Purpose of the Sagittarius Activity: This activity will allow students the opportunity to attempt to solve a problem using real astronomical equipment and data analysis. Using the scientific method, they will gather background information on a problem, create hypotheses, gather empirical data and analyze it, and finally draw conclusions and report their results.

Materials Required: There are some pieces of technology that will be required for optimal use of this lesson

1) Internet access
2) Microsoft Excel, or some other spreadsheet program
3) Contracted time on the 20m with the NRAO through SKYNET – more on this below
4) Microsoft Word, or some spreadsheet program for students to write their reports

Content Learning Outcomes:

1) Students will gain some understanding of the types of radiation found in astronomical objects and how it can be observed.
2) Students will understand how radio astronomers gather and analyze data.
3) Students will learn about objects within the constellation Virgo.
4) Students will learn about coordinate systems, such as Right Ascension/Declination, Altitude/Azimuth, and Galactic Latitude/Longitude.
5) Students will learn about HII regions and stellar genesis.
6) Students will see the differences between optical and radio images.

Science Education Standards (NRC, Chapter 6):
1) Science As Inquiry Standards (Table 6.1)
    A. Abilities necessary to do scientific inquiry
    B. Understanding about scientific inquiry
2. Physical Science Standards (Table 6.2)
    A. Structure of atoms
    B. Structure and properties of matter
    C. Motions and forces
    D. Interactions of energy and matter
3. Earth and Space Science Standards (Table 6.4)
    A. Origin and evolution of the universe

"Unifying Concepts in Science" That Are Addressed:

1) Systems, Order, and Organization
2) Evidence, Models, and Explanation
3) Constancy, Change, and Measurement
4) Form and Function

Obtaining access to the NRAO/SKYNET 20m Radio Telescope: Please download and read the relevant portions of the manual provided by the National Radio Astronomy Observatory. It outlines the procedures and contact information for teachers to use in order to gain access to this instrument.

Anticipatory Set:

Here are some ideas for activating prior knowledge:

1) Have your students explore the mythology behind certain constellations as well as how constellations are used by astronomers today to denote regions in the sky, rather than just groups of stars.
2) As a class, explore how parts of the electromagnetic spectrum are different from one another and use images to share how different wavelengths can provide us different information on an object.
3) Have your students role-play being astronomers at the National Radio Astronomy Observatory prior to the invasion and explore/brainstorm the kinds of science that take place there, the science behind radio/light emissions, the construction of radio telescopes and how they work, etc.
4) We use radio waves in our everday lives. Explore some of these with your students, including WiFi, cellular communication, satellite TV, microwave ovens, & AM/FM radios.

Ideas for Extension: There are plenty of ways in which to continue exploring the science behind radio astronomy and what it can tell us about the universe around us. Below is a short list:

1) Utilize some of the other lessons available from the NRAO for the 20m telescope.
2) Visit the NRAO in Green Bank, WV, tour the site and participate in some of the excellent education programs that are provided there.
3) Explore some of the science being done at other wavelengths, such as X-ray or Infrared.
4) Build an Itty-Bitty radio telescope (plans are available free online), or purchase one from SARA (society for Amateur Radio Astronomy), participate in Radio JOVE, INSPIRE, etc. in order to involve your students in the technology of receivers and to collect data from something that they built themselves!

Questions or Help: Contact Russell Kohrs (NRAO RET Summer 2012) at rkohrs@rockingham.k12.va.us

Sagittarius: Stellar Nurseries

Problem: The Star Fleet admiralty has asked the Enterprise, with Captain Kirk at its helm, to head to the galactic center to get a closer look at the birth of a star. However, they have left it up to the science officers on board, led by Commmander Spock, to decide which of these nebulae would be best to study in terms of active star formation. Star Fleet has also asked that the crew explore the Sagittarius B2 (SgrB2) region and attempt to better distinguish it from the nearby supermassive black hole, Sagittarius A (SgrA). Equipped with a 20m deflector dish, Spock suggests to Kirk that they simply convert it to a radio telescope with an X band receiver. Further, he suggests that they observe at a low X-band frequency, 8.2GHz, in order to best distinguish signals from noise in the various HII regions.

There are two questions to explore here:

1) Which of the HII Nebulae below is the best option for studying active star formation?
2) How is SgrB2 similar and different from these HII regions?

Resources: Encapsulating the very center of our Milky Way Galaxy, the constellation Sagittarius contains a plethora of nebulae. Ironic, perhaps, that the presence of these nebulae are sometimes overshadowed by the ultimate symbol of stellar death, Sagittarius A – the supermassive black hole.

You will have access to the NRAO/SKYNET (National Radio Astronomy Observatory) 20m radio telescope to collect your data.

1) The 20m Radio Telescope – Your search has been narrowed your search down to a few well-known nebulae that are also very bright in visible light. Images and descriptions of these objects can be found below. They are:

   A. M16 – Eagle Nebula
   B. M17 – Omega Nebula
   C. SgrA – Supermassive Black Hole
   D. SgrB2 – Giant Molecular Cloud
   E. M20 – Trifid Nebula
   F. M8 – Lagoon Nebula

2) The Internet – Choosing your references wisely, use the internet to gather any background information that you can on these objects and the background questions listed below.

Sagittarius: In Greek mythology, Sagittarius is identified as a centaur: half human, half horse. In some legends, the Centaur Chiron was the son of Philyra and Saturn, who was said to have changed himself into a horse to escape his jealous wife, Rhea. Chiron was eventually immortalised in the constellation of Centaurus or in some version, Sagittarius. This constellation is full of interesting objects, including SgrA, the galactic center.
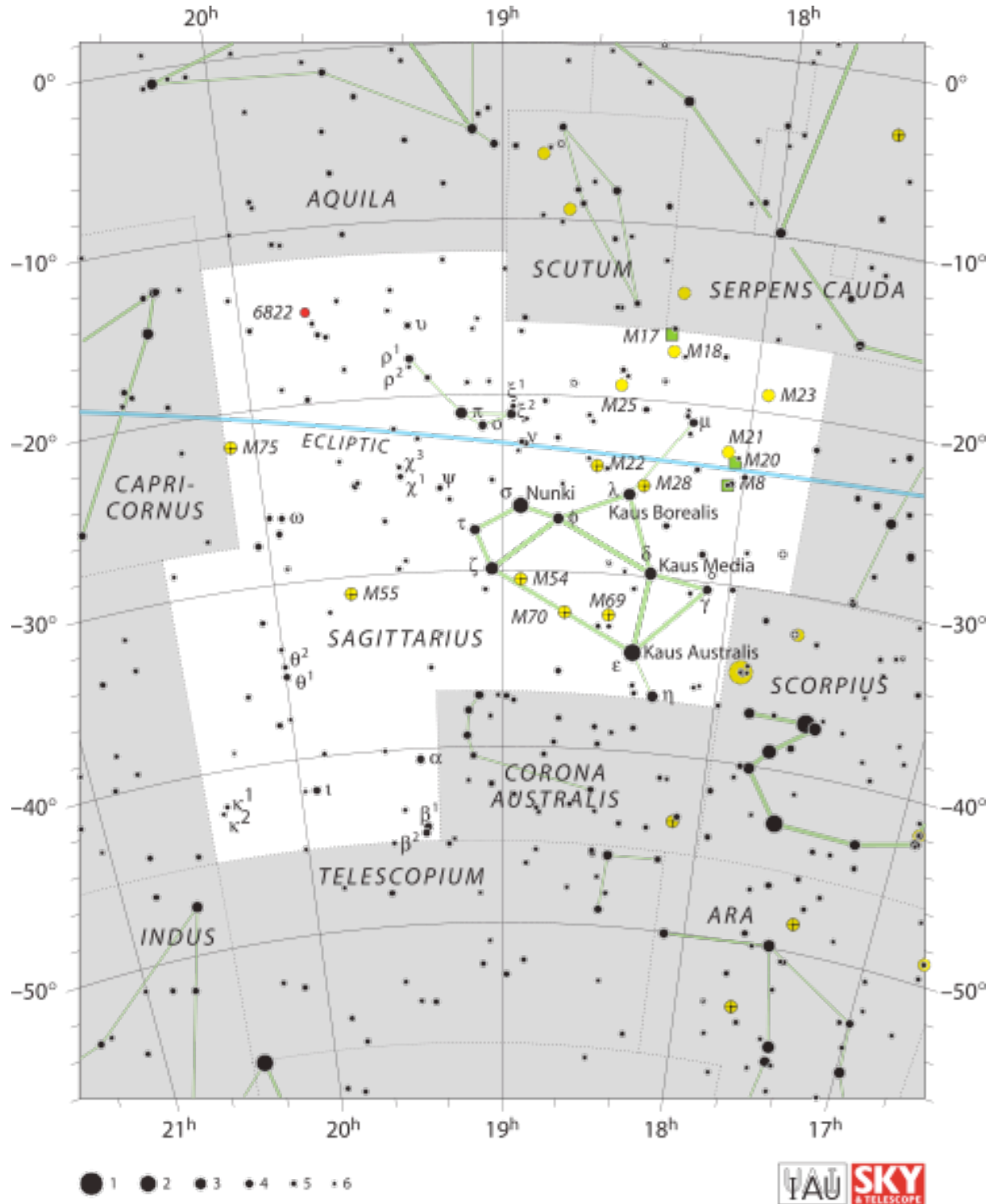
M16 – The Eagle Nebula is an HII region actually located just outside of Sagittarius, inside Serpens Cauda. It is included here due to its proximity. It is an emission nebula that is sometimes described as being shaped like an eagle. The famous "Pillars of Creation" (pictured below) of HST fame are located here.

M17 – The Omega Nebula, sometimes referred to as the Swan Nebula, the Checkmark Nebula, or the Lobster Nebula, is located near M16 but is just inside of the border of Sagittarius. An HII region emission nebula, it is located about 5-6,000ly from Earth.
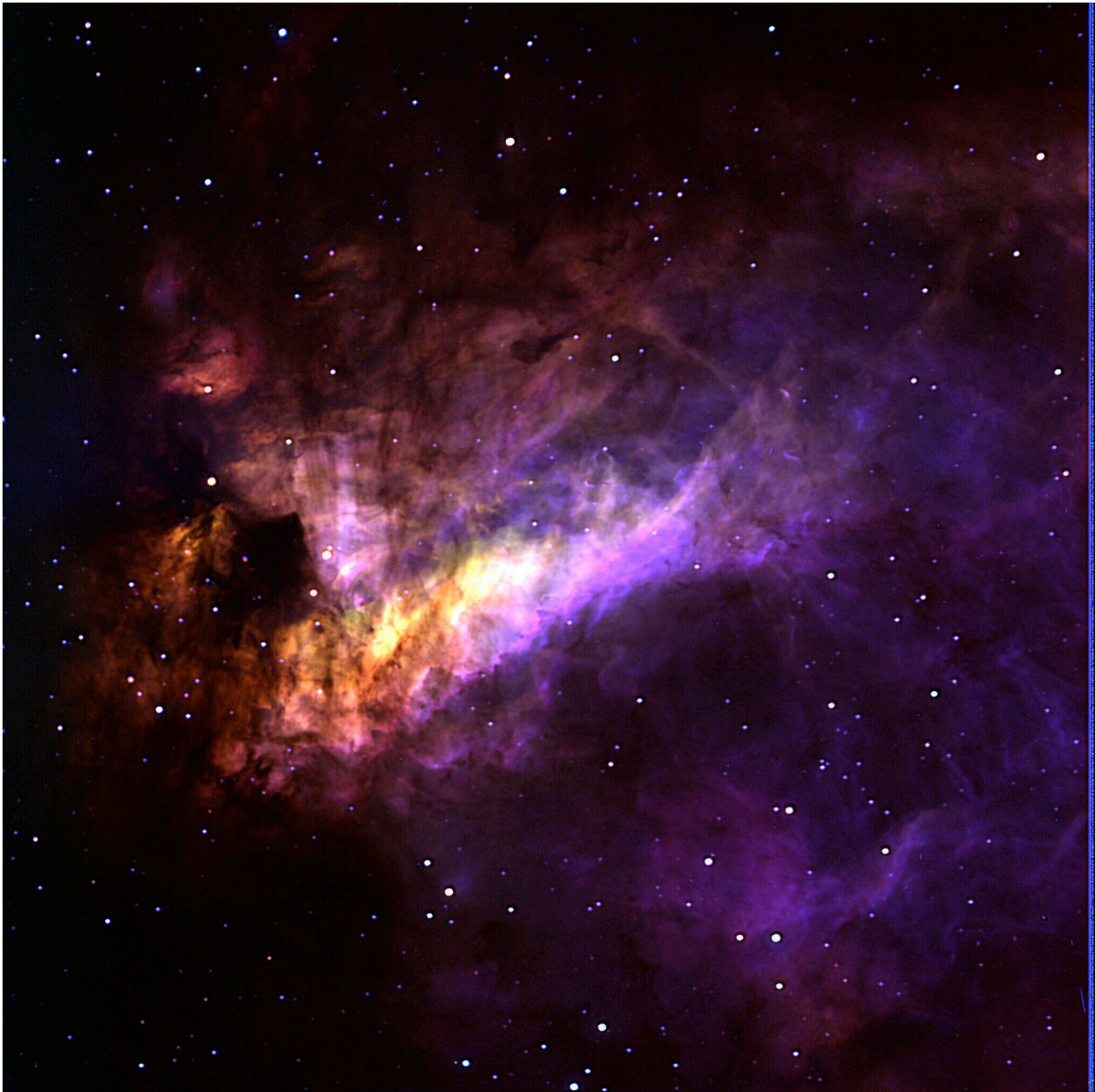
SgrB2 and SgrA – SgrB2 is a Giant Molecular Cloud containing many HII regions and is located very near SgrA, our galactic supermassive black hole that is one of the most powerful radio sources in the galaxy. It is located near the core of the galaxy and spans 150ly across. Nearly all known molecules have been detected near this feature.

M20 – The Trifid Nebula is an HII region that appears to have three lobes, hence its name. It is an unusual combination of an emission nebula, dark nebula, reflection nebula, and an open cluster of stars.
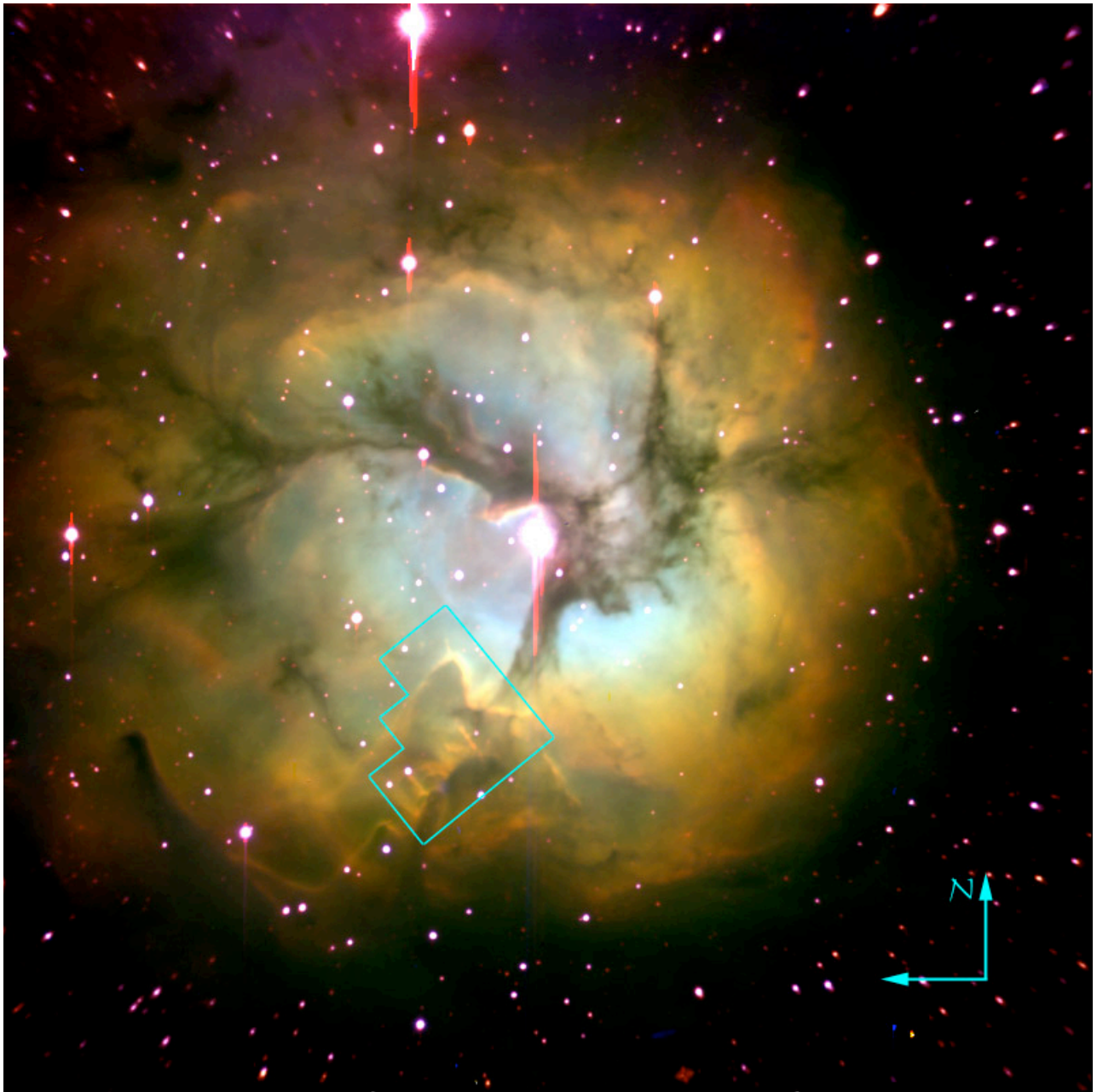
M8 – Located 4-6,000ly from Earth, this faint nebula is difficult to see with the naked eye as it appears gray due to the human eye's difficulty seeing color at low light levels.

Step 1: Questions for <u>Background Research</u> Before Starting:

1) What time of day will Sagittarius be up in the sky on the day you're observing?
2) What is an HII region and how is it different from HI regions?
3) How are supermassive black holes different from stellar mass black holes?
4) What are some of the similarities and differences between M16, M17, M8, and M20?
5) How are radio emissions created in these HII regions?
6) How is Virgo portrayed in cultures besides Greek?
7) In terms of the stellar life cycle, how are HII regions different from SgrA?
8) What is a Jansky and how is it measured?
9) Radio emissions are initially collected as intensities in counts. How can this information be converted to Kelvin temperatures and ultimately to Janskys?

Step 2: <u>Making Predictions</u>:

Make a prediction. Rank the sources below from what you predict will be the strongest to weakest sources at 8.2GHz. Use your background research to help you do this. After the name, write a brief description justifying your placement of that object in the sequence below.

1)

2)

3)

4)

5)

6)

Based on your work above, create two hypotheses in the space below that express your predicted answers to the questions posed on page one of this activity:

1)

2)

Step 3: Observation and Data Collection Procedure

You will be using the 20 meter telescope at the National Radio Astronomy Observatory's Green Bank, West Virginia site. The telescope will be set to observe at a center frequency of 8.2GHz with a 500MHz bandwidth. All observations are immediately processed and stored on this website: http://www.gb.nrao.edu/20m/peak/log/ and you'll want to keep that webpage open during the observation process. The website automatically names all of the files and includes a scan number that you will need to record.

You will be collecting data through the SKYNET interface as you will be creating Dec/Lat maps using galactic longitude coordinates that will take about 2 hrs of telescope time each to create. If you do not yet have a SKYNET login, refer to the comprehensive manual for the 20m , available on the 20m's website, for instructions on how to do so.   If you have not used SKYNET to submit observations before, be sure to check out the video tutorial also linked on the 20m website. Once you have a login for SKYNET, create one map for each object using the following parameters as you "add observation" to the queue:

Scan Type: Map
Coordinate Type: Galactic Lng/Lat
Map Type: Dec/Lat
RA/Lng/Az Length: 2 degrees
Dec/Lat/El Length: 5 degrees
Spacing: 0.0333 degrees
Sweep Duration: 90 or 120 seconds
Frequency: 8200 MHz

Leave all other inputs in their default.

Record the data from your observations on the included chart:

Step 4: Data Analysis:

1) Look at the data you collected and create a table below that lists the sources and their brightness in Janskys (Kelvins or Counts, see extension at the end of the activity) in order from strongest to weakest and report them here:

        A.
        B.
        C.
        D.
        E.
        F.

2) Does this ranking match your predictions from Part 2? Why or why not?

3) How does the path of the telescope match the data in the 2D plot?

4) How does the path of the telescope match the data in the 3D plots?

5) How are the various HII regions different from one another? Why?

6) How are the HII regions different from SgrB2 and SgrA?

8.2GHz Observations:

Date:

Time: _____

Observer(s): _____

Weather Conditions: _____

Purpose: _____

General Comments: _____

Object	Scan Number	Comments

Step 5: <u>Report Your Findings</u>

Report your findings in the form of a written paper. It should have several sections: Abstract, Introduction, Background Research, Observations and Data Collection, Data Analysis, and Conclusions (you may call it something like "recommendations" if you would like). Your paper should be about 2 typed pages, double-spaced, 12 point Cambria or Times New Roman font with no more than 1' margins. Be sure to answer your questions!

Further Investigation

Propose a topic for future research concerning some aspect related to Nebulae, Giant Molecular Clouds, and supermassive black holes. That is, if you had access to the 20 meter telescope in the future, what would you use it for and why? If you could alter the equipment a bit (receiver, etc.), what might you observe?

Extension:

In the data analysis, your teacher may prefer that you import ASCII data into Excel and convert the given left and right intensities (in counts) to kelvins or Janskys.

To convert to Kelvin:

1) The intensities in the ASCII file are total intensities, meaning the object intensity and the system intensity. You need to subtract the system values for the left and right polarizations (which can be found in the corner of the 2D plot) and then use the following conversion factors that can be found in an Excel table on the website.

To convert to Janskys:

Use the following equation (re-arrange as necessary):

$$S = \frac{2\sigma T_A}{A\eta_A}$$

Where:
S = Flux Density (Janskys)
σ = Stefan-Boltzman constant (1.38 x 10^{-23})
T_A = Average temperature (Left, Right polarization, in K)
η_A = Telescope Efficiency (elevation dependent, available on website)
A = Area of dish (available on website)