DRAFT

What Wavelength of Light Do We Use to Search for an Extraterrestrial Signal?

Overview: Light comes in wavelengths from radio waves to gamma-rays, all traveling at the speed of light but all with different energies or frequencies. If we are going to look for a signal from an extraterrestrial source, we'll need to look using light waves. Which wavelength of light to use has been a long debated question.

Purpose: The purpose of this lesson is to guide students to discover the best wavelengths of light to use in their search for an extraterrestrial signal.

Required Background Knowledge:

- Read GAVRT Looks for Life in Outer Space
- Read Solar EM Radiation Penetration into Earth's Atmosphere at http://www.windows2universe.org/earth/Atmosphere/earth_atmosph_radiation_budget.html

Students will be able to: Understand why scientists use radio and microwaves to search for extraterrestrial signals.

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.

- http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html
- http://www.windows2universe.org/earth/Atmosphere/earth_atmosph_radiation_budget.html
- http://www.seti.org/seti-institute/project/details/seti-observations
- http://www.astronomynow.com/news/n1004/26seti5

Resource/Materials Needed:

- Article GAVRT Looks for Life in Outer Space
- Article What Wavelengths of Light Reach the Earth's Surface? Including page for students to investigate the diagram

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 or websites from the computer onto a classroom screen. There are a variety of websites to look at, and you may want to do them as a class.

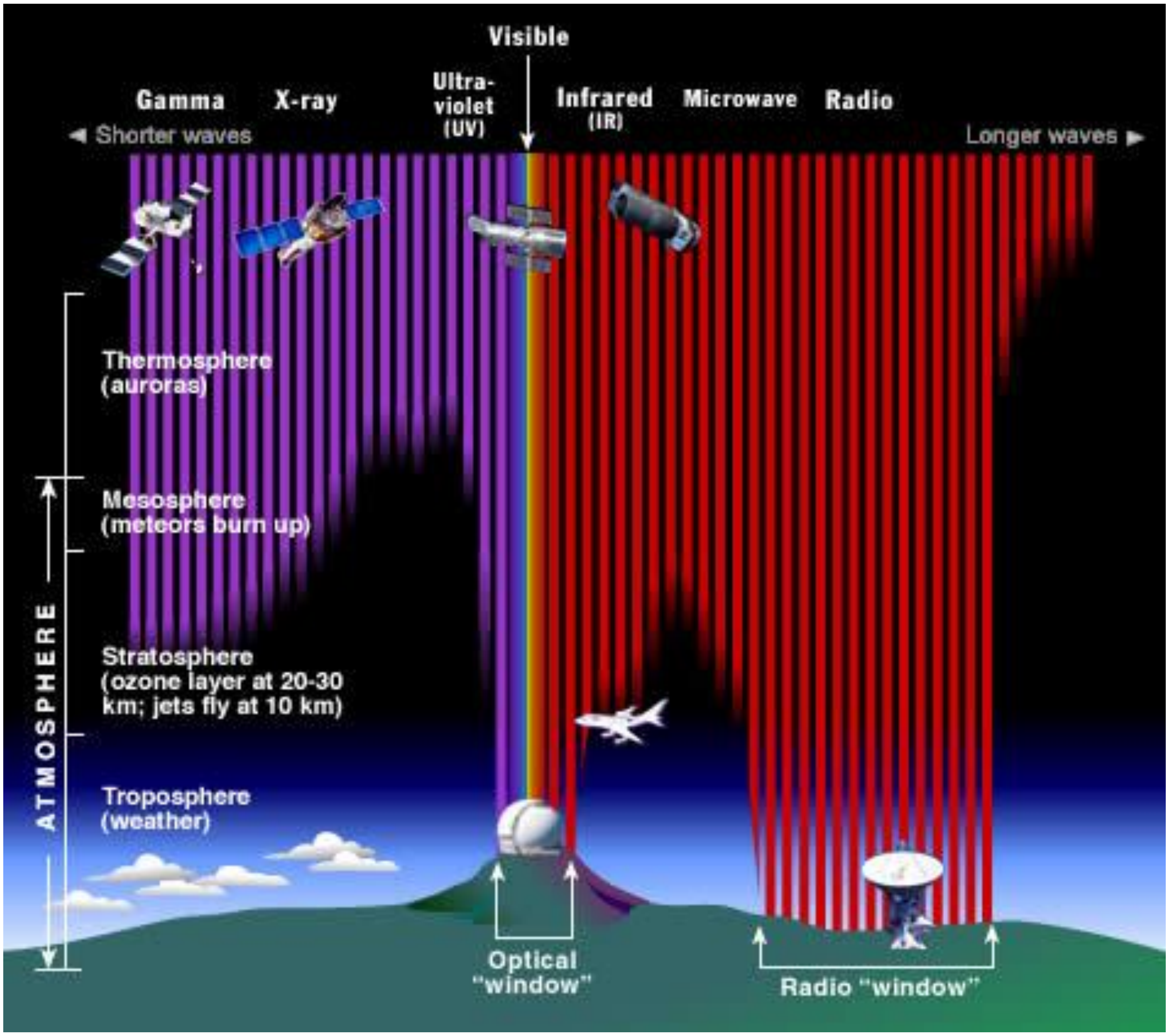
Teacher notes:

Some of the information in the above websites is very technical. It is suggested that you read through the material before attempting to do this activity with your students. Some of your students may be able to understand the last two URLs.   If not, you could read and then disseminate the information to your students.

DRAFT

Student Activity:

What Wavelengths of Light Reach the Earth's Surface?



(Various wavelengths of solar EM radiation penetrate Earth's atmosphere to various depths. Fortunately for us, all of the high energy X-rays and most UV is filtered out long before it reaches the ground. Much of the infrared radiation is also absorbed by our atmosphere far above our heads. Most radio waves do make it to the ground, along with a narrow "window" of IR, UV, and visible light frequencies. **Credit:** Image courtesy STCI/JHU/NASA.

http://www.windows2universe.org/earth/Atmosphere/earth_atmosph_radiation_budget.html). Don't include the parenthesis in the lesson.

DRAFT

Regions of the Electromagnetic Spectrum

Listed below are the approximate wavelength, frequency, and energy limits of the various regions of the electromagnetic spectrum.

	Wavelength (m)	Frequency (Hz)	Energy (J)
Radio	$> 1 \times 10^{-1}$	$< 3 \times 10^{9}$	$< 2 \times 10^{-24}$
Microwave	$1 \times 10^{-3} - 1 \times 10^{-1}$	$3 \times 10^{9} - 3 \times 10^{11}$	$2 \times 10^{-24} - 2 \times 10^{-22}$
Infrared	$7 \times 10^{-7} - 1 \times 10^{-3}$	$3 \times 10^{11} - 4 \times 10^{14}$	$2 \times 10^{-22} - 3 \times 10^{-19}$
Optical	$4 \times 10^{-7} - 7 \times 10^{-7}$	$4 \times 10^{14} - 7.5 \times 10^{14}$	$3 \times 10^{-19} - 5 \times 10^{-19}$
UV	$1 \times 10^{-8} - 4 \times 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{16}$	$5 \times 10^{-19} - 2 \times 10^{-17}$
X-ray	$1 \times 10^{-11} - 1 \times 10^{-8}$	$3 \times 10^{16} - 3 \times 10^{19}$	$2 \times 10^{-17} - 2 \times 10^{-14}$
Gamma-ray	$< 1 \times 10^{-11}$	$> 3 \times 10^{19}$	$> 2 \times 10^{-14}$

(http://imagine.gsfc.nasa.gov/docs/science/know_l1/spectrum_chart.html) Don't include in the lesson.

The chart above shows the wavelength, frequency, and energy per photon for various forms of electromagnetic radiation. Notice that the higher the frequency, the more energy is needed to produce a single photon. Sending a single bit of information requires at least one photon, so if an extraterrestrial wanted to send a signal using ultra-violet to gamma ray, enormous amounts of energy would be required. The higher the frequency the more energy is required to send it. One photon that is at 100 gigahertz (GHz) needs 100 times more energy than a photon at 1 GHz. (One gigahertz is equal to 1,000 megahertz or 1,000,000,000 hertz).

So assumptions are made that an extraterrestrial advanced civilization would use radio waves to microwaves to communicate across vast distances. Also we know that any noise or signal that is spread across less than 300 Hz in frequency is unlikely to be naturally made and may be artificial. Researchers look for narrow-band signals or ones that are confined to a small band of energy and wavelengths of the electromagnetic spectrum that do not require enormous amounts of energy to sustain the wavelength.

Student Investigation Sheet

1. Which wavelengths of light reach the Earth's surface? What does this tell you about investigations into various wavelengths of light?

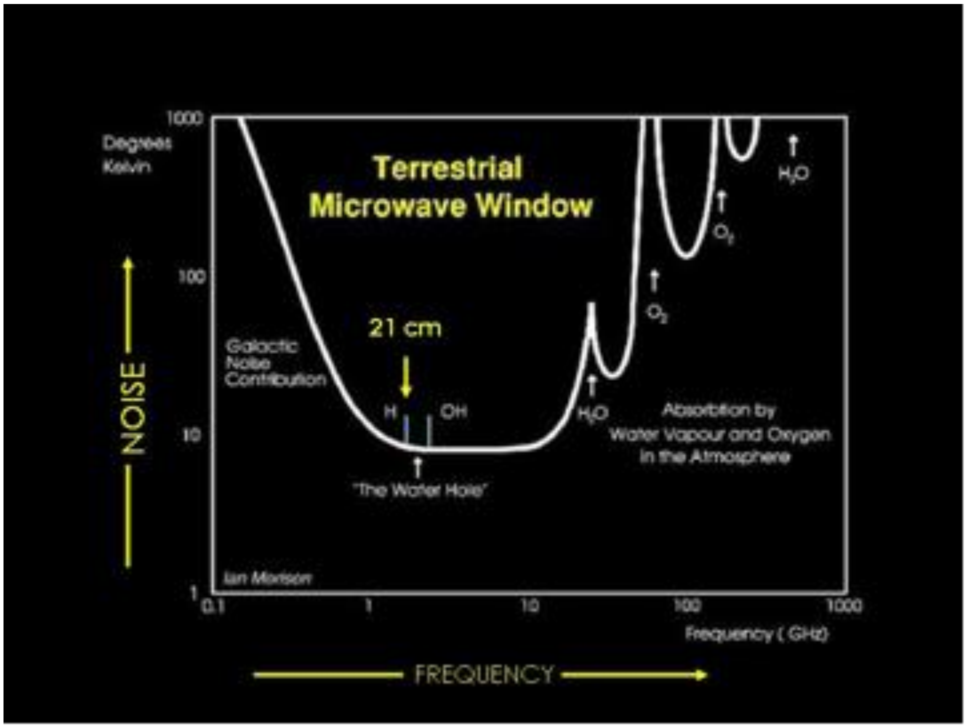
2. Match the wavelengths of light that reach the Earth's surface with the frequencies found in the second chart. List the wavelength and it's frequency below.

3. With this knowledge, which wavelengths of light can we use to look for extraterrestrial signals?

DRAFT

However, this is not the whole picture. When we are looking for a very faint signal, our biggest problem is interference from astrophysical sources (pulsars and quasars), satellites circling around the Earth, aircraft radar, WIFI or other manmade signals. So where do we look?

We look in the electromagnetic spectrum for an area that will not be noisy. If we look in the radio frequencies that are between a neutral hydrogen atom and a molecule of hydroxyl (one hydrogen and one oxygen atom), there is a quiet zone. Anyone or any being broadcasting in these frequencies would come out loud and clear. This quiet zone is called the Water Hole. This is where we will focus our search.



4. Looking at the chart above, what frequency are we going to observe and why is it probably the best to use?

DRAFT

5. However, SETI has been looking for 50 years without finding a true signal. Some scientists are suggesting other frequencies should be investigated. What would your suggestion be to those searching for another wavelength? Why do you suggest this new choice?

Procedures:

- Read "GAVRT Looks for Life in Outer Space."
- Read "What Wavelengths of Light Reach the Earth's Surface" and record your thoughts on student sheet
- Have a discussion with some of your fellow students discuss your findings. You may include new thoughts on your student sheet.

Additional Information:

Make copies so students can read.

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 2012/2013 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.

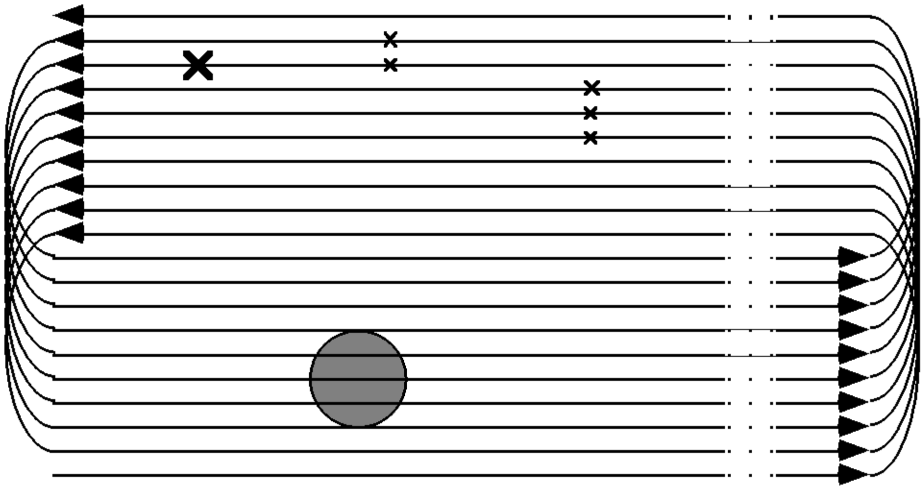
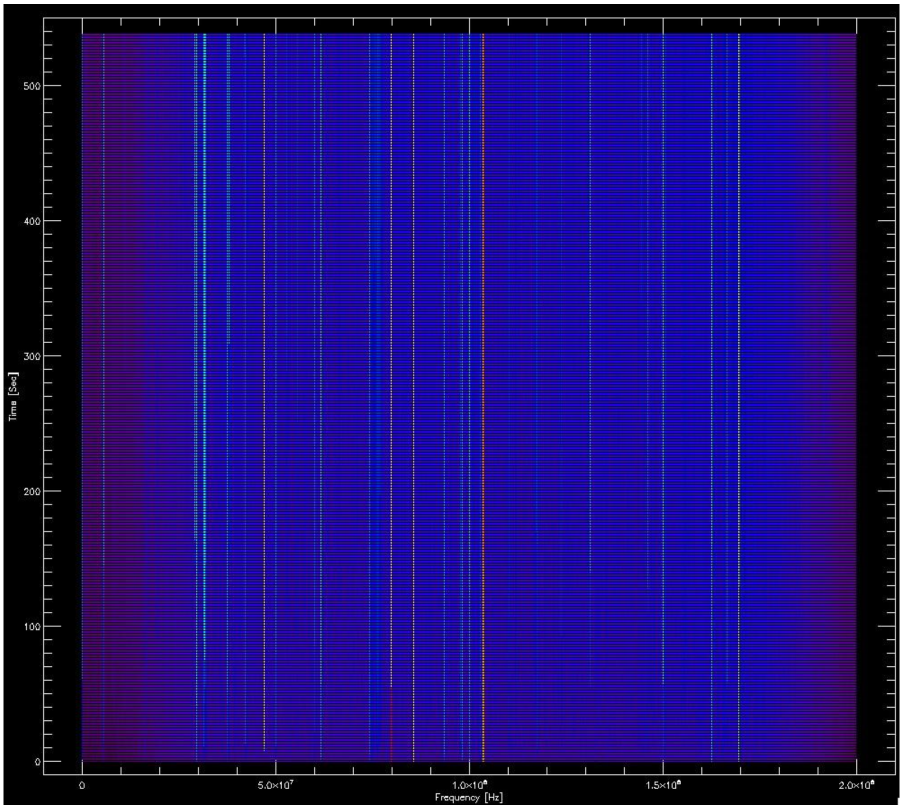


Figure 1. The racetrack scan pattern accommodates a simple technique for matching repeated observations. Arrows indicate the direction in which scanlines are observed. The racetrack is shortened for illustrative purposes. Skyframe width is approximately 25 times the height. The grey circle indicates the beamsize, 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 here 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).

DRAFT



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, but hopefully there will be the promise of a signal from an extraterrestrial source.

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.