



## Virgo: Exploring The Heart of Galaxies -- Teacher Page



**Purpose of the Virgo 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 different types of galaxies.
- 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 everyday 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](mailto:rkohrs@rockingham.k12.va.us)

## Virgo: Exploring the Heart of Galaxies

**Problem:** NASA's new cosmology division has been tasked with determining whether or not there is a correlation between the various types of galaxies and the amount of radio emission that is detectable from them. Galaxies within the constellation Virgo have been chosen because of the presence of so many galaxies, such as those contained within the Virgo Cluster. If such a correlation exists, it may be helpful in helping the effort to classify some of the fainter and more poorly aligned galaxies that can be seen in Hubble Deep-Field images by taking radio data for them to determine their type.

A small sample of galaxies was chosen by your working group as a test sample to begin your analysis. As chief telescope operator, you have been tasked with collecting data on these objects. You will be collecting data using the NRAO's 20m radio telescope equipped with an X-band receiver. X-band was chosen to allow for a high resolution survey to be conducted using as small a beam width (6 arcminutes) as possible as well as to avoid RFI (Radio Frequency Interference). Your observations will be done at 9GHz, which is at the center of the range at which the installed receiver operates. You have two questions to explore:

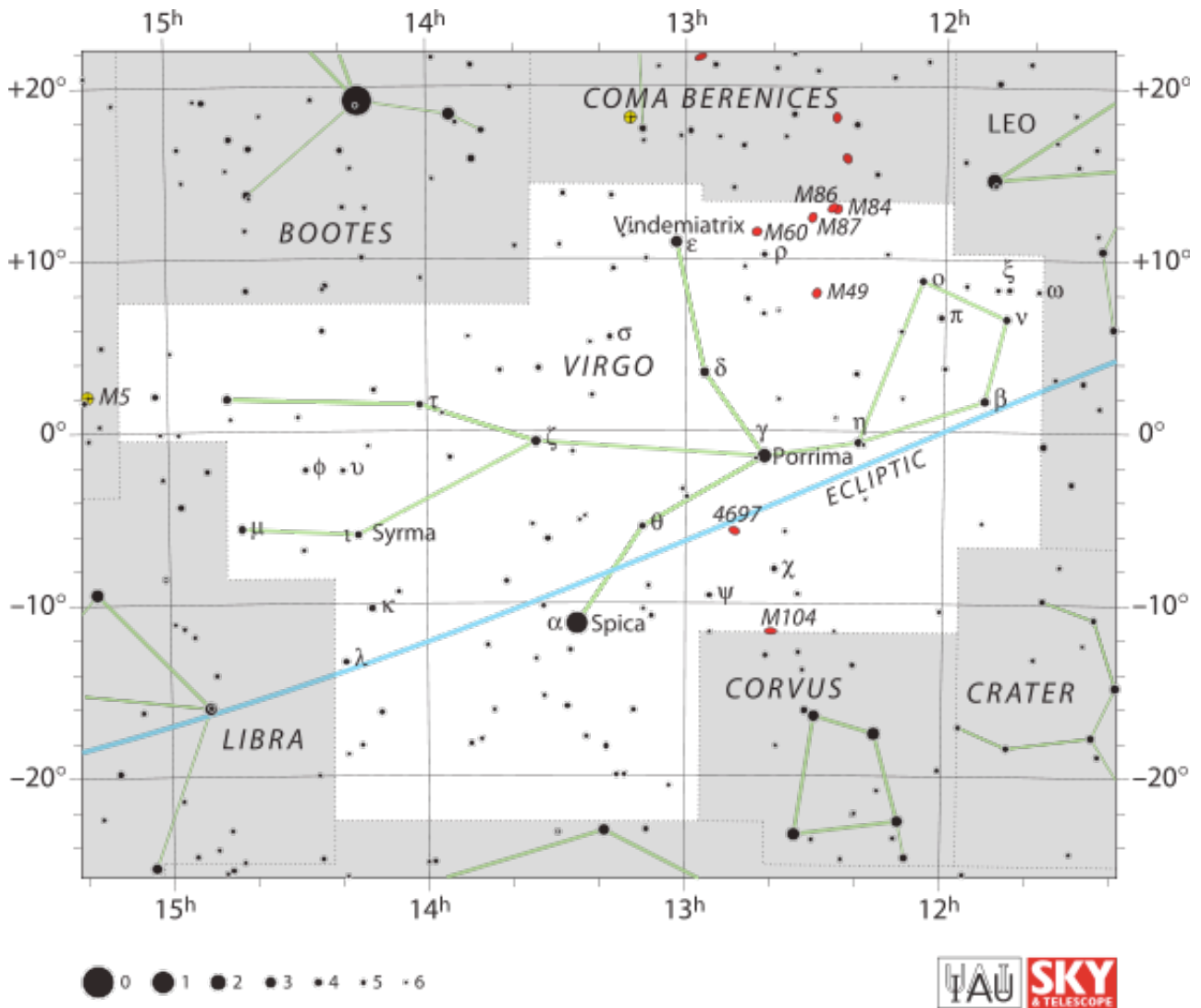
- 1) Which of these objects emit X-band radio waves?
- 2) Is there a correlation between emissions at this frequency band and galaxy type.

**Resources:** Arguably one of the most recognized constellations in our night sky, the Virgo Constellation contains a plethora of galaxies. Many of these galaxies are contained in the famous "Virgo Cluster".

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 objects that are very bright in visual light. Images and descriptions of these objects can be found below. They are:
  - A. M49
  - B. M104
  - C. 3C274/M87
  - D. M60
  - E. M100
  - F. 3C273
- 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.

**Virgo:** A very well-known constellation, Virgo is an area of the sky located near Leo, Libra, Bootes, and Coma Berenices. In Greek myth, Virgo is representative of the goddess Demeter, who due to her grief over losing her daughter Persephone to Hades for half of the year, causes the Earth to go through its endless seasonal cycle.



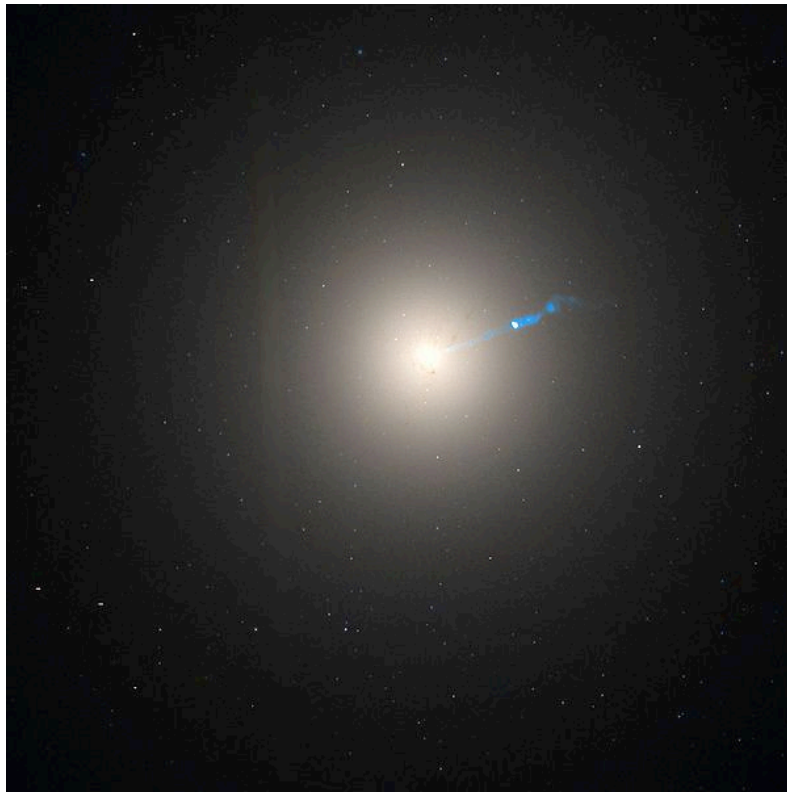
**M49** – An elliptical galaxy located 49 million light years from the Earth, it contains a large population of globular clusters and is the most visually luminous galaxy in the Virgo Cluster.



**M104** – One of the more famous galaxies optically, the Sombrero galaxy is a spiral galaxy with a bright nucleus and an unusually large halo. It is known for its huge dust ring that crosses in front of the galactic bulge.



**M87 (3C274)** – A featureless elliptical galaxy, M87 is the second brightest galaxy visually in the Virgo Cluster. It is located 53.5 million light years away and is a strong source of multiwavelength radiation. It was discovered in 1781 by Charles Messier.



**M60** - Discovered by Johann Gottfried Koehler in 1779 while observing a comet in that area of the sky, M60 is a giant elliptical galaxy located very close to NGC 4647.

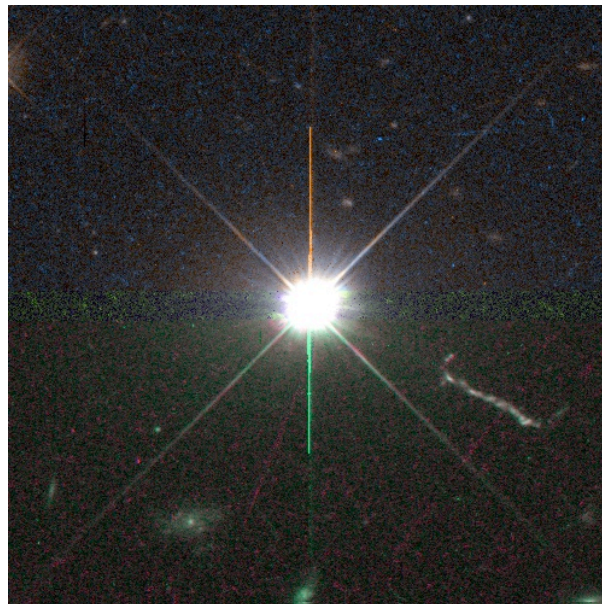




**M100** – M100 is a grand-design spiral galaxy and, as such, has very well defined spiral arms. It contains five supernovae and is larger than the Milky Way with a diameter of 160,000ly.



**3C273** – The first Quasar ever identified, 3C273 is a part of a very distant galaxy, one of the earliest galaxies to form after the Big Bang.







### **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 9GHz 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.

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 should be made as small as 10arcmin, 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

Radial Period (s): 60.0

Scan Duration (s): 120.0

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 daisy path of the telescope match the data in the 2D plot?

4) Can you discern any correlation between radio emissions and galaxy type?



## **Step 5: Report Your Findings**

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 related to galaxies and 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)

$\sigma$  = Stefan-Boltzman constant ( $1.38 \times 10^{-23}$ )

$T_A$  = Average temperature (Left, Right polarization, in K)

$\eta_A$  = Telescope Efficiency (elevation dependent, available on website)

A = Area of dish (available on website)

