Mission 6
The Chemical Elements in Stars

Can You See the Light?

Notes

In Mission 5*, students made models of the Sun's immediate cosmic vicinity and the Milky Way Galaxy. They learned that there are billions upon billions of stars in our galaxy. But what are these star*s *made of? Are they made of the same chemical elements that occur on Earth? Because we are so far away from other stars that we cannot visit them to directly sample what elements they consist of, we investigate them indirectly by examining their light—starlight.*

Overview

In Mission 6.1, students use prisms to learn about the electromagnetic spectrum. In Mission 6.2, students build and use their own spectroscopes to investigate different light sources to see what types of spectra they produce. In Mission 6.3, students use their spectroscopes to examine the emission spectra of pure elements. In Mission 6.4, students evaluate the spectra from several stars. They discover that some of the chemical elements that make up Earth, and life on Earth, are also found in the stars!

Mission 6.1
Materials

For a Class of 30

- Overhead projector
- Piece of white butcher paper, chart paper or poster paper
- Thermometer
- Source of bright incandescent light
- Source of ultraviolet light (such as a black light)
- 2 meter sticks
- Thumbtack
- Standard screw-type light bulb socket with a 25-watt bulb (clear glass with a long vertical filament works best)
- *(optional)* Radio
- *(optional)* Pictures taken with infrared-sensitive film
- *(optional)* Fluorescent paints and/or minerals (such as calcite)

For Each Team

- Direct sunlight or a light box
- 2 or more clear prisms of different sizes and/or shapes
- Colored pens, markers, or pencils (full “rainbow” set)

For Each Student

- “Light, Color, and Prisms” worksheet (pages xxxxxx)
- “Remote Controls” worksheet (pages xxxxxx)
- Safety glasses
- Pencil

Getting Ready

1. Copy the worksheets “Light, Color and Prisms” and “Remote Controls” for each student.

2. If you will be constructing light boxes, boxes with light from a bright light bulb projected through a small hole or slit, you will need one light box per team. Experience has shown that holding the prisms in direct sunlight works the best, as indoor white light sources often are not bright enough.

3. Find appropriate places in the classroom for the infrared and ultraviolet demonstrations, and set these up. Try all of the demonstrations. Many of these sound easy but take a little experience to get right.

4. Have a radio available, if one will be used.

Classroom Action

1. **Discussion.** Divide the class into teams of three to four students each. Ask students if they know what the electromagnetic spectrum is. If students are not familiar with the concept of waves, draw a wave shape and label the crest, trough, and wavelength. Discuss the concept of frequency, the number of waves that pass by a fixed point or are received per second (measured in hertz). A brief analogy to sea waves may be useful: the frequency is simply the number of waves that hit the beach in a given amount of time. Also, students can hold a dangling string and shake it at different rates to see waves of different wavelengths. If you have a poster of the electromagnetic spectrum, locate with the class the waves with the longest and shortest wavelength and the highest and lowest frequency. Make this discussion relate to students’ everyday lives by identifying the ways that *they* use the electromagnetic spectrum. Encourage students to imagine what their lives would be like without many of our modern-day conveniences that use electromagnetic radiation, such as remote control devices.

2. **Challenge.** Ask students if there are electromagnetic waves in the classroom at this moment. *(There are radio and television waves of course, as well as visible light.)* Ask students how

we know that there are radio and television waves in the classroom? *(We need a "receiver" to detect them because none of OUR senses can.)*

Optional: Turn on a radio and discuss the fact that there are many frequencies of radio waves in the room and the tuner allows you to hear them. (Surprisingly, many students think the radio waves come from the batteries or the AC current where the radio plugs into the wall.) This is a good opportunity to tell them that they will be building their own radio wave detector in mission 8.

3. **Demonstration.** Tell students that they will be dissecting light with a prism. Ask if anyone knows how to make a rainbow. When light from the Sun goes through a prism (made of glass, plastic, water, or any other transparent material) what happens? After several students have voiced their opinions, demonstrate to the class how to project a color spectrum onto a screen using a prism and an overhead projector. What is the source of the color? Was the color inside the "white" light all along but only the prism allows us to see it, or is the color put there by the prism? Allow time for students to respond to these questions, but don't tell them the answer yet.

   Teacher's Note**:** *To project the spectrum, cover all of the flat surface of the overhead projector but a narrow slit, ½" to 1" wide, with opaque paper. Black construction paper works well. Hold the prism in front of the head of the projector and rotate slowly in the beam of light until the spectrum appears on the screen or wall***.**

   Students think of "white" as a color, and sunlight as being clear or colorless. Explain to them that white is all colors combined, and that different colors are different wavelengths of light. Tell the class that they will be studying light and color for the next few days. The connection between the two may hold some clues about the stars and other distant objects in space.

4. **Activity.** Hand out the "Light, Color, and Prisms" worksheet to each student. Pass out the prisms, colored pens or pencils, and light boxes (if they will be used). Explain that the first step in this study is to carefully document the pattern of colors produced when light from the Sun (or a bright light bulb) is passed through the prism and projected. Students should sketch the colors as accurately as they can. When teams are done with the first prism, they should trade with one another and record the color "print" with a second prism. Allow time for observations and completion of the worksheet.

5. **Data Collection.** On a large piece of white paper, write the question "Is there a color pattern?" across the top. Tape the paper to the wall or whiteboard. After some class discussion, ask for volunteers to re-create their color pattern onto the large poster sheet. Make sure every color pattern students have observed is on the paper. The fact that they all saw very similar spectra produced by all the prisms should lead them to infer that color is a property of the light, not of the prisms.

6. **Demonstration: Invisible Light (Infrared).** Set up a very bright, full-spectrum (continuum) incandescent white light source and a large prism to get a full spectrum of color. (A fluorescent light will not work.) Use a thermometer to measure the normal room temperature.

Hold or tape a thermometer in the red range of the spectrum. Is there a difference in the temperature? *(Yes, but it may be slight.)*

Teacher's Note: *The light from a slide projector is full-spectrum.*

Put a thermometer in the area just beyond the red color, close to but not touching the red light. Do you note any increase in temperature? *(Yes.)* Stress that any increase in temperature implies that light, and therefore energy, is present.

What is the name of the radiation that is just beyond the red end of the visible light spectrum? *(Infrared.)* Did this area show a temperature increase? *(Yes.)* What can be concluded about infrared radiation? *(It exists just beyond the red visible range.)* What are some uses for infrared radiation? *(Infrared photography; heat-sensing; keeping hamburgers warm at McDonald's.)*

Optional: Find some pictures that were taken with infrared film. Discuss these photos. What do they show? Why are some areas brighter than others? *(They are hotter.)*

7. **Demonstration: Invisible Light (Ultraviolet).** Set up a source of ultraviolet light. Warn students not to look directly at the source producing the ultraviolet radiation as it is harmful to their eyes. Ultraviolet light also reflects off surfaces. Students should only view it through glasses or sheets of glass. In a darkened room, certain minerals (such as calcite and fluorite), even teeth and the phosphorus residue left in clothing after washing, can be illuminated with this type of radiation. Fluorescent paints can be used to paint pictures. Instruct students to view them in normal light and then in ultraviolet light. In normal light, hardly any color is visible, but in ultraviolet light, the painting will be vivid.

Caution: in some schools, fluorescent paints may now be illegal.

What is the name of the radiation that is just beyond violet in the visible spectrum? *(Ultraviolet.)* Which objects seem to show the most luminescence when illuminated with an ultraviolet light? *(Those that contain minerals that "fluoresce," usually those with calcium, fluorine, or phosphorus compounds.)*

Explain that there are animals that use ultraviolet radiation. *(Bees and butterflies see in ultraviolet reflected from the stripes on some flowers and use it to find nectar in these flowers.)*

8. **Discussion.** Finish the class by sharing theories about the sources of color. Tell students that in the next few classes they will continue to explore that question, but that the next step is to build a simple yet more advanced device that also creates a pattern of colors that we can see when light goes through it.

9. **Homework**. Hand out the "Remote Controls" worksheet to each student. Stress the relationship of prisms to remote controls: both use the electromagnetic spectrum. Note that a prism is a passive device because it is splitting the colors already present in light that was

generated by a source; the remote control is an active device because it is a source that generates infrared radiation.

Mission 6.2
Materials

For a Class of 30

- Roll of heavy-duty aluminum foil
- Poster-size sheet of thin tagboard
- Single-hole punch
- Variety of lights (fluorescent, incandescent, colored)

For Each Table

- Roll of masking tape or transparent tape
- Scissors
- Single-edge razor blade

For Each Student

- 1-inch square piece of diffraction grating (holographic grating preferred)
- Cardboard (toilet paper) tube
- Colored pens, markers, or pencils (full "rainbow" set)
- "Building and Testing a Spectroscope" directions (pages xxxxx).
- "Using Your Spectroscope" worksheet (page xxx)
- Pencil

Getting Ready

1. Ask for paper towel and toilet paper tubes a week or so in advance; most students should be able to bring some from home.

2. Copy the "Building and Testing a Spectroscope" directions and the "Using Your Spectroscope" worksheet for each student.

3. Cut grating into 1" squares and place the squares of diffraction grating into an envelope for safe-keeping.

   Teacher's Note: *Diffraction gratings are degraded by fingerprints. Wear plastic gloves like medical gloves when you are cutting up the squares from larger sheets of material.*

4. Cut the tagboard into squares just a little larger than the diameter of the cardboard tubes being used. With a single-hole punch, make a hole near the center of each.

5. Following the student directions, assemble a prototype of the spectroscope to show to the class.

6. Ensure that materials for building the spectroscopes ready to distribute. Set up a variety of light sources around the classroom.

Classroom Action

1. **Discussion.** Ask students if other solar systems are likely to be common in space, considering the existence of billions of stars. If there are planetary systems around other stars, does that alone indicate that there are living things inhabiting any of them? Ask the class what requirements and conditions have to exist to support life as we know it. List student ideas. If any of the following basic ideas are not mentioned, add them to the list:

    - An atmosphere
    - Liquid water
    - Not too hot or too cold
    - The chemical elements of life (C, H, O, N, S, P)
    - Enough time for life to start
    - Geologic (planetary) recycling of chemical elements
    - Moderately quiescent conditions

    Could the stars be made of the same chemical elements that support life on Earth? Considering the limitations of space travel as a way of gathering evidence, ask students how we might learn more about the stars. Are stars "sending" us anything? If students do not come up with it themselves, suggest that the starlight itself may contain some interesting information.

2. **Spectroscopes.** Inform the class that today each student will build an advanced color spectrum device that has several advantages over the simple prism. Show the one that you have made. Like a microscope or telescope, it is designed to be aimed at what you want to look at. Its small opening and solid walls make it dark inside, so that the light you're aiming at looks brighter and the colors more vivid. And the special plastic window that you look through, which has thousands of parallel grooves on it, is less expensive than a prism, although very delicate and easy to damage. It is called a diffraction grating and it does the same job as a prism.

    With a spectroscope, it is possible to ascertain what elements a star consists of because each element will absorb and emit certain specific wavelengths of radiation. Even the student built spectroscopes will accomplish this task.

    Teacher's Note: *Throughout the discussion in this lesson, it is assumed that the specific wavelengths emitted by atoms are detected as bright emission "lines." The light appears in the spectroscope as a bright line because it enters the scope through a long, thin slit. However, spectral lines are also often detected as dark absorption lines against a bright* *continuum background. You may wish to discuss this with students. (See "Teacher Background Information" in the appendixes.)*

3. **Activity.** Hand out the "Building and Testing a Spectroscope" directions to each student. Caution students about damaging the diffraction grating with fingerprints. Students should follow the directions for building the spectroscope. Once they have completed their spectroscopes, make sure to have plenty of light sources around the room for them to observe and study. They can get a nice solar spectrum if they look at sunlight reflecting off a piece of white paper. They should be able to see dark Fraunhofer bands in the solar spectrum; these will appear as dark lines. Explain that atoms absorb the same wavelengths that they emit. The dark "missing" wavelengths (dark lines) were absorbed by atoms in the cooler outer layers of the Sun as the light passed through on its way to Earth.

   Caution students to never look at the Sun directly. This may seem obvious, but warn them not to look at the Sun in a mirror either! Because it does not seem to be "direct" sunlight, some students might try it.

4. **Activity.** Hand out the "Using Your Spectroscope" worksheet to each student. Instruct students to draw what they observe and answer all questions except for the last one.

5. **Homework.** Ask students to answer the last question on their worksheet as homework.

Mission 6.3
Materials

For a Class of 30

- Data projector, computer, PowerPoint file
- Transparency or PowerPoint slide of "Spectrum Observation" worksheet
- Transparency markers or grease pens
- One spectrum-tube power supply*
- 5 or 6 different gas tubes (H, He, Ne, N, O, Na)*
- *(optional)* Poster of spectrum emission lines

For Each Student

- Student-made spectroscopes from Mission 6.2
- Colored pens, markers, or pencils (full "rainbow" set)
- "Spectrum Observation" worksheet
- *(optional)* Commercially made and calibrated spectroscopes
- Pencil

**This equipment is expensive, but it's an excellent way for students to directly observe the emission lines of some of the pure elements. If you don't have it, try to borrow the equipment from a high school in your district*

Getting Ready

1. Obtain or borrow from a high school one spectrum-tube power supply and six different gas tubes (H, He, Ne, N, O, Na).

2. Arrange a cluster of chairs around the spectrum-tube power supply (chairs should all be within a 5- to 1-foot radius). Place the power unit as high as possible so that students in the back can see (on a chair placed on a table perhaps). For their observation to be successful, students must be close to the light.

3. Copy the "Spectrum Observation" worksheet for each student.

4. Set up the PowerPoint projector.

5. If you will be using any commercial spectroscopes, make sure they are calibrated first; otherwise there will be a lot of confusion!

Classroom Action

1. **Discussion: Chemical "Fingerprints" in Light.** So far, students have discovered that light–especially white light–is not such a simple thing. Ask if anyone can explain this more fully. Ask students to share any observations made at night with their spectroscopes. Were there any interesting discoveries? Was it possible to get a spectrum from the moon or stars?

   The colors that make up light may be a clue to the nature of the object that is giving off the light. Ask what that might be. Color indicates temperature of stars; red stars are cooler, blue and white stars are hotter. Could this information alone tell you exactly what kind of stuff is producing the light? *(No.)*

   Explain that to more accurately find out what stars are made of, students will observe samples of some *pure* elements that are energized in a glass tube (just the same way that neon lights work). But before we can interpret the light of the stars, we must be clear about the "light signature" or "fingerprint" of each element by experimenting in the lab.

2. **Demonstration.** Gather students in front of the spectrum-tube power supply. Darken the room. Put in one of the gas tubes (helium is a good one to start with), turn on the power supply, and allow students to observe with their spectroscopes. After a brief time, turn off the power and ask for student observations.

   Optional: If you have them, pass out the commercial spectroscopes (one for every two students) that have a built-in spectrum scale. It is not important to know what the numbers stand for (they are labeled in Angstrom units, which is a wavelength measurement: 1 Angstrom = 1×10^{-10} m), but they will help students be more accurate in their observations. Turn on the same spectrum tube (helium) and give time for everyone to get a feel for using the scale and numbers. Tell them to concentrate on *where* they see bright lines (called emission lines) and *what color* these bright lines are.

***Teacher's Note**: If you could not locate the spectrum-tube power supply, use the color transparencies. These images show the colored lines, so students may draw from them, but they cannot use their spectroscopes. This is a simulation only. The authors highly recommend the spectrum tubes.*

3. **Transparency.** Ask for volunteers to draw in what they saw on the blank overhead transparency of the "Spectrum Observation" worksheet. Make sure that everyone is in agreement, and ask what caused the emission lines. Make sure students realize that these emission lines are caused by the glowing helium gas, and that no other element will show lines exactly like the ones they are viewing right now for helium. In this way, emission spectra from elements are similar to fingerprints for human beings. No two elements have exactly the same pattern of emission lines.

4. **Worksheet.** Hand out the "Spectrum Observation" worksheet and colored pens, markers, or pencils to each student. Demonstrate how to record observations for each test element.

   ***Teacher's Note**: Please notice that there are color bands labeled on the worksheet and that spectral lines of various colors are to be placed within the correct color band. Impress upon students to be as accurate as possible so that the class can share their observational data.*

5. **Activity.** Begin the series of observations of all your spectrum tubes, allowing about 3-5 minutes for each test. Either at the end of each test, or at the end of the series of tests, ask for volunteers to come to the overhead projector and draw the spectral lines that they saw.

6. **Discussion.** To summarize, ask what the light signature of each element has in common. How were they different? *(The number, thickness, color, and pattern of lines varies with each element. This is due to the unique "fingerprint" nature of the lines associated with each element.)*

   After students have viewed all the tubes and discussed the meaning of the spectral lines they observed, make sure that all students have accurate emission spectra data for helium, hydrogen, neon, sodium, nitrogen, and oxygen. This is important because students will use their data to interpret the "fingerprints" of six unknown stars on their worksheets in Mission 6.4. You may wish to hand out copies of the teacher's key to "Spectrum Observation" or show a transparency of the key on the overhead projector. Ask students to compare their observations with any of the same elements that are on their worksheet. Do their data look similar? Why or why not?

Mission 6.4
Materials

For a Class of 30

- Data projector, computer, PowerPoint file
- The *Project Haystack* PowerPoint presentation

- “Star Light, Star Bright” DVD script (pages xxxx)
- Overhead projector
- PowerPoint slide of He, H, Ne, N, O

For Each Student

- “Unknown Stars” worksheet (page xxx)
- “Project Procyon: Spectra of Seven Elements” worksheet (page xxx)
- “Project Procyon: Spectra of Five Stars” worksheet (page xxx)
- “Project Procyon: Questions” worksheet (page xxx)
- Completed “Spectrum Observation” worksheet from Mission 6.3
- Pencil

Getting Ready

1. Copy the “Unknown Stars” worksheet and the three “Project Procyon” worksheets for each student.

2. Set up the data projector. Start the PowerPoint presentation at the segment “Star Light, Star Bright.” Have the script handy.

Classroom Action

1. **Slide Show.** Show the images of emission spectra in “Star Light, Star Bright.” A script has been provided. It can be used as is to accompany the DVD, or its information can be paraphrased. If you used the spectrum tubes, this image show can serve as a review, with an added introduction to the analysis of the spectra of stars. The main point is: if a star contains hydrogen, the hydrogen pattern of spectral lines would be visible though a spectroscope. If a star contains two different elements, the spectral lines for both elements would be present when viewed through a spectroscope. In reality, stars are made up of many elements and, therefore, the stellar spectra viewed by scientists are usually very complex.

   Teacher’s Note: *The absorption of light mentioned in “Teacher Background Information” in the appendixes complicates the situation by subtracting some wavelengths (creating dark lines), but this is a useful simplification for younger students.*

2. **Activity.** Hand out the “Unknown Stars” worksheet to each student. These do not represent actual stars, but are simplified models of stars, with fewer overlapping spectral lines than real stars would have. Students must list whatever elements are found in these unknown stars by comparing their own emission spectra with the spectra of the unknown stars. Students may become confused because this page is in black-and-white. Explain that the lines represent the same colored lines they have seen before. They may trace over them with the appropriate colored pencils if that helps them to see. This exercise impresses upon students that stars are in fact composed of several elements, not just one kind.

3. **Activity.** Hand out the three "Project Procyon" worksheets to each student. Students will now analyze five real stars with complex spectra. They should use the "Project Procyon: Spectra of Seven Elements" worksheet that is printed on a different scale from their own chart ("Spectrum Observation" worksheet). It also lists three new elements that are common in stars: iron, magnesium, and lithium. This chart corresponds to the five real stars.

4 **Discussion.** As a wrap-up, students compare their findings. Allow time to complete the "Project Procyon: Questions" worksheet in class, or assign it as homework.

Going Further

Research-Activity: Neon Lights

Students have observed samples of certain pure elements that are energized inside a glass tube, which is how neon lights work. But are neon lights really made of neon gas? What is neon? What color is neon? Ask students make a list of colors seen in neon lights in your town. Instruct students to find out how these lights are made and what causes their brilliant neon colors. Is it the spectral glow of certain gases, or are the tubes themselves colored? If you have access to one, bring a neon novelty lamp to class and explain how it works.

Activity: Colorful Stargazing

Encourage students go out at night and look at the stars. Then ask if they can tell which ones are "red," "white," and other colors? In a city, light pollution will make it hard to tell the color of stars, and it will even reduce the number of stars that can be seen. Darker nights are best. Ask students to borrow binoculars or a neighbor's telescope if they don't have one or the other of their own. This will help them to see the colors. Ask some students to set up cameras with tripods for long exposure photographs. As stars move across the sky, color film will record their motion as colored streaks, or trails. Exposure times of several minutes are recommended, with the lens diaphragm wide open (lowest F/stop).

Ask students to find a constellation they recognize. Without looking at an astronomy book to see what color each star is supposed to be, they should make a sketch of the stars in the constellation using colored pens. Then they should compare the colors in their sketches with those in star charts. Color indicates temperature of stars: red stars are cooler, white stars are hotter. Ask students to look at the stars again and ask which are the coolest? The hottest?

Activity: Extraterrestrial Vision

Many animals that have evolved on Earth see in the same visible light range that we humans see in. But we cannot *expect* extraterrestrials to see in the same part of the spectrum that we do! Ask students what we would look like to an extraterrestrial with infrared vision. Gamma-ray vision? What would Superman actually see if he existed and had x-ray vision? *(Actually, not much, because there are very few x-rays around to see on Earth's surface– most everything would be black! That's why x-ray telescopes are launched into space; none of the x-rays that originate outside Earth can get through our atmosphere.)*

Activity: A Prism Made from Water

A prism can be made from ordinary water. Obtain an oblong glass dish about two inches deep, a white card, a small mirror that will fit into the dish, some foil, and a small stone. Cut a 1-by-½ inch window in the foil, and then wrap the foil around the mirror. Fill the dish with water. Place the mirror in the water. Use the stone to prop the mirror up against the short side of the dish. Put the water prism in direct sunlight, or focus a bright light on the mirror indoors. Move the white card around until the light reflecting off the mirror falls on it. Display this prism in the classroom.

Activity: Magnifying a Rainbow

Can a magnifying glass be used to make a rainbow bigger? Ask students to try it. Use a water prism, or any prism, to make a rainbow appear on a white card. Put a magnifying lens in the path of the separated light. What happens? (*If you hold it about three or four inches from the card, facing the mirror, the rainbow disappears–it turns back into white light!)* Ask students to explain why this happens. *(The lens combines the colors that the prism separated.)*

Mission 6
Script for Video Images

SETI INSTITUTE

"Star Light, Star Bright"

If you used the spectrum tubes, this image show will serve as a review, with an added introduction to the analysis of stars' spectra. Use the DVD and transparencies to verify students' earlier observations. It is important to standardize the position of the emission lines on the Student Worksheet: "Spectrum Observation," so students can use their observations to analyze the elements which are present in their worksheet: "Unknown Stars." If you were not able to use spectrum tubes, this image show will have to serve as a substitute. Hand out the Student Worksheet: "Spectrum Observation" and colored pens or pencils. Demonstrate how to record observations for each test element. Begin the series of observations of all the images, allowing about three minutes for each element.

Introduction

Many ancient peoples called stars "the lights in the sky." Today, we can interpret the light of the stars and find out what elements they are made of. We can see if the stars are made of the same elements that we are made of.

Image # 6.41: White Light, Rainbow Spectrum

You have discovered that white light is actually composed of all of the colors of the rainbow. You have used a prism to refract light waves into a rainbow. This is the same process that occurs when you see a real rainbow in the sky after a rain. Water droplets in the atmosphere act as prisms and bend the light. A full rainbow is called a spectrum. In this image, a light bulb produces white light that includes all the colors of the rainbow, so it produces a "continuous spectrum."

Teacher's Note: *You may want to spray mist in front of a light–an overhead–to produce a rainbow. Do not spray directly on a bulb as it may explode.*

Image # 6.42: Continuous Spectrum

This is a close-up of a "continuous spectrum." Notice that there are numbers along the top and the bottom of the spectrum. These numbers are Angstrom units; they are a measurement of wavelength. 1 Angstrom = 1×10^{-10} m. Scientists use these numbers to describe exactly what color they are talking about. What wavelengths correspond to the color "red"? *(Red is any light from about 6200 angstroms to 7500 angstroms in wavelength.)* You may use these numbers to be more exact and accurate in your observations of spectra. Commercial spectroscopes have a built-in spectrum scale with these measurements.

Image # 6.43: Wavelength and Frequency: Violet Waves and Red Waves

Light travels in waves. This picture shows two waves of different wavelengths. The shorter wave length is 3500 angstroms, which is violet. The longer wavelength is 7000 angstroms, which as we have seen is red. This longer wave is twice the wavelength of the shorter wave.

The visible spectrum contains light that ranges in wavelength from 3500 angstroms on the violet end to 7500 angstroms on the red end. What kind of light occurs at wavelengths shorter than 3500 angstroms? *(Ultraviolet light.)* What kind of light occurs at wavelengths longer than 7500 angstroms? *(Infrared light.)* What kind of light occurs at a wavelength of 5400 angstroms? *(Visible green light.)* All the colors that the human eye can detect are produced by light with wavelengths between 3500 and 7500 angstroms.

Image # 6.44: The Spectrum of Sodium

Although white light produces a continuous spectrum, individual chemical elements produce only a part of this spectrum. Sodium is a common element, which is found in table salt (sodium chloride). If pure sodium is burned, and viewed as in this image, it produces two distinct yellow lines that are close to each other, occurring at around 5850 angstroms. These bright lines are called emission lines. The entire spectrum of emission lines is called an emission spectrum. The emission spectrum of sodium is very simple. No other element will make spectral lines exactly like the ones you are viewing right now for sodium! That is why scientists call an emission spectrum the “light signature” or “fingerprint” of an element. Just as no two people have exactly the same signature, or the same fingerprints, no two elements have the same emission spectrum.

Image # 6.45: The Spectra of Stars

This image shows the spectra of six stars. Astronomers know that if a star contains sodium, this sodium pattern of emission lines would be visible though a spectroscope when we look at that star’s light. Can you see the spectral lines of sodium on any of these stars? *(Yes, on all of them!)*

Why are there so many other spectral lines? *(Stars are composed of several elements, not just one kind.)* The main point is: If a star contains two different elements, the spectral lines for both elements would be present when viewed through a spectroscope. In reality, stars are made up of many elements; therefore, the spectra viewed by scientists are usually very complex.

You will soon be asked to analyze the spectra of some “unknown stars” to see what elements they are made of. To do this, you must know what the emission lines for each pure element are like. This can be done by burning the element and looking at the flame, by using special “spectrum tubes,” or simply by looking at the patterns that scientists have discovered. In this image show, we will look at the patterns.

Teacher’s Note: *The continuous spectra with the dark lines is the spectrum from the star. The emission line spectrum above and below each continuous spectrum is a reference, or laboratory spectrum. So, the sodium lines appear as dark lines in the yellow part of the continuous spectrum in the same place as the bright sodium lines appeared earlier.*

Image 6.46 Neon and Sodium

The emission lines in the top spectrum are the ones caused by glowing neon gas. No other element will make lines exactly like the ones you are viewing right now for neon. If a star contains neon, this neon pattern of spectral lines would be visible through a spectroscope when we look at that star's light. Concentrate on *where* you see bright emission lines and what *color* these bright lines are. Draw these lines on your worksheet.

The emission lines in the bottom spectrum are the ones caused by glowing sodium gas. No other element will make lines exactly like the ones you are viewing right now for sodium. If a star contains sodium, this sodium pattern of spectral lines would be visible through a spectroscope when we look at that star's light. Concentrate on *where* you see bright emission lines and what *color* these bright lines are. Draw these lines on your worksheet.

Image 6.47 Helium and Hydrogen

The emission lines in the top spectrum are the ones caused by glowing helium gas. No other element will make lines exactly like the ones you are viewing right now for helium. If a star contains helium, this helium pattern of spectral lines would be visible through a spectroscope when we look at that star's light. Concentrate on *where* you see bright emission lines and what *color* these bright lines are. Draw these lines on your worksheet.

The emission lines in the bottom spectrum are the ones caused by glowing hydrogen gas. No other element will make lines exactly like the ones you are viewing right now for hydrogen. If a star contains hydrogen, this hydrogen pattern of spectral lines would be visible through a spectroscope when we look at that star's light. Concentrate on *where* you see bright emission lines and what *color* these bright lines are. Draw these lines on your worksheet.

Image 6.48 Nitrogen and Oxygen

The emission lines in the top spectrum are the ones caused by glowing nitrogen gas. No other element will make lines exactly like the ones you are viewing right now for nitrogen. If a star contains nitrogen, this nitrogen pattern of spectral lines would be visible through a spectroscope when we look at that star's light. Concentrate on *where* you see bright emission lines and what *color* these bright lines are. Draw these lines on your worksheet.

The emission lines in the bottom spectrum are the ones caused by glowing oxygen gas. No other element will make lines exactly like the ones you are viewing right now for oxygen. If a star contains oxygen, this oxygen pattern of spectral lines would be visible through a spectroscope when we look at that star's light. Concentrate on *where* you see bright emission lines and what *color* these bright lines are. Draw these lines on your worksheet

Image 6.49 Two Unknown Stars

Here is a chance for you to test your skills! These are the spectra of two different "Unknown Stars." Can you tell which elements are present in each star? Look closely, and use your worksheet to compare the emission lines. *(The first unknown star has hydrogen and sodium. The second unknown star has hydrogen and helium.)*

Both of these "Unknown Stars" only had two elements. These are simple examples. Look out! Real stars, and the Unknown Stars on your worksheet, have more than two elements present! This will take some good detective work. You will now have a chance to analyze three simulated, "unknown stars" for practice, and then you will analyze five real stars with complex spectra.

Stop and Assess "Star Light, Star Bright"

1. Back up and take a second look at various images if students want to study them.

2. After you have viewed all the images and discussed the meaning of the spectral lines they have observed, make sure that all students have accurate spectral data for helium, hydrogen, neon, sodium, nitrogen, and oxygen.

3. Ask: Can *you* identify all the elements in a star by looking at the light of that star?

Mission 6
The Chemical Elements in Stars

Light, Color, and Prisms–Teacher's Key

1. The two color "prints" should show the same colors, in the same order or arrangement, but the widths and intensities may be different.

2. This drawing should include the same six (or seven) basic colors: red, orange, yellow, green, blue, (indigo), and violet. (The seventh color, indigo, is seldom clearly different from blue or violet. Isaac Newton included it primarily due to his belief in the sacredness of the number seven.)

3 The color is part of the white light. White light is made up of many different wavelengths or colors. The prism, due to its shape, spreads the white light out into its several wavelengths *allowing* you to see the colors.

4. Stars give off light in a number of wavelengths, which combine to form white light. The Sun gives off white light and the Moon and other planets reflect some of this white light back to Earth.

5. They do! If you split up the white light coming from a star with a prism the light spreads out and it is possible to see the different wavelengths that make up the white light. However, starlight is too faint to do this without a sophisticated setup.

6. It is possible through a fairly simple arrangement of two prisms. If one prism is used to split up light, another prism positioned upside down with respect to the first one will reconstruct the white light. You will need to adjust the distances and the angles until it works.

Mission 6
The Chemical Elements in Stars

Remote Controls–Teacher's Key

1. Answers will vary: television, CD player, and so on.

2. The remote control needs batteries to create light in the infrared region of the spectrum.

3. There should be a clear or dark plastic panel somewhere on the front of the device. Behind this panel is a detector that can receive energy from the remote control device.

4. Depending on the strength of your remote control device it is possible that it will work at both 90° and 180°, while some devices barely work when they are pointing directly at the panel.

5. Again, some will and others will not, depending on their effectiveness.

6. When we tested our remote control device we got the following results:
   a. No (too thick)
   b. Yes
   c. No (electromagnetic radiation at these wavelengths will not penetrate any good electrical conductor, *e.g.*, metal)
   d. Yes
   e. Yes
   f. Yes
   g. No (too thick)
   h. No (electrical conductor)
   i. No (too thick)

7. Examples might include: a pillow, plastic plate, wood, and so on.

8. You have to point the remote control device directly at the glass or mirror and then have the angle from the glass to the detector panel be the same as the angle from the other side of the glass to the remote control device (the angle of incidence must equal the angle of reflectance).

9. The remote control device operates by sending infrared light from the remote control device to the detector panel. If a material allows this light to pass through it, then the controller will operate the device. In general thin, non-conducting materials like paper and cloth will transmit light. The light can also be bounced off the ceiling and various materials with a powerful controller.

10. The light spreads out in many directions and enough reaches the detector to have it detect the light. Some of the light is also reflected off of various objects and materials in the room including walls and ceilings and eventually reaches the detector.

11. Most remote control devices work in infrared wavelengths of the electromagnetic spectrum.

12. Wavelength is approximately 10,000 Angstroms or 10^{-6}m and frequency is 3×10^{14} Hertz.

SETI INSTITUTE

Mission 6
The Chemical Elements in Stars

Using Your Spectroscope–Teacher's Key

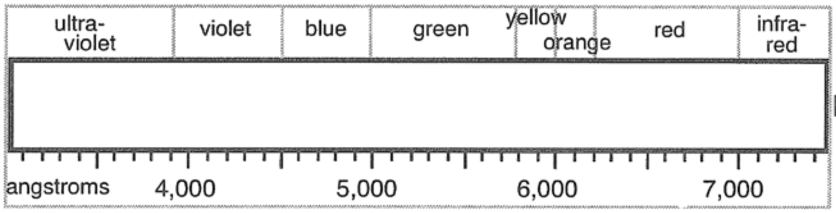
1. The sources of the colors that you are observing are the various elements that are present. These elements are in their atomic or molecular forms and can be excited with an electric current coming from the wall, or with batteries. Each color (or spectral line) is created when an electron is forced to jump from one orbit to another in the atom of that element. The orbits are spaced differently in different elements, causing the light created by the jumps to be of different wavelengths.

2. We see different spectral lines because the light sources contain different elements. Each element has a unique color signature or set of spectral lines. Even though the light from different light sources appears to be white light, it actually has dominant wavelengths due to its specific elements. When you look at a light source with a grating you see the dominant wavelengths that correspond to the element's "spectral lines." This implies that every spectrum consists of discrete lines. However, an incandescent light or the Sun produce continuum light as well. That is light that is spread over the entire visible spectrum. The concept of a continuum may need to be addressed, both because the Sun (or any star) produces such a thing, and because if you don't mention it, students who look at incandescent light and fail to find lines may think they're doing something wrong. The distribution of continuum light is determined by a star's temperature, and that is why the color of a star is a direct indicator of how hot it is.

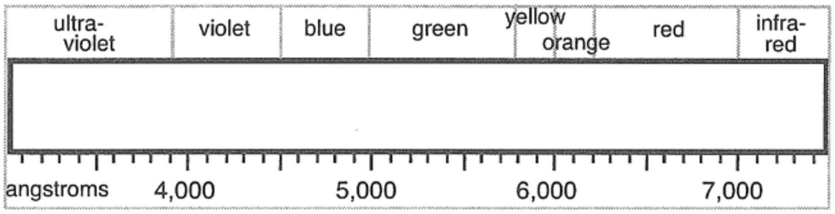
Mission 6
The Chemical Elements in Stars

Spectrum Observation–Teacher's Key

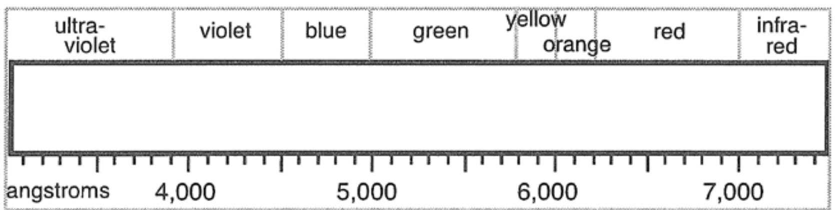
Figure 6.1.



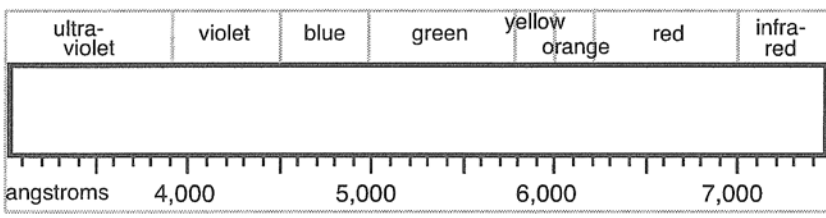
HELIUM



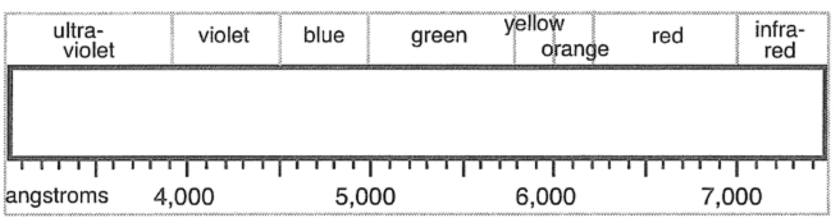
HYDROGEN



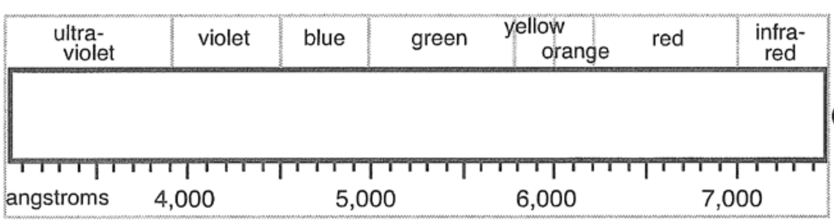
NEON



SODIUM



NITROGEN



OXYGEN

Mission 6
The Chemical Elements in Stars

Unknown Stars–Teacher's Key

The "unknown stars" contain:

Star # 1: Hydrogen and Neon
Star # 2: Hydrogen, Helium, and Oxygen
Star # 3: Neon and Oxygen
Star # 4: Helium, Sodium, and Oxygen
Star # 5: Hydrogen, Sodium, and Nitrogen
Star # 6: Helium and Nitrogen

Mission 6
The Chemical Elements in Stars

Project Procyon Questions–Teacher's Key

1. Nitrogen and Oxygen.

2. Iron, Lithium, and Magnesium.

3. There are over 100 elements; each list selected a few common ones. In class, we used nitrogen and oxygen because they are common elements in living things. In "Project Procyon," iron, lithium, and magnesium were used because they are common in stars.

4. The "Project Procyon" stars are:

   Procyon: Hydrogen, Sodium, Lithium, Helium

   Betelgeuse: Hydrogen, Iron, Neon, Sodium, Lithium, Magnesium, Helium

   Aldebaran: Hydrogen, Iron, Sodium, Lithium, Magnesium, Helium

   Sirius: Hydrogen, Helium

   Sol (our Sun): Hydrogen, Iron, Sodium, Lithium, Magnesium, Helium

5. No. The spectral lines of some elements are missing from all stars except Betelgeuse.

6. Hydrogen and Helium.

7. Possible explanations: Lines of other elements and/or molecules; interference lines from terrestrial sources such as sodium vapor street lights.

8. Possible explanations: The thickness of the line may be proportional to the quantity of the substances; thicker lines may really be composed of many narrow, densely packed lines. *(Optional: The thickness of the line may depend on pressure in the stellar atmosphere. The lines will also be thicker if the star is rotating rapidly.)*

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