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Our Scan!

Overview:
After completing all five lessons leading up to the actual scan, your students are ready to conduct their search for an extraterrestrial signal. As your students begin their scan, Dr Levin has a few words of encouragement. "We won't know if there's life out there until we look for it, and today you could be the person who makes that discovery. Thanks for helping and good luck on your search!"

Purpose:
The purpose of this lesson is for your students to use the tools real scientists use and do real science. They may well discover of a signal from outer space and in doing so change the entire world around them.

Required Background Knowledge:
- All five GAVRT SETI lessons should have been completed before the students use the telescope.
- Read GAVRT Looks for Life in Outer Space

Students will be able to:
- Use a 34 meter radio telescope to look for an extraterrestrial signal.
- After the scan the students will be able to decipher their data.

From the National Science Standards:
All students should realize:
- As a result of this activity in grades 5-8 and 9-12, all students should develop an understanding of science as a human endeavor, nature of science, abilities of technological design, and understanding about science and technology.
- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science, there is much experimental and observational confirmation. Those ideas are not likely to change greatly in the future. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations.

- In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered. Different scientists might publish conflicting experimental results or might draw different conclusions from the same data. Ideally, scientists acknowledge such conflict and work towards finding evidence that will resolve their disagreement.

Web Links for Further Investigation These should open.

- You can follow the GAVRT telescope position at http://rye.caltech.edu:8000/devel/default/gsky
- You can see a live video feed of the telescope at http://www.lewiscenter.org/Global-Programs/GAVRT/Video-Feeds/DSS28-Video/index.php

Resource/Materials Needed:

- Computer to run the telescope with and to review the data on day two.
- A copy of GAVRT Looks for Life in Outer Space
- A copy of the following: Searching for Extraterrestrial Intelligence with the GAVRT Radio Telescope Scan Sheet, SETI Data Analysis worksheet, and Candidate Signal workpage.
- Paper, pencils, and crayons for the centers.

One-Computer Classroom:

If there is only one computer in the classroom, it is recommended that teachers use an overhead, LCD, white board, or television screen to project images from the computer onto a classroom screen. A variety of activities are provided so that the students have material to work on if they are not running the telescope. Having the computer images projected will allow those students who are curious to see what is currently happening to do so without disturbing the group that is driving the telescope. It is also suggested that you divide your class into groups of four to five students, so the group conducting the scan is not so large that the Lewis Center assistant or you, the teacher, can be heard over the excitement of the students. Once the scan is started, there is very little to do by the way of controlling the telescope until it completes the 40-minute skyframe. You may wish to have only one group running the telescope and another group stowing it. The rest of your class may do the activities listed below or watch what is happening from the projection. The second day activity of reducing noise can be done as a class.

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Multi-computer Classroom:

If your classroom has more than one computer or you have a computer lab available, some computers can be on the GAVRT SETI site. Students could be analyzing the data with the waterfall plot by looking at the current data being collected or looking at data from previously observed skyframes. The waterfall plot for your particular scan will be updating as the telescope retrieves the data. Students not running the telescope could start analyzing your data and thus get a head start on day two. It is still important to have the actual scan screen projected so that those students not actually running the telescope will feel that they are part of the information being collected.

Teacher notes:

- Either read or make copies for your students to read of GAVRT Looks for Life in Outer Space.
- Review the operating procedures for the radio telescope and stress the need for students not operating the telescope to remain quiet.
- Place your students in teams of 4 to 5.
- Review the other activities provided in this lesson.
- If you have only one computer, set up centers and have your students move quietly every 15-20 minutes (depending on the time frame for your science period). Make sure you are able to project what is happening on the computer so that those students not running the telescope can observe what is happening.
- If you do not want your students to move though centers, put a list of the activities provided on the white board. Instruct your students that they may pick from these activities to work on.
- If you have more than one computer or a computer lab available, have some of the computers connected to the GAVRT SETI site so students not running the telescope are able to investigate the current data being collected or look at data from previously observed skyframes.
- On day two, your students can work together as a class deciding how to remove noise from the scan your students completed on day one.

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Student Activity: Activity for Day One: Scanning with Your Radio Telescope

Procedures:

For Centers:

- Go to your center and start the activity. Remember you will only have a short period of time to complete each task.
- When your time is up, move to the next center in the order decided by your teacher
- If you did not finish an activity, your teacher may allow extra time after the session is over or you may take them home to complete.

For Classrooms that do not have centers:

- Look at the list of activities on the board.
- Pick one and work on it quietly.
- You may pick another activity if you finish the first.

For Classrooms with multiple computers:

- Look at the GAVRT SETI site. You may choose to start analyzing the data being collected by your scan.
- You may also look at data collected from previous scans.
- Start deciding what is noise and what is a possible signal.

Searching for Extraterrestrial Intelligence with the GAVRT Radio Telescope

SCAN SHEET (This should print on one page)

Name _____ Date _____

School _____

Spectrometer Start Time _____ UTC

Skyframe Start Time _____ UTC

Skyframe Number _____

Comments and Notes

_____

_____

_____

_____

_____

_____

_____

_____

_____

Additional Activities for the teacher to choose from:

- Write a brief article that explains the importance of finding an extraterrestrial signal. What changes would that cause in our world?
- Write a brief article that explains the importance of NOT finding an alien signal. What implications does that have for our world?
- If the extraterrestrial planet sending the signal is huge and has heavy gravity, write or draw what the aliens might look like. In other words, what affect would heavy gravity have on the shape of the alien?
- If the extraterrestrial planet is mostly atmosphere, and the aliens abide in the air, what would they look like? You can either draw or write about their appearance.
- If the planet sending the signal is a water world with no land above the waterline, how would that affect the alien's appearance?
- If the extraterrestrial planet is very small with little gravity, what would the alien look like?
- If the aliens have deciphered our television and radio signals, what do you think their opinion is about humans?

Activity for Day Two: GAVRT SETI Data Analysis or Did We Find Anything

A few words from Dr. Levin about the importance of what you are going to be doing on day two:

"This is the real heart of what the students are doing. In many ways, they are doing this analysis because it is too hard for a computer to do. People do a great job at recognizing patterns. Computers generally need to be told what sort of pattern to look for, and they are very literal about it. So when you add a little noise to the RFI signal, and let it wander in frequency a bit, with perhaps some starts and stops or changes in power level, it gets hard to write a computer program which will still

recognize it as RFI. A human being has no such problem. Most of us can glance at a plot, see the vertical lines in the data, and immediately recognize the difference between a long line and a short one."

Procedures:

- Use your web browser to go to http://galileo.gavrt.org/seti and click the "plot skyframe" button.

- Near the bottom of the screen, use "Data Source" to choose your data file from the pull-down menu.

- Because the radio telescope moves during a skyframe, a real signal can only be visible for a few seconds. Man-made signals which leak into the system are called "Radio Frequency Interference", or RFI. RFI leaks in from the sides, so it is not affected the same way by the telescope motion. We want to "mask" the RFI by removing some of the frequency channels, to allow us to look for a real signal, which could be evidence of extraterrestrial life. By entering plot ranges and color scales into the on-screen form, adjust the plot to look for RFI, and make a list of frequencies which should be removed. We don't want to remove too much (Why ?), but we don't want to fool ourselves by leaving in any RFI either, so use your best judgment about what to remove.

- Together with your classmates, decide on a final list of channels to be removed from your data set, and pass that along to the GAVRT SETI science team. We will publish it on the website alongside the data. (Use the provided worksheet)

- Look at the remaining plot, with known RFI removed. Are there any bright signals left ? If so, these could be just noise or intermittent RFI, but they might just possibly be evidence for intelligent life beyond Earth. We'll need more information. What should we do to learn more ? How will a real signal differ from RFI or noise ? Together with your classmates, make a list of candidate signals to be investigated further.

- Watch the radio telescope as it scans the sky. There is a repeating pattern. We don't scan over the exact same spot twice in a skyframe, but we do come close. How long does it take until the telescope comes around again to almost the same location? What would it mean if you saw a signal which repeated a few times with just the right timing?

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SETI Data Analysis (This should print on one page)

Data File Name _____

Radio Frequency Interference (RFI) Rejection

Frequency Range	**Reason for rejection**
_____ **to** _____	_____
_____ **to** _____	_____
_____ **to** _____	_____
_____**to** _____	_____
_____**to** _____	_____
_____**to** _____	_____
_____**to** _____	_____
_____**to** _____	_____
_____**to** _____	_____
_____**to** _____	_____
_____**to** _____	_____
_____ **to** _____	_____
_____**to** _____	_____
_____ **to** _____	_____

Explain Your Choices:

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Candidate Signals (This should print on one page)

Time	Frequency	Notes

Explain your reasoning:

If you found a possible signal, what should happen next?

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Additional Information: (the following article should print on two pages)

GAVRT Looks for Life in Outer Space

We are embarking on a new GAVRT science campaign: the Search for Extraterrestrial Intelligence (SETI). The goal of the GAVRT SETI project is to look for radio signals from distant stars. Our search will cover most of the stars in our galaxy, and we'll look for radio signals at all the frequencies DSS-28 can reach, 200 MHz at a time. This will take a few years, and the participation of lots of students and teachers. One or two GAVRT classes will observe the first small patches of sky this school year, to test out the system and provide feedback on how it works in the classroom. Over the summer, we'll make improvements and start to develop classroom lessons, so that we can begin in earnest during the 2011/2012 school year. We'll need to run the telescope for several thousand hours to cover most of the stars at all the frequencies we can reach, so it's a long-term project.

Our galaxy is shaped like a giant disk, so most of the stars fall within a narrow band on the sky, called the "galactic plane". This is the famous "Milky Way" that you can see when you look at the sky on a dark night. For GAVRT SETI, this means we can scan across most of the stars in our galaxy by sweeping the telescope along a fairly small region of sky. GAVRT students will monitor the galactic plane for an hour at a time, choosing which patch of sky and which frequency band to observe. The telescope scan pattern is a "racetrack" scan, as shown in the picture below.

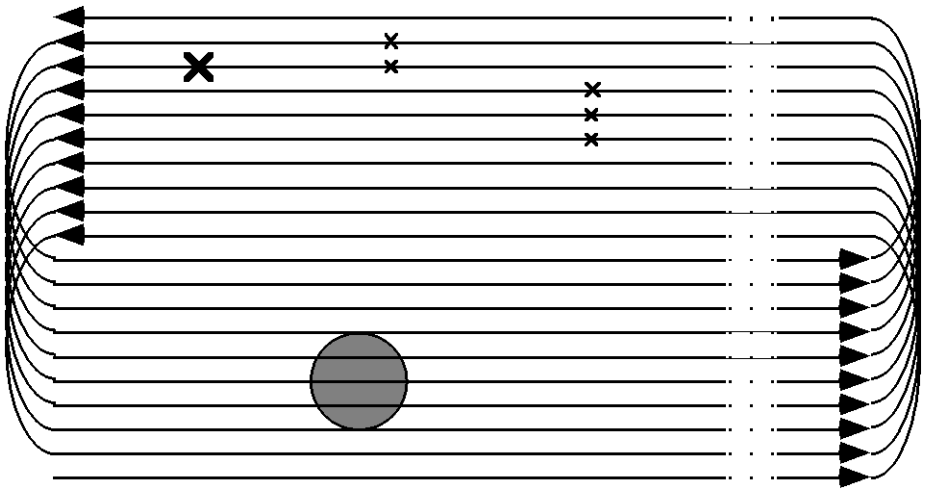
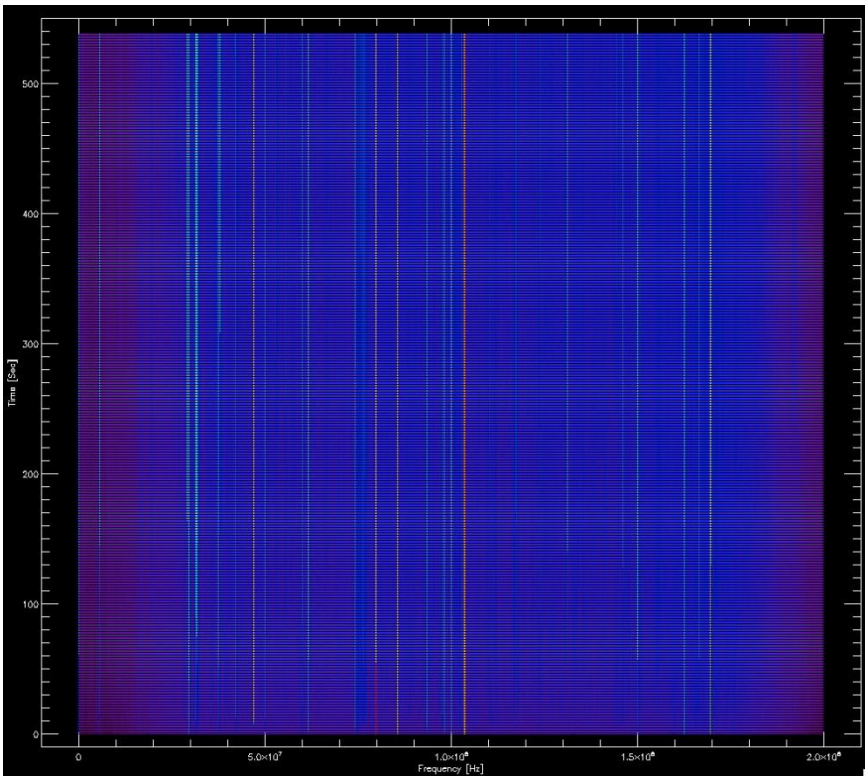


Figure 1. The racetrack scan pattern accommodates a simple technique for matching repeated observations. Arrows indicate the direction in which scanlines are observed. The racetrack is shortened for illustrative purposes. Skyframe width is approximately 25 times the height. The grey circle indicates the beam size, and the x's indicate possible detections, as described in the text.

One of the most difficult problems in SETI is rejecting Radio Frequency Interference (RFI). These are radio signals which come from hear on Earth, rather than the sky. In our search, the telescope will always be moving, so any real signal from the sky will appear and disappear as the telescope beam sweeps over it's position. On the other hand, RFI which

leaks into the system will not depend much on where the telescope is pointing, so it won't match this pattern. Also, the racetrack pattern comes back to nearly the same position every 6 minutes, so a real signal might appear a second or even a third time, when the telescope sweeps past the same location on an adjacent scanline.

One of the main tasks for the students will be to examine the data, and attempt to reject all of the RFI. The main tool we envision for this is the waterfall plot, shown below. In this color graph, the horizontal axis represents frequency, the vertical axis represents time, and the color coding represents signal intensity. In this example, you can see a number of vertical lines, caused by RFI. If there were a real signal present, it would show up as a very short vertical line, representing extra power showing up in one channel for just a few seconds, or perhaps two or three such short lines, separated by 360 seconds (the 6 minutes it takes to come around to the adjacent scanline).



We will be collecting a new spectrum (200 million frequency channels at a time) about every 2/3 of a second. This is far too much data to store, let alone analyze, so the spectrometer will pass along only a few of the channels from each spectrum, choosing the ones which record the most power. As with any real-world system, there will be noise in the receiver, and at 200 million channels every 2/3 of a second, even "1 in a million" noise events will occur hundreds of times each second. So our data will consist mostly of noise and RFI.

Questions:

As with all investigations, one question may give rise to more. Keep a journal of your questions as you complete your investigation. If these questions have not been answered when you have finished your GAVRT/SETI scan, you may need to do further investigations using NASA websites. You are on the cutting edge of scientific research. Your journey may need to continue after your project is complete.