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Prep for telescope discussion

Series of readings about the history of telescopes:
http://history.amazingspace.org/resources/explorations/groundup/
Introduction to radio astronomy and radio telescopes:

- https://public.nrao.edu/radio-astronomy/what-are-radio-waves/
- https://public.nrao.edu/radio-astronomy/our-solar-system/

Constructing a HUGE radio telescope, and what can go wrong:
https://youtu.be/9idOe_ITRys?t=1985 (watch just a couple minutes… you'll see)
The telescope today: https://greenbankobservatory.org/science/telescopes/140-ft/

Have a set of discussion questions and reflection writing time to go with that?

Then break up into groups...

Extra resources:
Radio JOVE Help Pages with all you need to know about construction and operation:
https://radiojove.gsfc.nasa.gov/help/

Collection of Radio JOVE educational materials:
https://radiojove.gsfc.nasa.gov/education/materials.htm

Construction Groups

Antenna Manual

Antenna - Wire and Coax Group (4ish students + Nate)

Introduction: Each group should identify generally what an antenna does and how it works to receive radio signals. See sections 2 and 3.1 of Antenna Manual and https://www.cv.nrao.edu/~sransom/web/Ch3.html (Specifically 3.1.1, 3.1.3-5, 3.6.1-2 and DON'T worry about the math.)

Explain a bit about antenna function. During the build process, have students document with pictures and note taking!

Tasks:

- Measure and cut wire, coax, and rope (5.1)
    - 2 people per length?

- Thread insulators with wire and rope (5.2)
    - Half of group works on 5.2 while other half starts 5.3
- Prep and solder coax (5.3)
    - Note, I should bring lengths of practice coax
- Install toroids and connectors (5.4)
    - Can use techniques from 5.3 plus snapping on connectors

Antenna - PVC Mast Group (4ish students + Derek)

Introduction: Each group should identify generally what an antenna does and how it works to receive radio signals. See sections 2 and 3.1 of Antenna Manual and https://www.cv.nrao.edu/~sransom/web/Ch3.html (Specifically 3.1.1, 3.1.3-5, 3.6.1-2 and DON'T worry about the math.)

Explain a bit about antenna function. During the build process, have students document with pictures and note taking!

Tasks:

- Figure out which antenna height to use
    - I'll create an abbreviated version of Section 3, or just figure it out and give you the measurements
- Do appropriate mast assembly for chosen height (6.2)
    - Mark out where holes will be drilled using guidelines
    - Check and recheck with Figure 6.2
    - Drill all holes
    - Secure bolts and glue ends

Receiver and Calibrator Manual

Introduction: First, you want to be able to describe and discuss what receivers DO with your group. You can start with the "Theory of Operation" section in the Receiver Manual.
Discuss the importance of accuracy in scientific measurements. This receiver needs to be accurate in order to produce scientific results.

Calibration Group (4ish students + Ana)

This group will explore the workings of the receiver and talk about how to calibrate data. There is a good writeup about this process at https://radiojove.gsfc.nasa.gov/observing/Measuring%20Antenna%20Temperature%20Jove%20.pdf.

Procedure:

1. We don't have the antenna yet, but that's okay! You can introduce the noise source (little silver box labelled RF-2080). That is going to mimic a specific sky brightness.
    a. Here would be a good place to discuss why radio astronomers often use "temperature" as a measure of brightness. It's NOT necessarily the temperature of the source that you are looking at. It is in cases of THERMAL emission (the kind you saw with the Itty Bitty Radio Telescope and the infrared camera) because objects give off light corresponding to their temperature. Yes, even radio light! Antenna temperature is a measure of how bright the source is that the radio telescope is pointed at. (If you really want to read more details, try https://www1.phys.vt.edu/~jhs/phys3154/Radio%20Astronomy%20Fun%201.pdf) How can you tell that this data does not represent a REAL temperature? Check the values on the y-axis. They are typically in the 100,000s of Kelvin, which is way hotter than the planet Jupiter actually is. From this, we can tell the emission in non-thermal (something ELSE).
    b. You might want to lead a discussion here about how brightness (antenna temperature) measured by a telescope has no meaning until you know what the output means! (The calibration/receiver group is testing that at the very same time.) So, you have to calibrate by pointing the telescope at known source of radiation OR, as in our case, attaching the little calibrator box to the receiver, which simulates a radio source of known brightness (antenna temperature). This is partially covered in the section on "SkyPipe Units" in the calibration link above.
2. Set up receiver (see also Receiver manual). Plug in the power cord, the speakers, and the cable that goes to the computer microphone. Make sure it is turned off before plugging the power into the outlet. (ALWAYS PLUG THE CORD IN TO THE BOX BEFORE YOU PLUG IT INTO THE OUTLET.)
3. Open Skypipe on the computer. Turn the receiver ON. Click "Start chart." Explain that this graph is a measure of radio brightness.
    a. Identify the x and y axes of the graph
    b. Explore with the students what the different buttons do with help from the data tutorial link.
    c. If the static is coming through the speakers but NOT showing up on the chart, go to the Options window. Under "Data Source" make sure that CH1 is set to "Sound Card" (left or right is fine) and detection method "Average." Under "Sound," make sure the USB microphone is selected.
4. Explore the settings on the receiver. Change the gain, or how much the signal is amplified by the receiver. The level will go up as you increase gain. Have them

identify the spiky bits at the beginning. When first changing a setting, you have to wait for the electronics to “settle.”
    a. If you turn the gain all the way up, it will be loud enough to hear through our speakers!
    b. Notice ALSO that as the gain goes up, the NOISE goes up. Upping the gain doesn’t necessarily make you more sensitive.
5. Play with the frequency knob. This is like the tuner dial on your car radio. Observe what happens as you change the frequency of the measured radio waves. Since we’re just listening to background noise right now, there is no frequency dependence in the SOURCE, but the level sure does change on the graph. This means that our receiver is more or less sensitive to different frequencies.
6. Now, connect up and turn on the noise source. What does that do to the line? (It adds a definite signal.)
7. Now we can calibrate. Start the section on “The Calibration Wizard” from the calibration link. This will require you to learn about the types of lengths of cable in order for the wizard to do its job. The Calibration Wizard can only be done on the PRO version, so you’ll need the laptop. (I’ll get a mic adapter for that so it’ll work by Tuesday).
8. Discuss the importance of calibration. It must be done EVERY TIME you do a new setup or start a new observation. This allows us to make scientific measurements and compare them to those from other telescopes around the world.

From here, you might go on to Lesson 7 which talks about sources of radio emission and talks more about data analysis. This dovetails into what the Data Group is doing.

Data Analysis

Data Group (4ish students + Lindsay)

This group will look at Radio JOVE data from other telescopes to learn/decide what we can do with our data at the end. Here is a tutorial to follow: https://radiojove.gsfc.nasa.gov/data_analysis/data_tutorial.htm. You could even dive into Lesson 6 from the NASA Educator packet (Graphing Jupiter Radio Signals).

Data Tutorial For Sky-Pipe Standard Features (physics lab computers)

1. You may want to introduce the concept of graphing using Lesson 6 from the Radio JOVE Lessons. It goes really well with the kinds of things I've sketched out here.
2. Open SkyPipe from the RadioJOVE folder on the Desktop
    a. If this is the first time SkyPipe is being opened on this machine, accept all the pop-up windows about file formatting, then give it the name 'StA-Phylab#' but replace # with the actual number of the computer on the sticker on the monitor.
3. Follow the instructions at http://www.radiosky.com/skypipehelp/find_data_in_jove_archive.html to download a data set from the global user community.
    a. Click "Reload Index" and wait for the file names to stop flashing by
    b. Search for Jupiter only, Any Date
    c. Click on an observation and Click "Download SPD." (I believe that SPD stands for "SkyPipe Data" and is the file format for data files used with this program.
    d. Back in the main SkyPipe window, an observation will appear!
4. Now you can pick up the instructions at https://radiojove.gsfc.nasa.gov/data_analysis/data_tutorial.htm from "Radio-Skypipe Control Settings."
    a. Explore with the students what the different buttons do with help from the tutorial link above.
5. Discussion of the data
    a. Identify the x and y axes of the graph
    b. Here would be a good place to discuss why radio astronomers often use "temperature" as a measure of brightness. It's NOT necessarily the temperature of the source that you are looking at. It is in cases of THERMAL emission (the kind you saw with the Itty Bitty Radio Telescope and the infrared camera) because objects give off light corresponding to their temperature. Yes, even radio light! Antenna temperature is a measure of how bright the source is that the radio telescope is pointed at. (If you really want to read more details, try https://www1.phys.vt.edu/~jhs/phys3154/Radio%20Astronomy%20Fun%201.pdf) How can you tell that this data does not represent a REAL temperature? Check the values on the y-axis. They are typically in the 100,000s of Kelvin, which is way hotter than the planet Jupiter actually is. From this, we can tell the emission in non-thermal (something ELSE).
    c. Notice that the data is CALIBRATED. You might want to lead a discussion here about how brightness (antenna temperature) measured by a

telescope has no meaning until you know what the output means! (The calibration/receiver group is testing that at the very same time.) So, you have to calibrate by pointing the telescope at known source of radiation OR, as in our case, attaching the little calibrator box to the receiver, which simulates a radio source of known brightness (antenna temperature).

   d. Now, the fun part. What are you seeing in this graph? Explain the background "noise" which is a combination of many sources (the background sky, the electronics themselves, etc) and the fact that you can see a clear peak in emission at a certain time. That has been identified by the observer as a spike in radio emissions from Jupiter. (Here is an article about what astronomers learn from radio waves from Jupiter, written to follow the discovery article you did in the first week: https://radiojove.gsfc.nasa.gov/library/sci_briefs/decametric.htm.)

6. What else can we learn about this data? The importance of taking NOTES during scientific observations can be discussed here.
   a. Click the Button for "Show/Edit Datafile MetaData."
   b. Talk about the different types of data displayed in the tabs.
7. Feel free to explore more data sets in the Archive. You can even move on to the Sun or other sources if you feel comfortable doing so. What are some problems that show up in various data sets?
   a. More details on observing Jupiter: https://radiojove.gsfc.nasa.gov/education/educ/jupiter/emission/material/cmlio.htm
   b. More on the Sun and other planets in radio emissions: https://public.nrao.edu/radio-astronomy/our-solar-system/

From here, you might go on to the CML-Io explanation (maybe use some spheres from the lab to demonstrate?) and do the plotting activities in Lesson 6 there

Outdoors Testing

Post-construction, testing the antenna and receiver together:
https://radiojove.gsfc.nasa.gov/help/Testing_Rcvr_Ant_Together.htm

Introduction to Radio Astronomy

Public resources on radio astronomy:

- Step through the National Radio Astronomy Observatory's pages on the basics, with no math, at https://public.nrao.edu/radio-astronomy/what-is-radio-astronomy/
- The Smithsonian has a short primer on Jupiter's radio emissions - https://airandspace.si.edu/exhibitions/exploring-the-planets/online/solar-system/jupiter/environment.cfm

College level resources on radio astronomy:

- Essential Radio Astronomy (https://science.nrao.edu/opportunities/courses/era) - this is the notes for an upper level undergraduate (or lower level graduate) course on radio astronomy that I took. I have the textbook in my office, but the website is pretty complete.
- MIT Haystack tutorial (https://www.haystack.mit.edu/edu/undergrad/materials/RA_tutorial.html) - not super well formatted, but a good introductory source as well on radio astronomy

More related lesson plans:

- MIT Haystack hosts a "Research Experience for Teachers" along with their REU program. They post many of the lessons developed by these teachers at https://www.haystack.mit.edu/edu/pcr/resources/lessonplans.html