Orion: The Avenger -- Teacher Page

Purpose of Orion the Hunter 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 Orion.
4) Students will learn about coordinate systems, such as Right Ascension/Declination, Altitude/Azimuth, and Galactic Latitude/Longitude.
5) Students will learn about the structure of nebulae and how they differ from stars.
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: The story line for this lesson is based loosely upon the movie, the Avengers. So, any activities that you use for activating prior knowledge could certainly only benefit from your use of this theme, though the theme is certainly not meant to be the learning outcome of the lesson. In some cases, it might be useful to show a clip from Star the movie so that students who have not seen Star Wars can identify with the story line.

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

Orion: Awakening the Avenger!

Problem: The Earth is beset by the evil villain Loki and the only hope for saving the planet is in summoning the combined powers of the individual superheroes collectively known as “The Avengers”. However, despite the outcome of the story in the recent movie, the reality of the situation is actually quite different. In fact, while the Avengers were able to make some progress in their fight, several (Black Widow, Ironman, and Hawkeye) found themselves injured and unable to continue fighting due to being imprisoned in magnetic confinement through a last-minute contribution to Loki’s efforts by Magneto, another infamous villain, looking for a share in the conquest. Upon regrouping their efforts, the Avengers decided that their only hope was to explore what, to most of them, was just a bedtime story – activating the legendary hero Orion. While Captain America scoffed at the idea, the Hulk and Thor decided to go ahead, hoping that awakening this legendary giant, if even possible, could help rid the Earth of this villainous pair forever. However, the legend says that in order to awaken Orion, a charge of intense radiation must be focused at just the right location in the constellation, a region where 10GHz emissions are strong. For this, they would need to enlist Cyclops help, meaning that the Hulk would have to make friends with him, so that he could use his laser vision to focus a beam of energy at just the right spot in Orion.

You have one questions to answer:

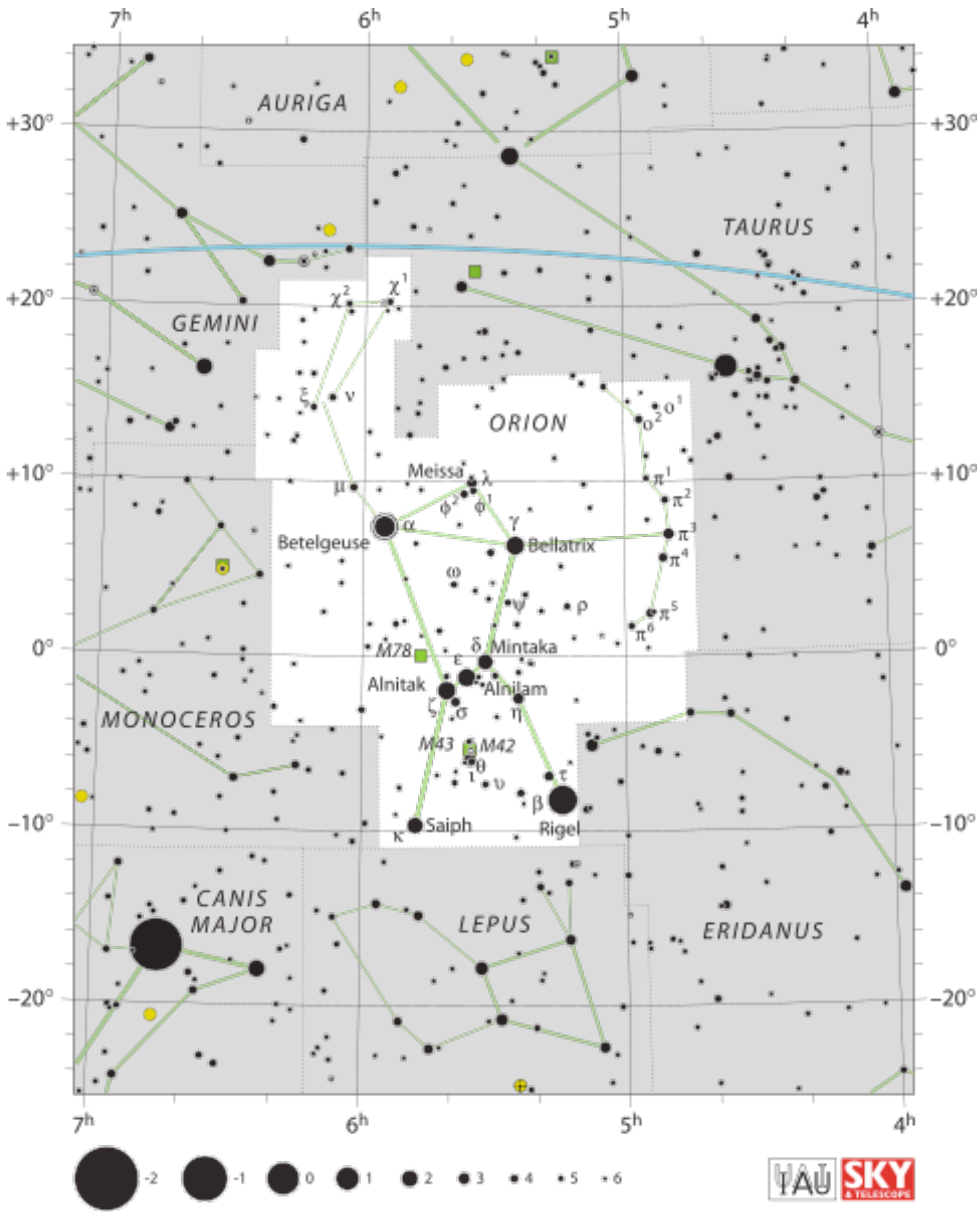
1) Which object in Orion has the strongest emissions at 10GHz?

Resources: Arguably one of the most recognized constellations in our night sky, the Orion Constellation is a wealth of astronomical data and variety. This includes two of the brightest stars in the night sky, Betelgeuse and Rigel, as well as the extremely popular horsehead nebula. Since the remaining Avengers have no knowledge of radio astronomy and how to detect signals at 10GHz, they have enlisted your help, as a prominent radio astronomer, to identify the best object at which to focuse a beam of energy to awaken the legendary Orion.

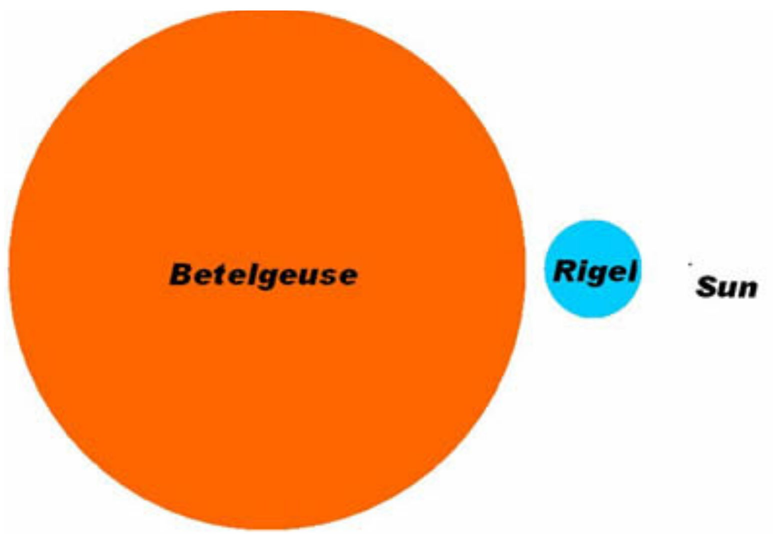
1) You will have acces to the NRAO/SKYNET (National Radio Astronomy Observatory) 20m radio telescope to collect your data.
2) The Avengers have narrowed your search down to a few well-known objects that are very bright in visual light. Images and descriptions of these objects can be found below. They are:
   A. Betelgeuse
   B. Rigel
   C. M42
   D. M78

In visible light we are all familiar with Orion’s belt and the basic shape of the constellation. But what does Orion look like in radio light? What can we learn from Orion in radio wavelengths? These are the questions we will be trying to answer today using the 20 meter telescope at the National Radio Astronomy Observatory in Green Bank, West Virginia. Which of these sources is the brightest at a frequency of 10GHz?

Orion: One of the most well-known and identifiiable constellations, is an area of the sky located near Gemini, Taurus, Canis Major, and Eridanus. In Greek myth, Orion was a hunter who, with his hunting dogs Canis Major and Minor, is depicted standing near the river Eridanus fighting Taurus, the Bull, or hunting Lepus, the hare. Sometimes, he has a lion in his hand.



Betelgeuse- A red supergiant star near the end of it's lifetime and is the eighth brightest star in the night sky. When it 'dies' it will create an explosion so large and bright it will be visible during the day time. The image below is an artist's rendition but accurately reflects the size of Betelgeuse as compared to the Solar System bodies (accurately spaced).



Rigel- A blue supergiant equivalent to 18 solar masses, it's the brightest star in Orion and the 6th brightest star in the night sky.

M42 (The Orion Nebula)- Located 1344ly from Earth, it is the closest stellar nursery and **emission nebula** to the Earth. It has a mass of 2000 times that of the sun and is one of the most studied and photographed objects in the sky. This is a visible light image of the nebula.

M78 - Discovered by comet hunter Pierre Mechain in 1780, it is the brightest diffuse **reflection nebula** within the Orion Cloud Complex and is about 1600ly from Earth.

Step 1: Questions for Background Research Before Starting:

1) What time of day (or night) will Orion be up in the sky on the day you're observing?
2) What is the difference between a red supergiant and a blue supergiant?
3) Where would Rigel and Betelgeuse fit on an HR Diagram?
4) What is responsible for the reddish tint in M42? The blue color in M78? What type of nebula are they?
5) What might be some causes of radio emission from these objects?
6) How is Orion portrayed in cultures besides Greek?
7) Go to: http://www.gb.nrao.edu/~rmaddale/Education/OrionTourCenter/index.htm and take the tour of the hidden Orion.
8) What is a Jansky and how is it measured?

Step 2: Observations and Data Collection:

Rank the sources below from what you predict will be the strongest to weakest sources at 10GHz. Use your background research to help you answer these questions.

1)

2)

3)

4)

Explain why you choose that order. Specifically comment on how you choose which star would be brighter, which nebula would be brighter, and if stars or nebula will be stronger radio emission sources.

Based on your work above, created a hypothesis in the space below that expresses your prediction for which area of Orion would be best for Cyclops to target:

Hypothesis:

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 frequency of 10 GHz with a 500 MHz 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 the 4 digit scan number you'll need to record.

It's now time to use the telescope! You will be using a 'daisy' scan to observe the objects. It's called a daisy scan because the telescope moves in a pattern that looks like daisy petals. Remember the telescope is as tall as a 6 story building and we use a daisy pattern to minimize the wear and tear on the telescope. We wouldn't want a 6 story building wildly swinging back and forth. You can do these scans using SKYNET or manually through an armorhead Teamviewer session. See the manual on the 20m website for how to set up either of these.

For your purpose you can leave all the settings as they are, except for the scan radius which can be made as small as 10 arcmin, and click OK. The scan will last for 120 seconds from the time it starts and you can monitor how much time remains by looking at the top left of the screen where it displays the remaining time in seconds. Repeat this process for all objects twice, making sure you keep an excellent observation log below. If an object looks very different in the two scans repeat the observation. It's very important your data is consistent from one daisy scan to another.

SKYNET or manual Daisy Scan Parameters (Leave all other fields in their defaults):

Radius (arcmin): 10.0 (keep at 30.0 for M42 and M78)
Radial Period (s): 60.0
Scan Duration (s): 120.0

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:

1)

2)

3)

4)

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

3) A daisy scan is a good indicator of how strong a radio source is but it doesn't tell you much about the shape of the object you're observing. For this purpose you will be creating a map of the sky with the 20m. Select the strongest and weakest source based on the data you've already collected to make maps. To create a map, click on the dec/lat map button. You can monitor how much time remains in the top left portion of the screen. Zoom in on the object to watch the path that the telescope takes to make the object. Once the first map is completed, repeat the process for the other object. Once again the images of the map will be displayed on the webpage.

4) What are the similarities and differences of the daisy scans and the maps?

5) How do the sweeps of your daisy and maps scans compare to your signals in the 2D and 3D plots?

10GHz Observations:

Date:

Time:

Observer(s):

Weather Conditions:

Purpose:

General Comments:

Object	Scan Number	Comments

Step 5: Report Your Findings to the Avengers

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 1-2 typed pages, double-spaced, 12 point Cambria or times New Roman font with no more than 1' margins.

Further Investigation

Propose a topic for future research concerning some aspect of nebulae or star radio brightness. That is, if you had access to the 20 meter telescope in the future, what would you use it for and why?

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 (1.38×10^{-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)