the OMC may not be in their experience, this module will introduce students to the lab, familiarizing them with the large-scale physical and chemical processes occurring 1500 light years from Earth!

Students will explore the environment conducive to star formation via multimedia and real time radio observation. The radio observations will be done using the PARI 4.6-meter radio telescope with the 21cm receiver in spectrum mode. Students will measure the rotation velocities of many different HII regions.

#### Laboratory 2: Proplyds

Students will focus on proplyds embedded within the large-scale processes of the OMC. The goal is to teach the nature of proplyds and relate them to the origin and evolution of our Solar System. This module will use primarily HST data.

Since the 4.6-meter radio telescope does not have the spatial resolution for students to make real-time radio observations of proplyds, this module will consist exclusively of HST Fits data and interactive multimedia webpages. Incorporated into the webpage will be access to an online image processor that will allow students to zoom in on proplyds and study their morphologies. The software for image processing must meet three basic requirements. First, it must be economical; schools are often on tight budgets and cannot invest in expensive software. Second, the software must be able to do the analysis. Third, it must be user friendly. The *Sky Image Processor* (SIP; <http://www.phys.vt.edu/~jhs/SIP/>) is a JAVA based tool that can be used with any net browser, and is not installed on the user's computer. So, students can run this from school, home, the library, or any place they can acquire an Internet connection.

A selection of archived Fits images of the Orion Nebula taken with WFPC2 at different wavelengths will be available on the SGRA webpage. Students will be able to download an image and compare the morphology of different proplyds. The students will calculate the

linear size of the proplyds.

[\[Nebula Lab\]](#) [\[Proplyd Lab\]](#)

Laboratories and  
Webpage designed by  
Andrew Nicholson  
2004

Home

SGRA

Pisgah Forest Institute

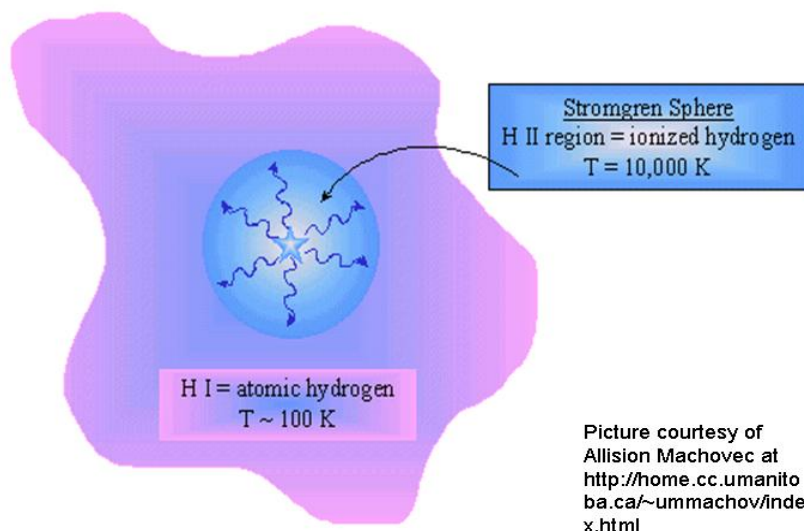
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## Introduction:

In this lab we will be measuring the rate of rotation of different clouds of hydrogen surrounding stars, called nebula. We will measure the rate of rotation of a nebula of ionized hydrogen surrounded by very hot stars. The rotation can be measured from the frequency Doppler Shift of the hydrogen intensity in the nebula. Now we will discuss some of the terms above. Intensity is the average energy per unit area per unit time. As a star radiates light, the light gets spread apart more and more the further the observer is from the star. Intensity is just the measure of how much light there is in a certain area over some time. Smiley is a radio telescope so it detects radio waves, not optical waves that our eyes detect. Radio waves and optical waves are both electromagnetic waves, just radio waves have a much smaller frequency than optical waves. Frequency is just the measure of the number of waves per unit time.



Picture courtesy of  
Allision Machovec at  
[http://home.cc.umanito  
ba.ca/~ummachov/index.html](http://home.cc.umanito.ba.ca/~ummachov/index.html)

Now let us discuss HII regions. Many spiral galaxies contain stars surrounded by clouds of hydrogen. The hydrogen closest to the star is heated to or above  $10^{14}$  Kelvin or  $1.8 \times 10^{15}$  degrees Fahrenheit. Hydrogen atoms become unstable at these temperatures leading to the breakdown of the atom into a proton and an electron. Hydrogen in this state is said to be

ionized and we call this a HII region. The free protons and electrons formed by the ionization of hydrogen can recombine forming another hydrogen atom. At the time of formation the electron of the newly created hydrogen atom occupies a high energy level, but over time the electron will drop to a low energy level. The transition in energy levels produces a photon, or a particle of light. The photon produced by the recombining of the hydrogen atom then may travel outward to the next part of the hydrogen cloud, the HI region. A HI region is neutral hydrogen. The HI region surrounds the HII region and is below  $10^{14}$  Kelvin so the hydrogen atoms are not unstable. If the photon created in the HII region strikes an atom of neutral hydrogen in the HI region it can cause the electron of the neutral hydrogen to spin-flip. Think of a spin-flip as a change in the orientation of the electron. The spin-flip is unstable and eventually the electron flips back to its original form, creating another photon. For further discussion on spin-flip transitions see [Lab 1](#). These are the photons we detect with Smiley. These photons have a wavelength of about 21 cm or a frequency of about 1.42 GHz. Thus we can study an HII region by detecting signals from the surrounding HI region.

Because many nebulae surrounding stars are rotating, light coming from these regions experience a dopplar shift, or a shift in frequency. As the nebula rotates some of the hydrogen gas is traveling towards us and some of the it is moving away from us. The radio waves given

off by the hydrogen gas will be blue shifted at the part of the nebula moving toward us and will be red shifted at the part of the nebula moving away from us. Because we know the base frequency of these waves, 1.42 GHz, and we know what the shifted frequency of the waves is we can calculate the rate of rotation of the source. The Doppler shift is given by the equation:

$$(\Delta\nu/\nu)=(v/c)$$

where  $\Delta\nu$  is the amount the frequency is shifted,  $\nu$  is the base frequency (1.42 GHz),  $v$  is the velocity of the source, and  $c$  is the speed of light. So by solving for velocity we find that:

$$v = (\Delta\nu/\nu)c$$

Now that we have found the different velocities of different regions coming toward and away from us, we can subtract these two velocities and find the HII regions rate of rotation.

### Procedure:

1. Please refer to the [Smiley Users Manual](#) for a complete explanation of how to get into Smiley as well as an explanation of Smiley's controls.
2. Here is a table of many different nebulae. Note the season and the time of day, will all of these nebulae be in the sky?

### Right Ascension Values for the Seasons

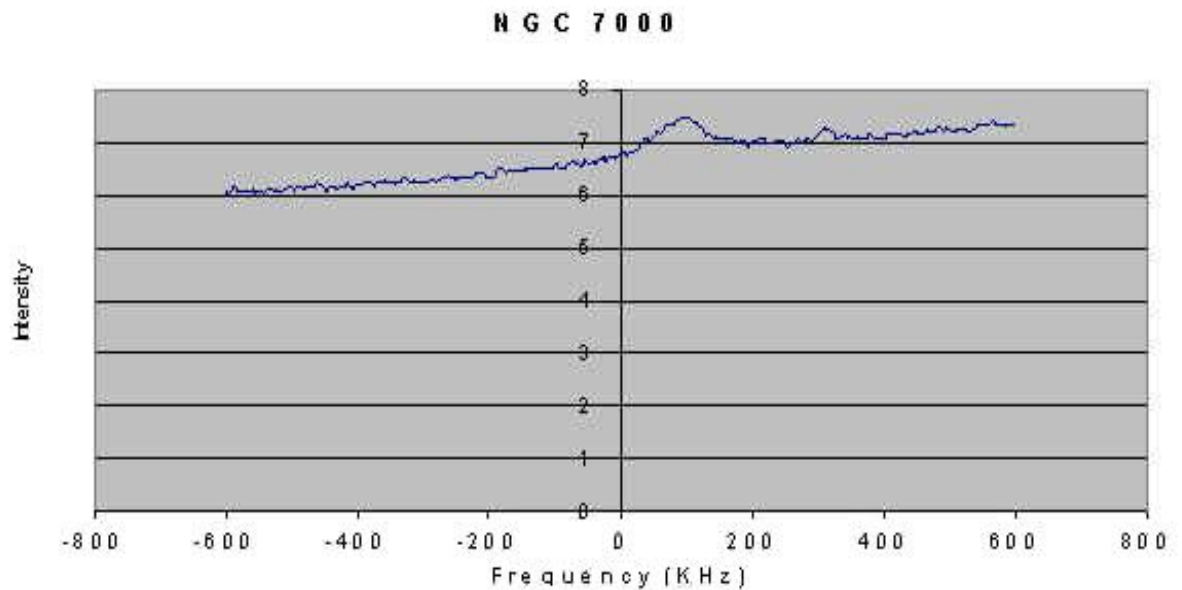
	Spring	Summer	Fall	Winter
Right Ascension	20-4 hours	2-10 hours	8-16 hours	14-22 hours

### Nebulae

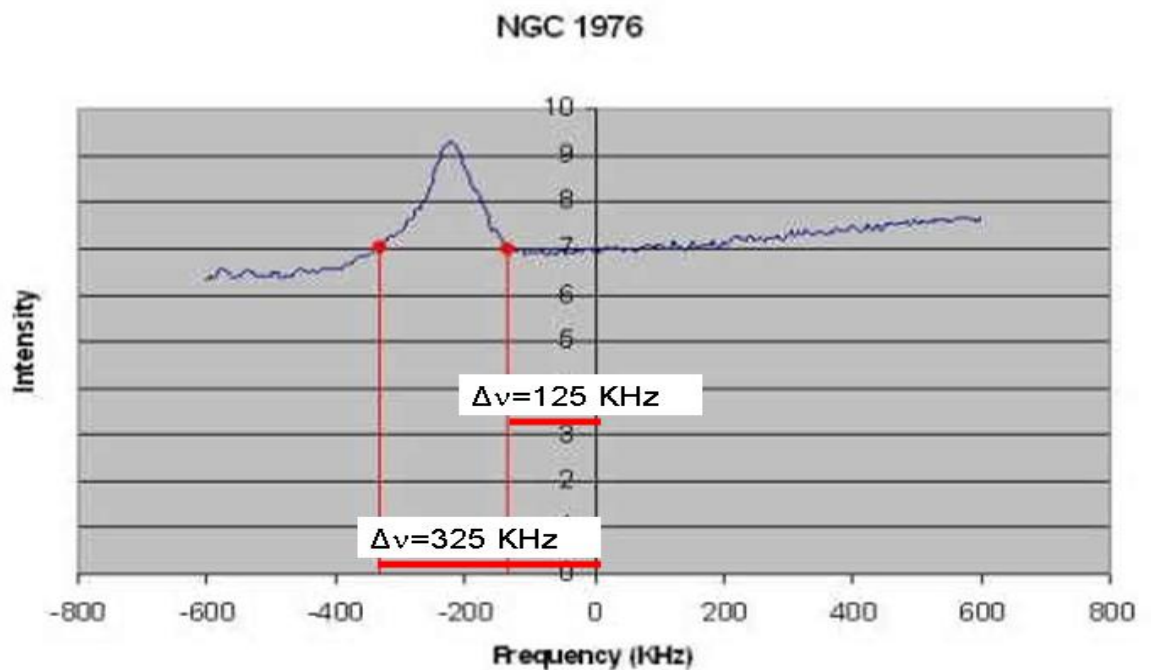
Name	Right Ascension	Declination
Lynds 1288	0 35 0	65 50 0
Lynds 1495	04 15 0	27 30 0
NGC 1976	05 35 18	-05 24 0
Lynds 1625	06 25 0	6 0 0
NGC 6514	18 02 23	-23 02 0
NGC 6523	18 03 36	-24 23 0
M 16	18 18 48	-13 47 0
M 17	18 20 26	-16 11 0
NGC 6888	20 12 18	38 25 0
NGC 7000	20 58 47	44 19 0
Lynds 1176	21 30 0	66 30 0

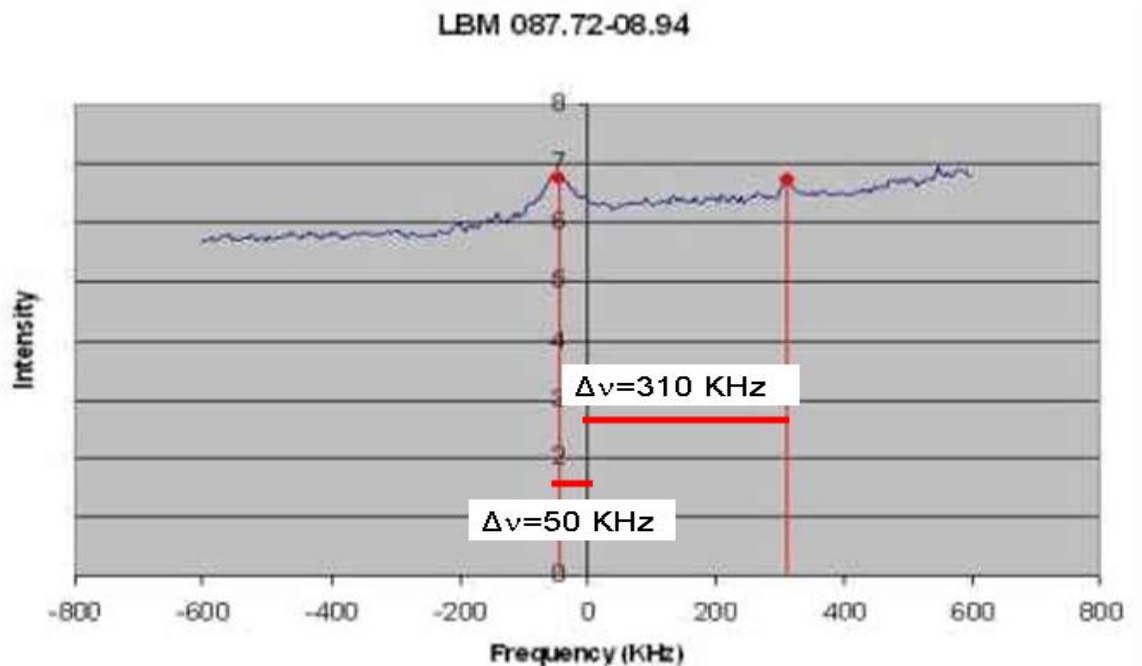
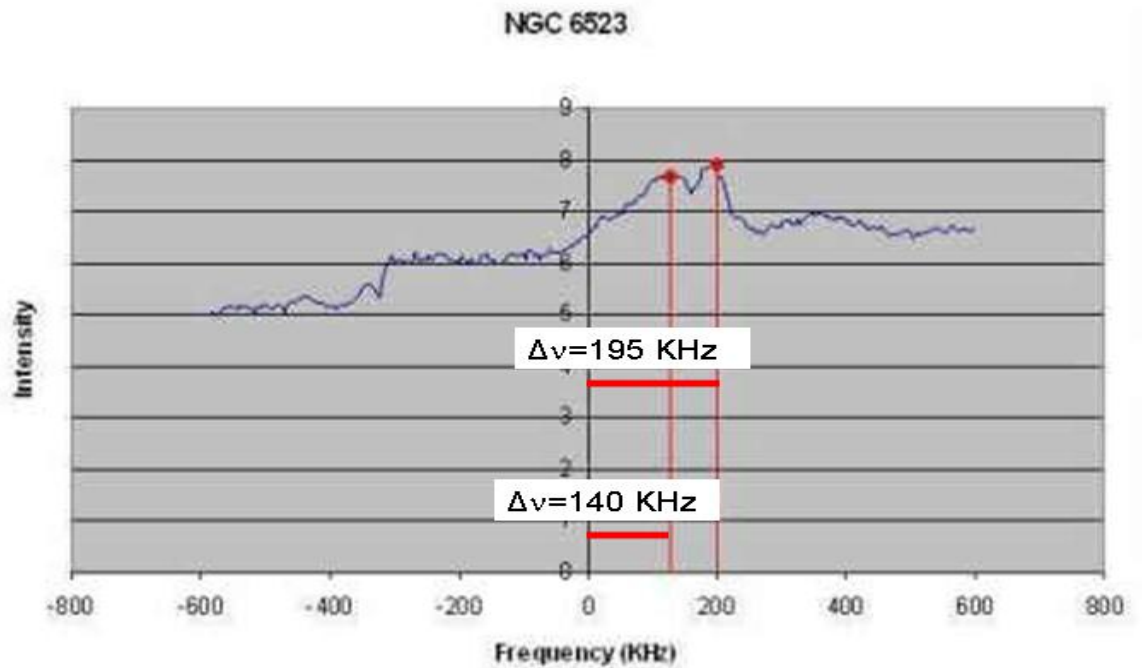
LBM 887,72-08.94	21 38 00	40 18 0
Lynds 1204	22 25 0	60 10 0

3. Pick 2 of the above HII regions.
4. Log into Smiley and enter the coordinates of one of the regions in NEW coordinates and click GO. (<http://smiley.pari.edu:8080/smiley/login.html>)
5. Check the CURRENT coordinates with the NEW coordinates. Are they close? They should be, but we can get them even closer by using HandPaddle. Do not worry about getting Smiley exactly on the NEW coordinates, just get as close as you can. While using HandPaddle I found it easier to refer to the ALT and AZ instead of RA and DEC.
6. Now click on the Spectrum button.
7. Please set your IF GAIN to around 17. Some sources will require more IF GAIN than others; generally you want your IF GAIN as high as possible without losing data.
8. Right click on the graph and click on Show Grid.
9. Now click on Begin Scan. You should see red dots appear on the graph to your right.
10. After the data points have reached the end of the graph, Smiley will start over again. You only need one set of points so click on Stop Scan when the data points start to repeat.
11. Now you need to save your scan, so click on Save Scan.
12. Click on Open Data File and open the scan you just saved.
13. Click on the List to bring up your data points.
14. Notice how the data points start with a Frequency Offset of -600 kHz, then go to 600 kHz, and finally the cycle begins again. You only want the first cycle.
15. Starting from your intensity at 600 kHz highlight your data up to -600 kHz and copy this data. Paste this data into a spreadsheet program, Excel is recommended. Be sure to leave 5 extra rows at the top.
16. Now go back to the Control Room and copy and paste the information at the top of the list (this includes the name of the file, the date, the time, the values of RA and DEC, and the IF gain) in the 5 extra rows you left above your data in the spreadsheet.
17. Your data may not be aligned, so align it by copying and pasting and increase or decrease the column width as you desire.
18. If you are using Excel, highlight both data columns. On the tool bar click on Insert, then Chart.
19. Now choose XY (Scatter) and Scatter with data points connected by lines without markers. Click on *Next*.
20. Make sure your graph looks something like the graph below and click *Next*.



21. Now label your axes. Your x-axis should be frequency while your y-axis should be Intensity. Also label your graph. Now click finish.
22. Pick two points on your graph. If there is only one peak then pick points at the bottom of the peak. If there is more than one peak then pick the points at the top of the two peaks. To find the value of the frequency simply click on the point that corresponds with the peak or look at the data recorded from Smiley. Some examples of points chosen are below.





23. From these frequencies we want to calculate the rate of rotation of the nebulae. Each Frequency will tell us the velocity of one area of the nebula, but by subtracting the two velocities from each other we can get an idea about how quickly the nebula is rotating. Calculate the rate of rotation of your nebula. Some sample calculations can be found below.

Example: NGC 1976

$$v = (\Delta v/v)c$$

$$v_1 = [(325 \cdot 10^3)/(1.42 \cdot 10^9)]c \\ = 6.86 \cdot 10^4$$

$$v_2 = [(125 \cdot 10^3)/(1.42 \cdot 10^9)]c \\ = 2.64 \cdot 10^4$$

$$\text{Thus } v_{\text{rot}} = v_1 - v_2 = 4.22 \cdot 10^4$$

Example: NGC 6523

$$v = (\Delta v/v)c$$

$$v_1 = [(195 \cdot 10^3)/(1.42 \cdot 10^9)]c \\ = 4.12 \cdot 10^4$$

$$v_2 = [(140 \cdot 10^3)/(1.42 \cdot 10^9)]c \\ = 2.96 \cdot 10^4$$

$$\text{Thus } v_{\text{rot}} = v_1 - v_2 = 1.16 \cdot 10^4$$

Example: LBM 087 72-08.94

$$v = (\Delta v/v)c$$

$$v_1 = [(50 \cdot 10^3)/(1.42 \cdot 10^9)]c \\ = 1.06 \cdot 10^4$$

$$v_2 = [(310 \cdot 10^3)/(1.42 \cdot 10^9)]c \\ = 6.54 \cdot 10^4$$

$$\text{Thus } v_{\text{rot}} = v_1 - v_2 = 5.49 \cdot 10^4$$

**Challenge Question:** What are the rates of rotation in miles per hour?

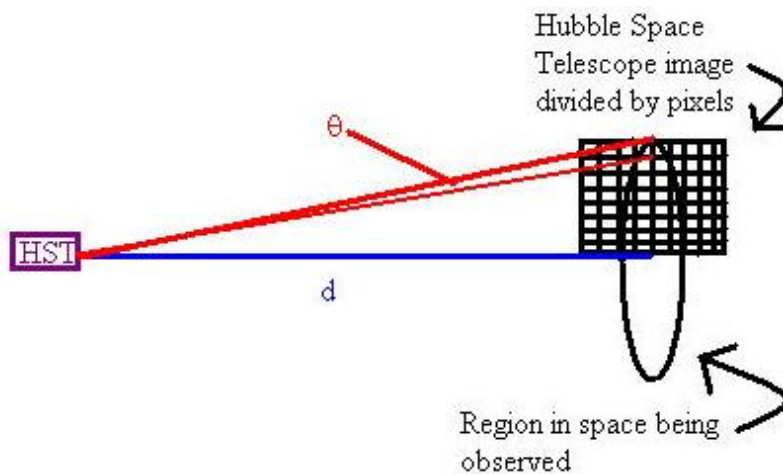


## Introduction:

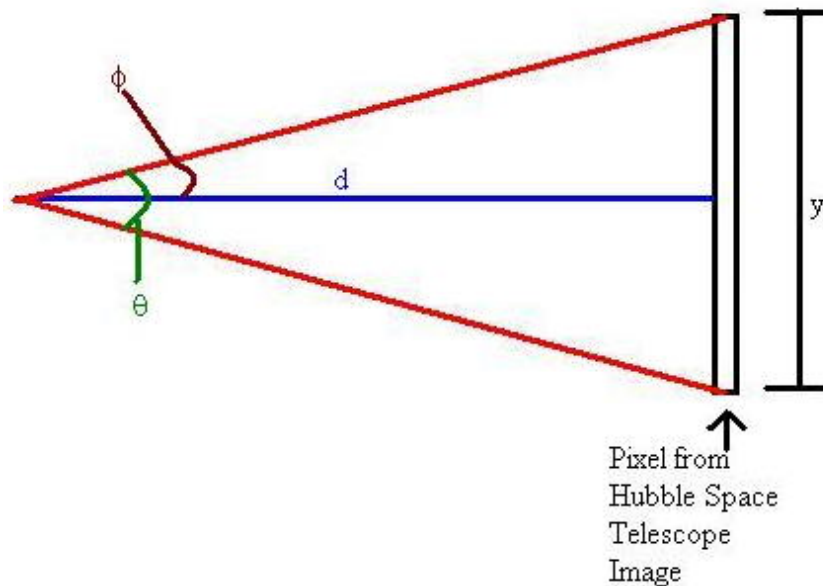
Have you ever wondered if there are other solar systems like ours in the universe? In 1994 the Hubble Space Telescope (HST) looked deep into the Orion Nebula (M42) and found newly forming stars with clouds of dust and gas (including ionized hydrogen) surrounding them. If these stars have protoplanetary disks, disks that may one day evolve into planets, then they are proplyds. In the picture to the left you can see four potential proplyds. In this lab we will study some HST images of proplyds using the [Sky Image](#)

[Processor](#) (SIP), a free JAVA based image processor, and measure the size of the proplyds.

Now let us go over how to measure the size of a proplyd. When the Hubble Space Telescope takes a picture of a region in space each pixel in the picture has an angular size ( $\theta$ ) as shown in the diagram below.



where  $\theta$  is the angular size of each pixel and  $d$  is the distance from the Hubble Space Telescope to the region in space being observed. Now if we look at just one pixel:



where  $\theta$  is the angular size of the pixel, is half of  $\theta$ ,  $d$  is the distance from the Hubble Space Telescope to the pixel and  $y$  is the length of the pixel. After doing some trigonometry to find the length of the pixel:

$$y \cong d \cdot \theta$$

So if we know the angular size of a pixel and the distance from the Hubble Space Telescope to the region being observed we can find the size of the region. Luckily we know both of these values. The angular size of a pixel is  $4.85 \times 10^{-7}$  radians or 0.1 arc seconds and the distance from the Hubble Space Telescope to the proplyds we are studying is 1500 light years or 103131500 AU (Astronomical Units). Thus each pixel on the Hubble Space Telescope has a length of:

$$y \cong d \cdot \theta = (4.85 \times 10^{-7} \text{ radians})(10313500 \text{ AU}) = 50 \text{ AU}$$

or 50 times bigger than Earth's orbit around the Sun!

For those interested in the derivation:

$$\tan(\phi) = [(y/2)/d] = y/(2d)$$

$$\text{Thus, } y = (2d)\tan(\phi) \text{ or } y = (2d)\tan(\theta/2)$$

Because  $\theta$  is very small we can use a useful

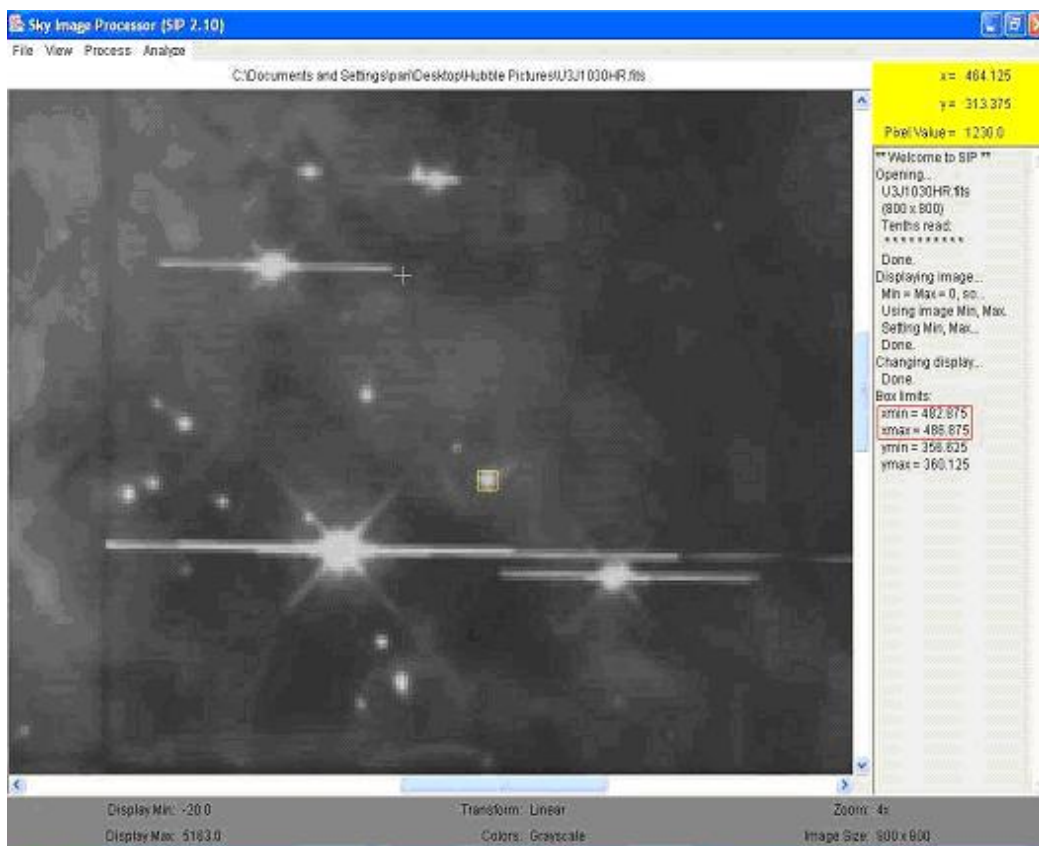
approximation

$$\tan(\theta/2) \cong (\theta/2)$$

$$\text{Thus, } y \cong (2d)(\theta/2) \text{ or } y \cong d \cdot \theta$$

**Procedure:**

1. Please go to <http://www.phys.vt.edu/~jhs/SIP/>. If a Java Security Warning window appears click on *Grant This Session*.
2. Now click on *Start SIP*.
3. Under *File* click on *Open Image File From The Internet*.
4. When asked for the URL type <http://campus.pari.edu/tw/SGRA/U3J1030HR.fits>
5. Another way to open the file is SIP is to type <http://campus.pari.edu/tw/SGRA/U3J1030HR.fits> in Internet Explorer and click on *Save*. Then, in SIP, under *File* click on *Open Image File From User's Machine* and tell SIP where you saved the image file.
6. If the picture is very dark click on *Automatic Contrast Adjustment* under *View*.
7. Under *View* click on *Change Image Display Parameters*.
8. Change the *Zoom Factor* to x4. If you get a blue screen, close your web browser completely and open a new window.
9. Click and drag a box around the proplyd. Notice the gray bar at the right side of the window, after drawing the box it should give you the box limits. Choose either x or y direction and calculate how many pixels are in either direction. See the example below:



Box limits:  
 xmin = 482.875  
 xmax = 486.875  
 ymin = 358.625  
 ymax = 360.125

10. Now calculate the length of the proplyd by taking the number of pixels in either the x or y direction and multiplying that by 50 AU.

**Challenge Question:** How does this compare with the size of our solar system?