Extrasolar eclipses

Using coronagraphy to find extrasolar planets

Age: 8 +

Activity Time: 60 min

Prep Time: 15 min

Summary

Like the Moon during a total solar eclipse, a coronagraph blocks out the brightest part of the Sun, allowing viewers to see the wispy corona surrounding the Sun. Scientists now use coronagraphs to image dim exoplanets orbiting around bright stars. In this activity, you will set up a model star and exoplanet system that your students can practice observing with home-made coronagraphs.

Credit: Activity created by Space Telescope Science Institute
http://outreachoffice.stsci.edu/

Objectives

- Demonstrate that eclipsing a star allows us to better observe its exoplanets.
- Introduce the electromagnetic spectrum. Show that hot, bright stars tend to be more blue and that cooler stars tend to be more red.
- See the difference in making exoplanet observations in visible and infrared light.

Materials

All Activities

- ❑ 40 watt clear lightbulb and lamp

Activity 1: White Light Coronagraphy

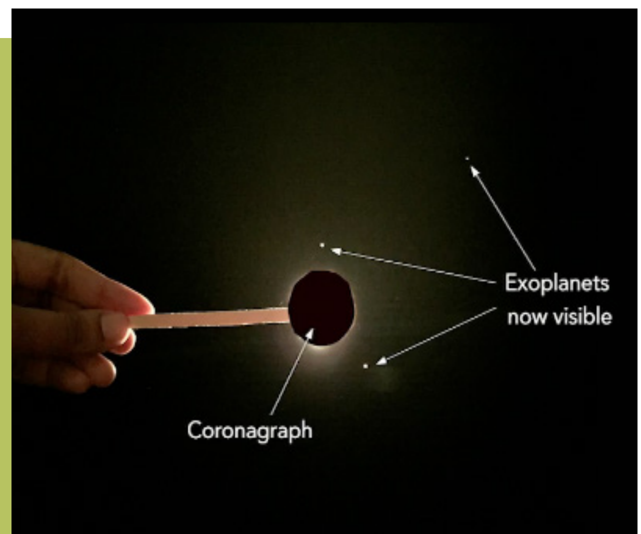
- ❑ tri-fold display board (preferably black)
- ❑ 7 thin popsicle sticks/coffee stirrers
- ❑ utility knife
- ❑ ruler or tape measure
- ❑ 1 large sewing needle
- ❑ tape

Activity 2: Temperature and Spectra

- ❑ dimmer switch
- ❑ diffraction grating/glasses

Activity 3: Red Light Coronagraphy

- ❑ all items needed for Activity 1
- ❑ red lightbulb
- ❑ 3 headlamps
- ❑ red permanent marker
- ❑ 3 velcro dots

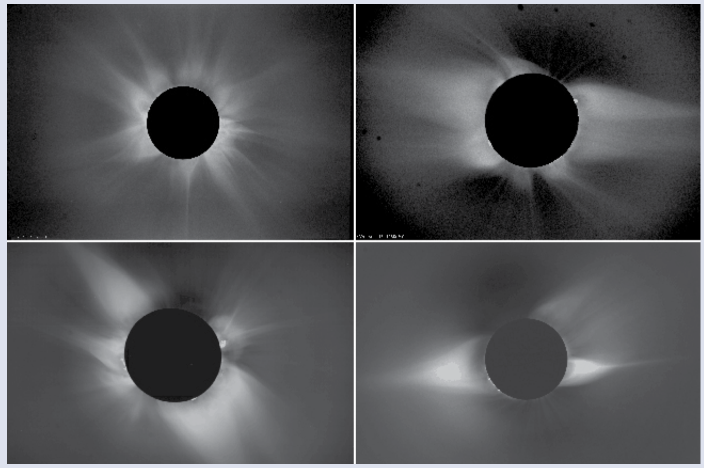


WARNING:

- The set up for the coronagraph activities require the use of sharp objects and should only be done by an adult.
- These actvities involve the observation of an unshaded lightbulb. When in use, lightbulbs can get hotter than 100 °F (38 °C). Prevent anyone from touching the bulb during the activity.
- Looking at very bright lights can be harmful. Prevent anyone from looking directly at the lightbulb, observing for too long and/or looking directly at the lightbulb filament. Follow the additional safety guidelines included.

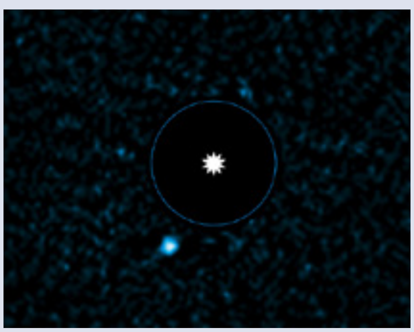
Science Background

asdfsadf *What is the brightest star we can see from Earth? The Sun, of course! People noticed as early as 1307 BCE that during a total solar eclipse, when the Moon passes in front of the Sun, that wispy structures streaming away from the Sun in all directions could suddenly be seen. This part of the Sun is now called the "corona" (which is Latin for "crown" - the corona somewhat resembles this royal headwear) and consists of plasma extending millions of kilometers away from the Sun. The corona is always there but is normally too dim to see compared the bright photosphere. In the early 20th century a device called a "coronagraph" was invented that mimics the effects of a total solar eclilpse by blocking light from the disk of the Sun.*



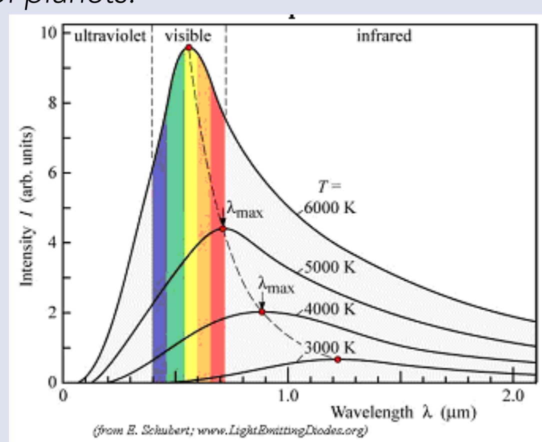
The Sun's corona during the 1980, 1988, 1991, and 1994 total solar eclipses
Credit: High Altitude Observatory

More recently, scientists have started using stellar coronagraphs to find and directly image dim planets orbiting around other stars. Stars are generally billions of times brighter than their planets, so looking for exoplanets is kind of like looking for a firefly sitting next to a lighthouse lamp. Because of this, very few exoplanets have been directly imaged. The easiest exoplanets to see are very large and located far away from their host star. Scientists would really like to know more about Earth-like planets (relatively small and located close enough to the star for water to be liquid). Stellar coronagraphs will be essential in making observations of these kinds of planets.



Exoplanet HD 95086 b with host star blocked
Credit: European Southern Observatory, VLT

Much of the light we receive from exoplanets is reflected from their host stars, but planets emit their own light as well! Warm objects like Earth emit primarily in infrared light; which is not visible to our eyes (although some animals can see infrared light). In fact, all objects with a temperature above absolute zero emit some kind of light. The hotter an object is, the more short-wave radiation it gives off and the more light it gives off in every wavelength from each square inch of its surface area. Hot, bright stars give off bluer light and relatively small, cool stars give off redder light.

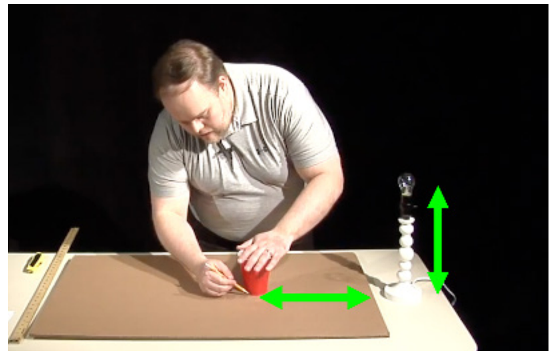


Light intensity versus light wavelength. A 6,000 K star is bluer than a 5,000 K star, which is redder: the peak wavelength, λmax, is inversely related to temperature. Hotter objects emit more light per square inch in all wavelengths.
Credit: E. Schubert, www.LightEmittingDiodes.org

Procedure

Set Up (Activity 1: White Light Coronagraphy)

1. Place the light bulb in the lamp. Measure the distance from the bottom of the lamp to the filament of the light bulb.



2. Mark the spot on the display board that is this distance from the bottom and in the center of the middle panel.

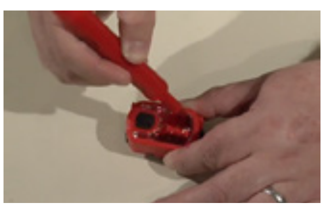
3. Draw a 2 inche diameter circle aroud this point using a compass or by tracing a circular object. Carefully cut this circle out using the utility knife.

4. Using a large sewing needle, poke 3 holes in the display board: one about 2 inches from the edge of the large hole, one 4-8 inches away and one 12 inches away. Exact distances are not imporant and these can be randomly placed about the center.

5. Print out the sheet of coronagraphs provided on page 10. Cut out the black circles and tape them to your small popsicle sticks or coffee stirrers. This can be done by the students, if desired.

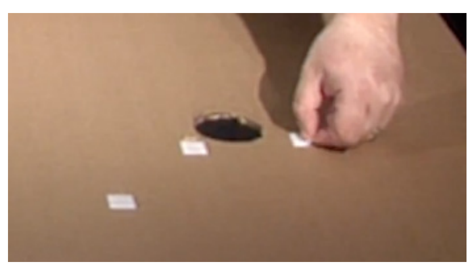
6. Print the attached electromagnetic specturm (pages 8 and 9) and tape to your display board.

Set Up (Activity 3: Red Light Coronagrapy)



7. Color the lens of the headlamps in with the red Sharpie. Depending on the brightness of the headlamps, this may require multiple colorings to ensure that they emit red light.

8. Stick 3 velcro dots on the back of your display board above the 3 small holes. When the headlamps are attached, they should shine through the holes to the front of the project board. You can either stick the velcro dots to the board first and then attach headlamps as shown, or stick the dots to the headlamps then stick those to the board.



Procedure

Activity 1 - White Light Coronagraphy

1. Set up the display board on a table with the the lamp and clear bulb placed behind it. Have the light bulb as close to the board as possible without the bulb touching the board. Mark a spot 12 feet (3.75 meters) away from the board as the observing location.

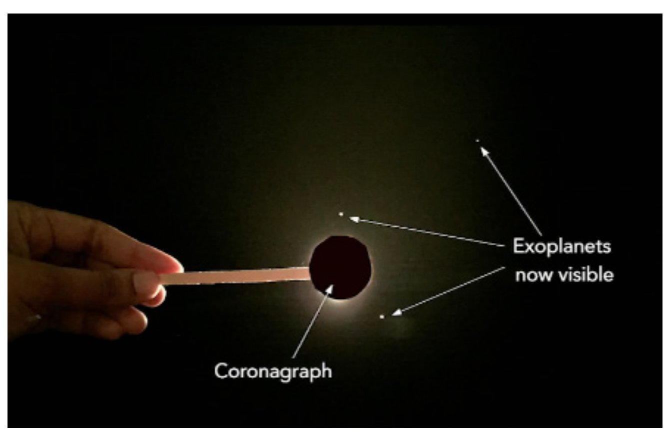
2. Tell your students about coronagraphs and how they enable us to see the Sun's corona; which is usually not visible even though it is always there. Explain how this method is being used to look at objects around other stars. The Science Background section on page 2 and the webcast links on the back page of this lesson plan will be useful for this. At this point, you can choose to tell them about observations of exoplanets or you can allow them to discover the exoplanets in your model upon observation.

3. Turn the light bulb on (if you are using the dimmer switch, make sure the light is on all the way) and then dim or turn off the lights in the room.

4. Describe parts of the model: The lightbulb represents a star that is shining in white/yellow light (like our Sun). The black circles on sticks are coronagraphs.

5. Standing at the observing location one at a time or in small groups, have your students observe the star system using the coronagraphs. They should close or cover one eye and block the light coming directly from the light bulb through the large hole with the 1/2 inch coronagraph. Ensure that students are using the coronagraph and not staring directly at the lamp; refer to the notice for more eye safety tips.

6. Ask the students to observe the area around the blocked light and describe what they see. They should be able to see the light shining through the 3 small holes, representing exoplanets.



SAFETY NOTICE:

1. Adult supervision is required. Use caution when using the utility knife and lamps
2. Do not look directly into the lamp. The purpose of the coronagraph is to block the light. Remind students with eye sensitivities to look away from the light source frequently.
3. When observing the spectra of the lamp at, do not stare at the filament (bright part).
4. Use caution around an active lamp—adult supervision is strongly recommended. Remember, lamps can heat objects to over 100 degrees C (the temperature at which water boils)!
5. When observing in a dark room, be sure to prepare your space appropriately. Move unnecessary furniture, wires, and other objects that can be hazards.

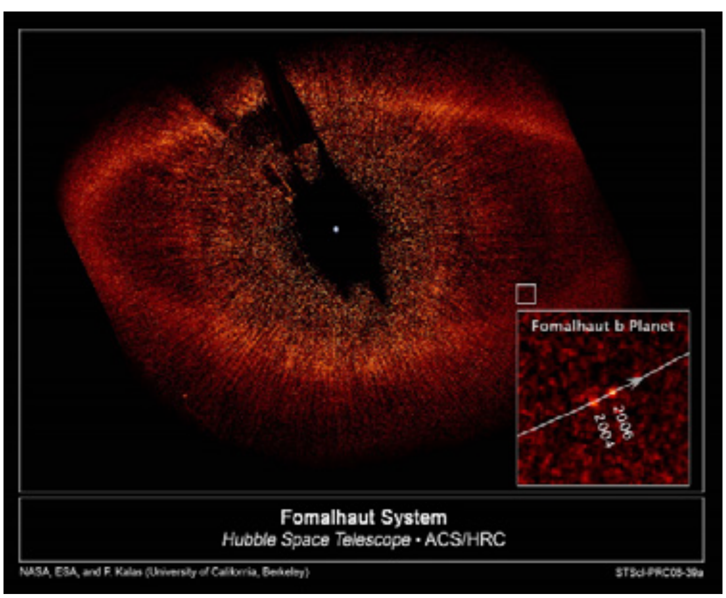
Procedure

Take It One Step Further:

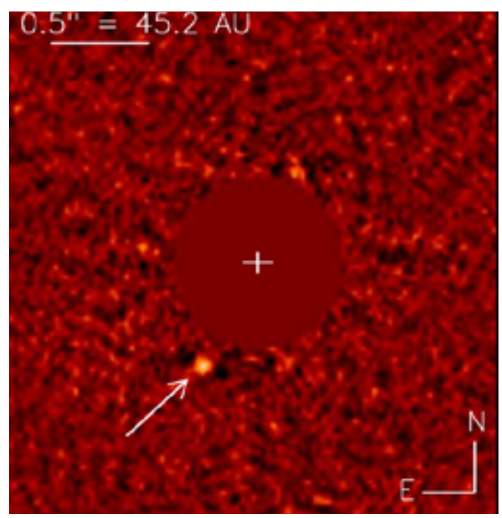
7. Have your students use different sized coronagraphs to observe the model. What changes? What does a larger coronagraph do? What does a smaller coronagraph do?

8. Using different sizes, the audience should notice that a coronagraph that is too large will obscure the planets. One that is too small will be ineffective at blocking out the light making the exoplanets difficult or impossible to be seen. The right-sized coronagraph will allow you to see the exoplanets best.

9. Show the participants images of exoplanets taken with a coronagraph. Two are provided below:



Exoplanet Fomalhaut b visible by use of star-occulting coronagraph
Credit: NASA, ESA, and P. Kalas (University of California, Berkely)



Exoplanet HD 95086 b. The lowest mass exoplanet discovered via direct imaging at time of publication. This planet is several times the mass of Jupiter.
Credit: VLT, J. Rameau et al. (UJF-Grenoble, Institut de Planetologie et d'Astrophysique de Grenoble)

Procedure

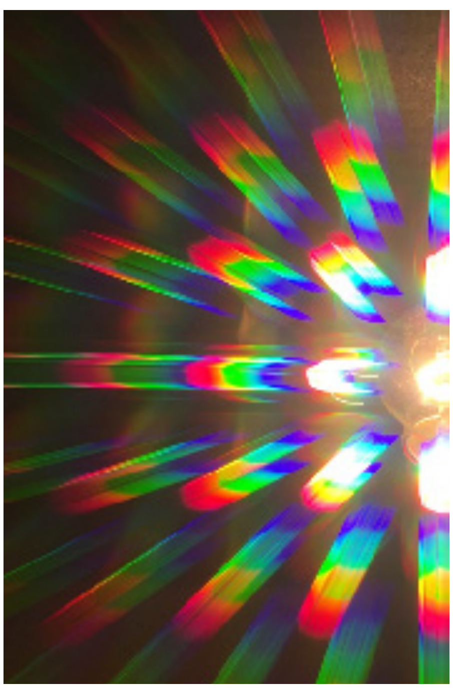
Activity 2 - Temperature and Spectra

1. Hand out diffraction grating or diffraction glasses.

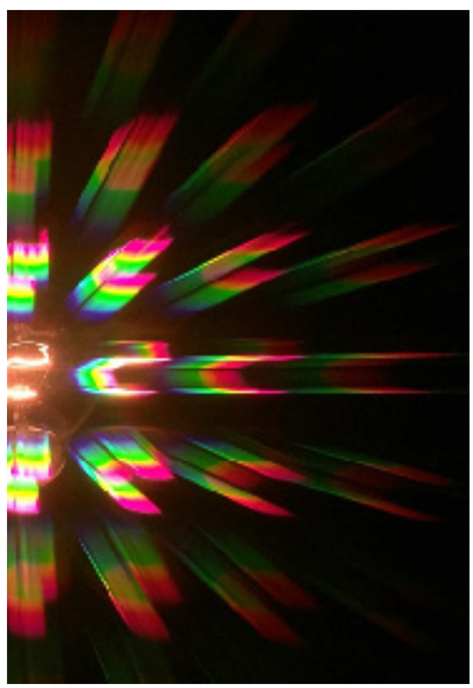
2. With the bulb at full brightness, have the students observe the light from the bulb through the diffraction grating. (Do not have participants stare directly at the bulb. The spectrum should still be visible by looking near the bulb and this should not be done for long periods of time). The spectra coming through the glasses should be include all the colors of the rainbow and specifically red, green, and blue.

3. With the audience still observing, turn the blub down slowly all the way to the dimmest setting without going off. While the bulb is dimming, have the participants observe the bulb with their diffraction glasses. The audience should notice how the colors change as the bulb dims - red should stay the same, but green shrinks a little, and blue shrinks the most (see examples below).

4. Discuss that stars with more energy will be hotter and bluer and stars with less energy will be colder and redder. How could different types of stars impact our observations of exoplanets?



At 100% the light has distinct green, blue and indigo regions.



At 10%, the spectrum is dominated by red wavelengths, with green and blue being less prominent.

Procedure

Activity 3 - Red Light Coronagraphy

1. Velcro the headlamps onto the back of the display board so that the light from the headlamps goes through the exoplanet holes.

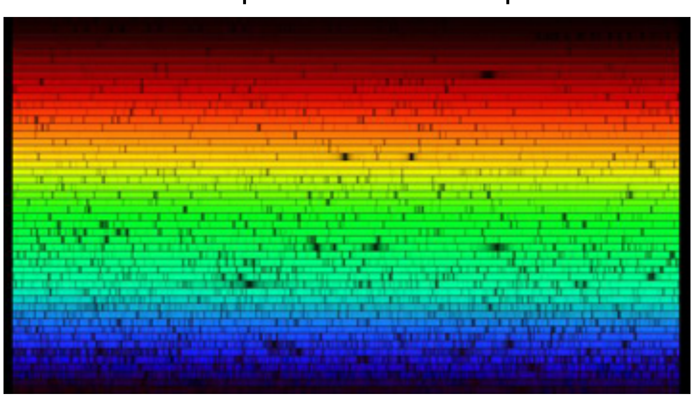
2. Replace the clear bulb with the red bulb. Careful! Be sure to let the white light bulb cool down before you remove it.

3. Explain the scientific underpinning for this activity. You can choose to do this now or wait until after the students have made their observations. Relay that warm objects like planets emit their own light, in infrared. The wavelength of infrared light is just outside our range of view, with wavelengths a little longer than red light (refer to the electromagnetic spectrum diagram on your project board for this). In this activity red light is used as an approximation of infrared light since it is the closest wavelength to infrared that we can see.

4. As before, have your students observe the star system using the coronagraph.

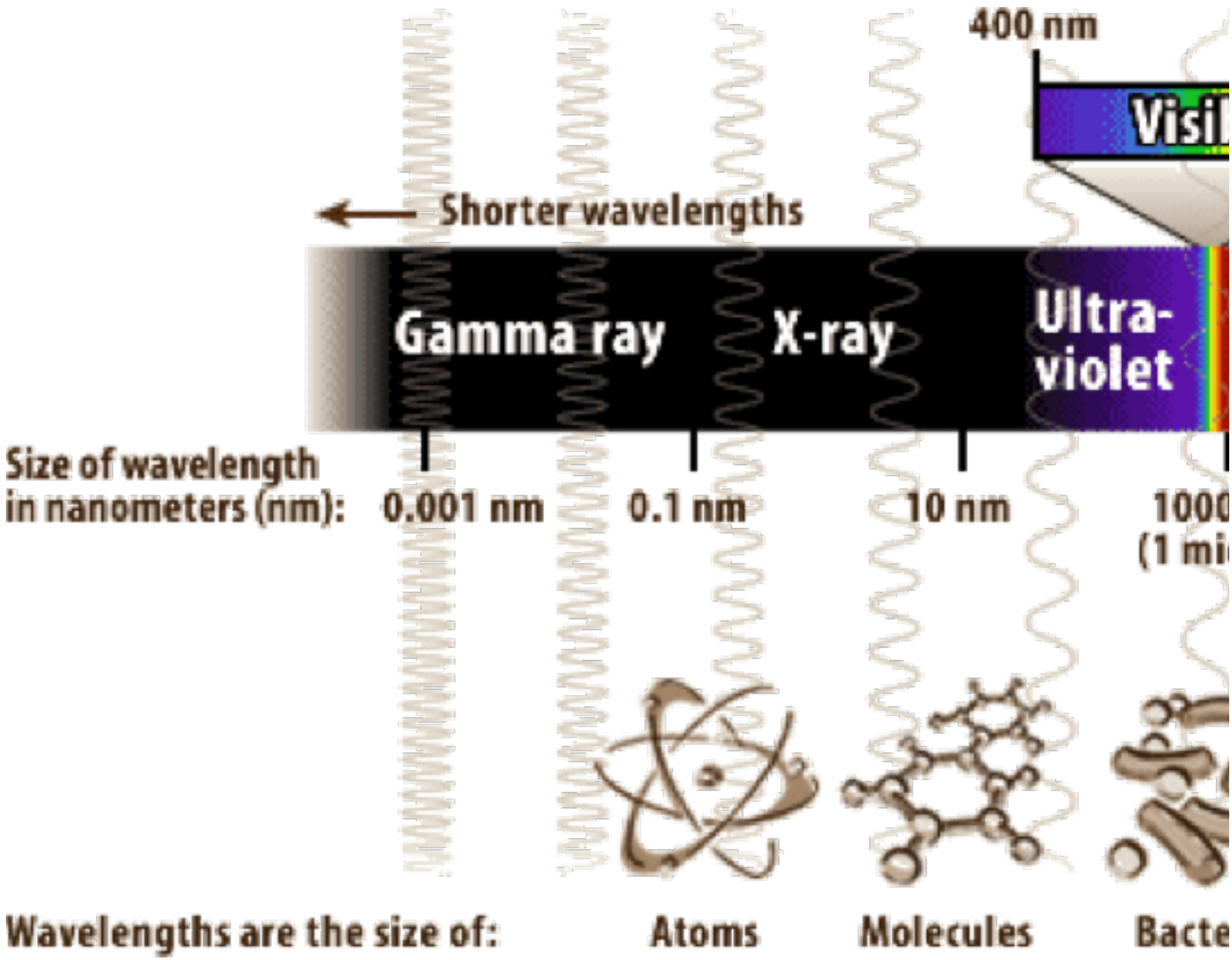
5. What do you see now? How is what you are seeing different from observing in visible light?

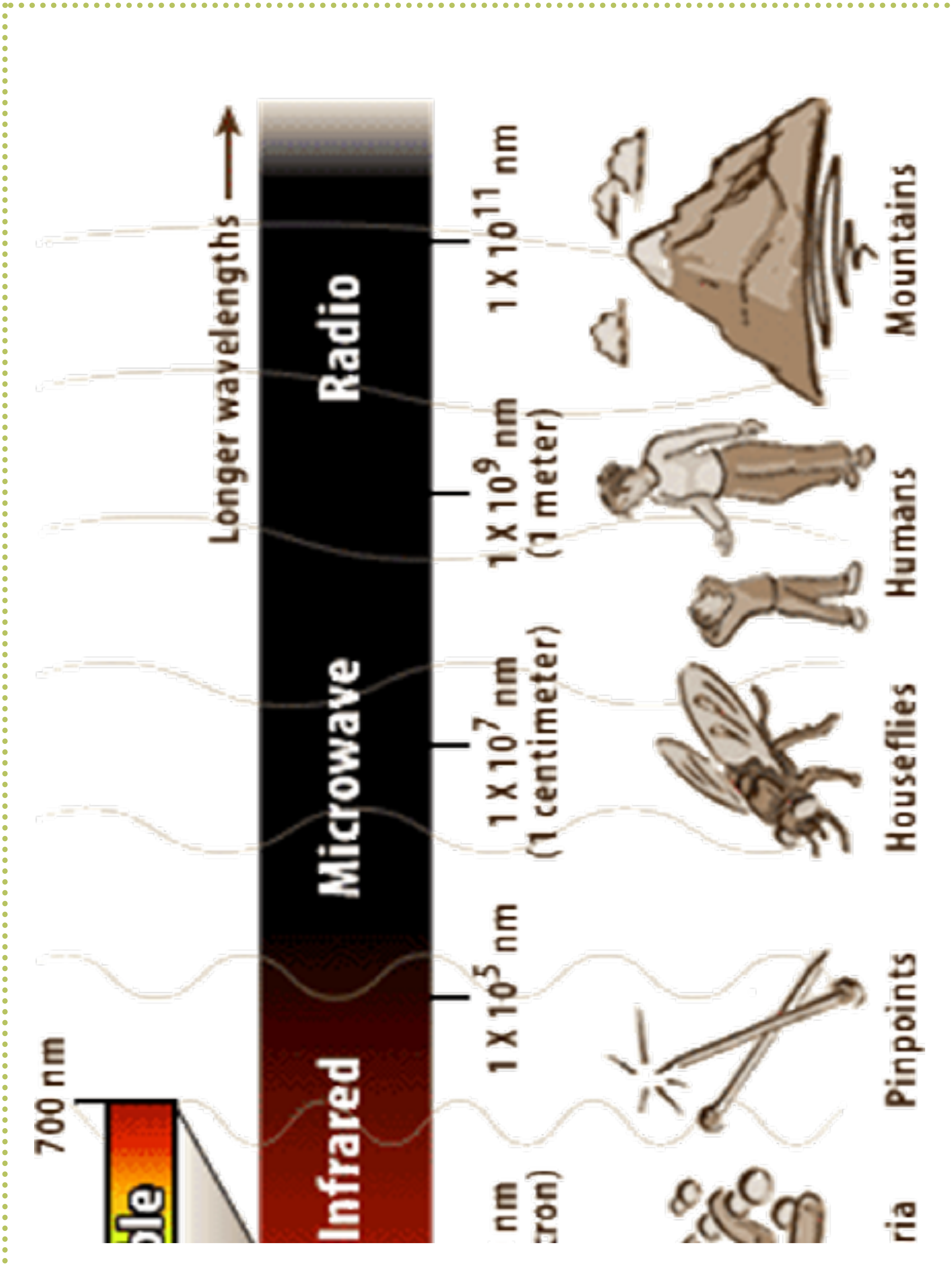
6. Looking at planets in the infrared helps us to observe their emitted light, since stars are hotter than planets and emit more of their light in shorter wavelengths. Additionally, particular atoms and molecules like water and methane have signatures in infrared light. When we use a spectrograph to break up the light from an object to sufficiently resolved component parts, it can be possible to determine if these atoms or molecules are present in the exoplanet's atmosphere.



A high resolution spectum of the Sun with many dark absorbtion lines corresponding to species in the Sun's atmosphere. Such detailed spectra are helped by the proximity of the Sun and by increasingly large ground-based telescopes. Seeing absorption lines in the spectra from other stars is more difficult since they are so much further away and we receive fewer photons. Increasingly large space-based telescopes are helping to improve our ability to detect the presence of various species in the atmospheres around exoplanets. Molecules like CO2 absorb infrared light, and make infrared spectroscapy very interesting to scientists.

Credit: NAOA


400 nm
Visi
Shorter wavelengths
Gamma ray
X-ray
Ultra-
violet
Size of wavelength
in nanometers (nm):
0.001 nm
0.1 nm
10 nm
Wavelengths are the size of:
Atoms
Molecules



Longer wavelengths
700 nm
Infrared
Microwave
Radio
1 X 10^5 nm
1 X 10^7 nm
(1 centimeter)
1 X 10^9 nm
(1 meter)
1 X 10^11 nm
Pinpoints
Houseflies
Humans
Mountains

Size (inches)	Coronagraphs		
		1.25	
0.50		1.50	
0.75		1.75	
1.00		2.00	

Watch a video tutorial of this activity on YouTube:
http://bit.ly/MakingACoronagraph

Find out more by watching our solar magnetism webcast:
http://bit.ly/Webcast6-EclipsingExoplanets

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