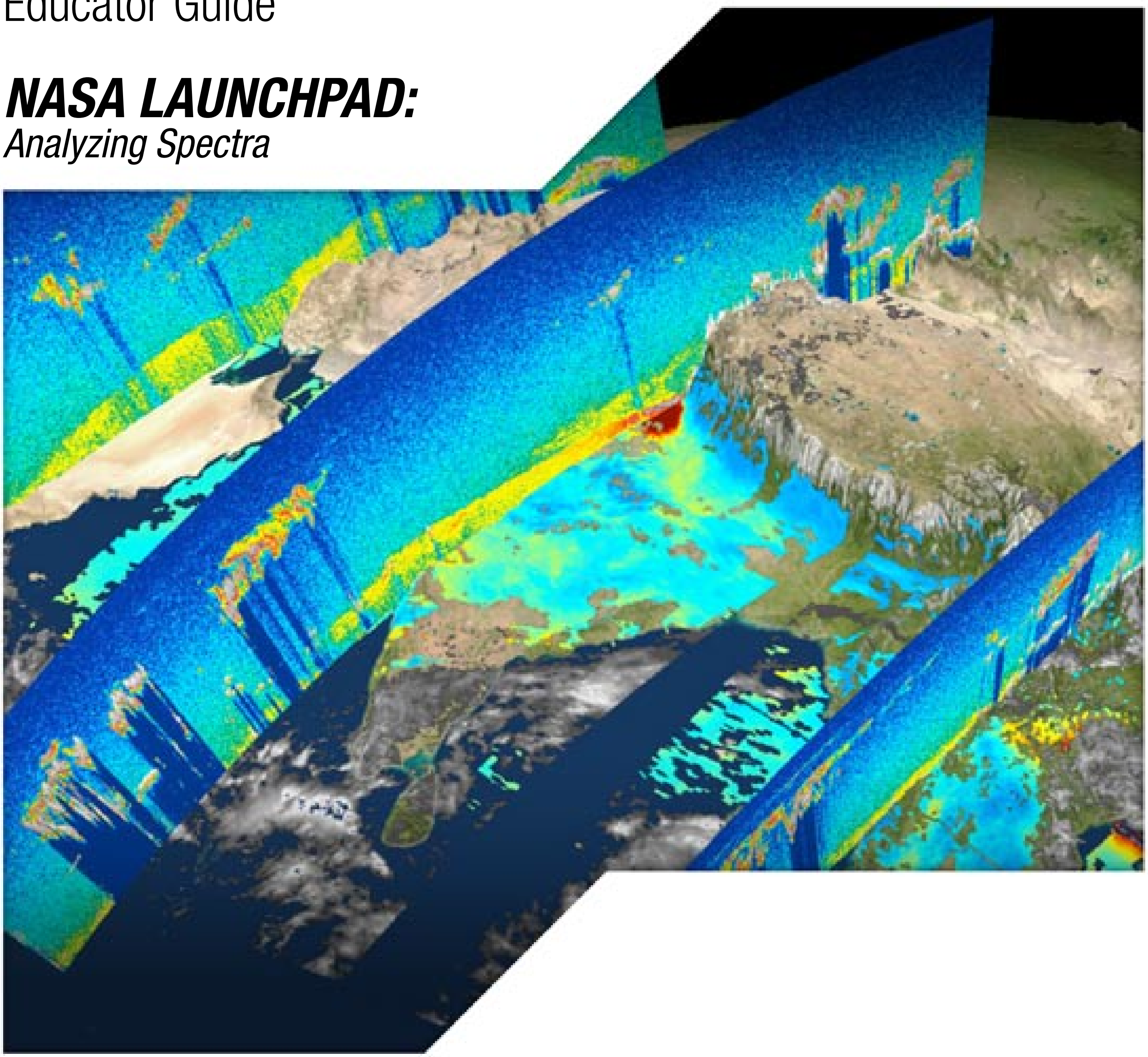
National Aeronautics and Space Administration

NASA eClips™

Educator Guide

NASA LAUNCHPAD:

Analyzing Spectra



Educational Product	
Educators & Students	Grades 8-10

EG-2010-07-011-LaRC

ANALYZING SPECTRA

National Standards:
National Science Education Standards (NSES)

Science as Inquiry
Abilities necessary to do scientific inquiry
Understanding about scientific inquiry

Physical Science
Interactions of energy and matter

Science and Technology
Understanding about science and technology

National Council of Teachers of Mathematics (NCTM)

Measurement
Understand measurable attributes of objects and the units, systems, and processes of measurement

International Society for Technology in Education: National Educational Technology Standards (ISTE/NETS)

Digital Citizenship
Advocate and practice safe, legal, and responsible use of information and technology

Grade Level:
8-10

Subjects:
Physical Science, Earth and Space Science

Teacher Preparation Time:
20 to 30 minutes

Lesson Duration:
Two 55 minute class periods

Time Management:
Class time can be reduce to one 55 minute period if students complete the EXPLAIN, EXTEND, and EVALUATE sections at home.

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5E Inquiry Lesson Development

ENGAGE (15 minutes)

1. Write ROY G BIV on the board. Ask the students to discuss what they think the letters represent. *(They represent the colors of the rainbow in order – red, orange, yellow, green, blue, indigo, violet.)*
2. Ask students to explain how a rainbow is formed. *(Light is being refracted by small water droplets in the atmosphere.)* Tell them you will demonstrate this with a prism.
3. Turn the lights off and shine a red light through a prism. Be sure the light exiting the prism shines on a screen or board. Ask the students to share what they observe. *(Students will observe that the light exits at a different angle than it entered.)* Lead students to understand that the red light is being refracted by the prism as it travels through the prism.
4. Ask students to predict what will happen if a blue light is used instead of a red light. Shine a blue light through a prism and ask the students to compare their predictions to their observations. *(Students should observe that the blue light exits at a different angle than the red light.)*
5. Ask students to predict what will happen when light white is used. Shine a white light through a prism and ask the students to discuss what they observe. *(Lead students to understand that white light is composed of all of the colors of the rainbow and that each color represents a specific wavelength of light. As the white light passes through a prism, the different wavelengths of light are refracted at different angles so the individual colors can be observed.)*
6. Keeping the prism and the light source location constant, shine each light through the prism and on to a white board or white poster paper. Mark the position of the light on the board.

EXPLORE (40 minutes)

In this activity, students will build a spectrometer and view a spectrum of a fluorescent and incandescent light.

1. **(TECHNOLOGY)** Show the NASA eClips™ video segment *Launchpad: Neon Lights – Spectroscopy in Action* (5:55) to the students. This segment can be found on the NASA eClips™ page of the NASA web site:

   http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms=neon&category=0000

   The video may be streamed or downloaded from the nasa.gov web site; a captioned version is also available at the nasa.gov site.

   (MODIFICATION) This video may be streamed from the NASA eClips You Tube™ channel: http://www.youtube.com/user/NASAeClips#p/c/D7BEC5371B22BDD9/2/SPgYrsONgwU

2. Have students read the background information on pages 1 and 2 of the Student Guide.

   (CHECK FOR UNDERSTANDING) Ask students the difference between a continuous spectrum, an absorption spectrum, and an emissions spectrum. *(A continuous spectrum contains all the colors of the rainbow as one continuous band and is produced when an object is heated. An absorption spectrum looks similar to a continuous spectrum except that there are black lines where elements absorb specific wavelengths of light. The pattern of black bands is different for every element. An emission spectrum looks like a negative image of an absorption spectrum. Elements in the gas state can release certain wavelengths of light when exposed to high energy.)*

3. Divide the class into groups of two or three. Distribute the materials for the activity to each group.

4. Have students complete the EXPLORE activity on pages 3 – 5 in the Student Guide.

   (MODIFICATION) Allow students time to use different light sources such as flashlights, LED lights, computer screens, etc.

   (MODIFICATION) Classroom sets of spectroscopes can be ordered from the Stanford Solar Center http://solar-center.stanford.edu/posters/colors.html.

5. **(MODIFICATION)** Using spectrum glasses and different gas emission spectrum tubes allow students to see the spectra of different elements. Ask students to sketch what they observe and share their sketches with the class.

EXPLAIN (15 minutes)

1. While still in groups, ask students to answer the questions on page 6 of the Student Guide.

2. **(CHECK FOR UNDERSTANDING)** Ask students to share their answers with the class. Lead students to understand that an incandescent light and a fluorescent light produce light by different methods. Most fluorescent lights use mercury vapor and a phosphorescent coating to produce light whereas incandescent lights produce light by heating a filament.

EXTEND (15 minutes)

1. **(TECHNOLOGY)/(CONNECTIONS)** Show the NASA eClips™ video segment *Launchpad: New Horizons Heads Towards Pluto* (6:04) to the students. This segment can be found on the NASA eClips™ page of the NASA web site: http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms="heads%20towards%20pluto"&category=0010

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The video may be streamed or downloaded from the nasa.gov web site; a captioned version is also available at the nasa.gov site.

(MODIFICATION) This video may be streamed from the NASA eClips You Tube™ channel: http://www.youtube.com/user/NASAeClips#p/c/D7BEC5371B22BDD9/27/_a9UnZeBExo

2. Ask students to complete the EXTEND activity on pages 7 and 8 of the Student Guide.

   (TECHNOLOGY) Use the virtual spectrometer at the very top of http://mo-www.harvard.edu/Java/MiniSpectroscopy.html to view spectra of a fluorescent lamp, the sun, a red LED, and several galaxies *(there is a drop-down menu to select the source)*. Ask students to compare them to and explain the differences they see.

3. Ask students to share their answers with the class.

4. **(CHECK FOR UNDERSTANDING)** Ask students to compare the work they completed during this lesson to the work the instruments on board New Horizons do as the satellite travels to Pluto.

5. Have students brainstorm other uses for the spectroscope thy have built. Have students design an activity that incorporates one of their ideas.

EVALUATE (20 minutes)

1. Use questions, discussions, and student handouts used throughout the lesson to assess students' understanding.

2. Ask students to summarize their learning by answering these journal questions:

   a. What are the basic properties of light that can be examined with a spectrometer?
   (A spectrometer can be used to determine the individual wavelengths that make up light, the intensity of the light, and the source of the light, i.e. heat or elements absorbing or releasing light.)

   b. How does the use of spectra help scientists learn about the universe?
   (Scientists can use the information gathered about spectra to determine the composition, density, temperature, rotation, and speed of celestial objects.)

   c. How does technology advance science?
   (As technology advances, scientists gather information about the universe. In this lesson, students learned about how sophisticated spectrometers enable scientists to learn more about Pluto.)

ANALYZING SPECTRA

Essential Questions

- What are the basic properties of light that can be examined with a spectrometer?
- How does the use of spectra help scientists learn about the universe?
- How does technology advance science?

Background

Scientists can learn a great deal about an object in space by studying its spectrum. They can determine such things as the composition, temperature, and density of the object. They can also determine the object's rotation and how fast it is moving towards or away from Earth.

The study of the light and associated spectrum emitted from an object is called **spectroscopy**. **Spectrometers** are instruments which measure light by spreading it out to create its spectrum. Within this spectrum, scientists study emission and absorption lines.

There are three types of spectra which an object can emit: continuous, emission and absorption. **Continuous spectra**, also called a thermal or blackbody spectra, are emitted by any object that radiates heat. As shown in Figure 1, the light is spread out into a continuous band of colors with every wavelength having some amount of radiation. For example, when sunlight is passed through a prism, its light is spread out into its component colors.

Figure 1. A continuous visible light spectrum. Image credit: SIRTF Science Center.

If you use a more precise spectrometer to look at the Sun's spectrum, you will notice the presence of dark lines, as shown in Figure 2 below. These lines are caused by gaseous elements in the Sun's atmosphere absorbing light at these **wavelengths**, so this type of spectrum is called an **absorption spectrum**. The atoms and molecules in a gas will absorb only certain wavelengths of light. The pattern of absorption is unique to each element and tells us what elements make up the atmosphere of the Sun. Compare Figure 3, the absorption spectrum of hydrogen, with Figure 2. There are dark bands in the same part of both spectra, indicating the presence of hydrogen in the Sun.

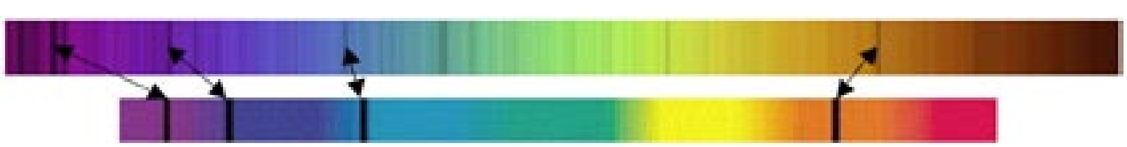

Figure 2 and 3. The absorption spectrum of the sun and hydrogen. Image credit: SIRTF Science Center.

An **emission spectrum** occurs when the atoms and molecules in a hot gas emit light at certain wavelengths, causing bright lines to appear in a spectrum. As with absorption spectra, the pattern of these lines is unique for each element. We can see emission spectra from comets, nebula and certain types of stars.

Figure 4. The emission spectrum of hydrogen. Image credit: SIRTF Science center.

Resources

Infrared Spectroscopy
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/ir_tutorial/spec.html

Imagine the Universe
http://imagine.gsfc.nasa.gov/docs/science/science.html

Vocabulary

absorption spectrum – An **absorption spectrum** is a spectrum, broken by a specific pattern of dark lines or bands, observed when light passes through a gas. The absorption pattern is unique and can be used to identify the gas.

diffraction grating – A **diffraction grating** is a surface with many closely spaced parallel grooves or splits in it which splits and diffracts light to produce the light's spectrum.

electromagnetic spectrum- The **electromagnetic spectrum** is a continuum of radiation based on wavelength ranging from radio waves through gamma radiation.

emission spectrum – An **emission spectrum** is a spectrum of bright lines or bands of light of specific wavelength which are emitted when a gaseous element is exposed to high energy. Each element has its own unique pattern of bands.

Kuiper Belt – The **Kuiper Belt** is the region beyond the orbit of planet Neptune, similar to the asteroid belt, consisting of the remnants from our Solar System's formation.

spectroscope – A **spectroscope** is an instrument used to produce and observe spectra.

spectroscopy – **spectroscopy** refers to the science and practice of using spectrometers and spectroscopes and of analyzing spectra.

spectrometer – A **spectrometer** is a spectroscope equipped with scales for measuring wavelengths or indices of refraction.

wavelength – **wavelength** refers to the distance between two points of the same phase in consecutive cycles of a wave.

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EXPLORE

A compact disc (CD) contains a large amount of information encoded onto its surface. This information is stored in concentric rings that are read by a laser beam while the disc is spinning. If the light hits the concentric rings just right, the rings act as a **diffraction grating**, separating the light into the component colors that make it up. You will use this property to build a spectroscope with a CD. The **spectroscope** will allow you to observe the spectra produced by different light sources and compare them.

1. Your group should gather the following materials:
    - fluorescent light source
    - incandescent light source
    - compact disc or DVD
    - cardboard tube 25 cm long, such as the tube from a roll of paper towels
    - opaque, peel and stick compact disc label
    - scissors
    - tape
    - ruler
    - colored pencils
2. Cut a 1.5 cm x 4.0 cm wedge out of the peel and stick compact disc label as shown in figure 5 below.

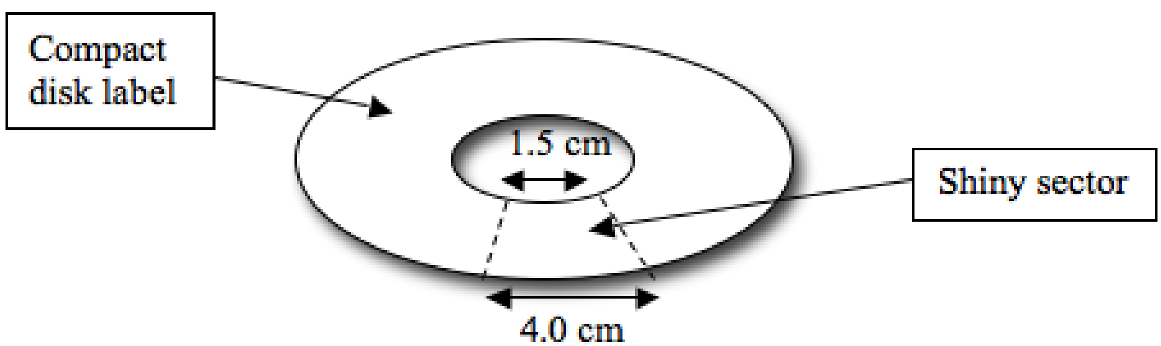

Figure 5. Preparing compact disk label.

3. Lay the printed or labeled side of the compact disc facing downward on a flat surface.
4. Peel off the backing and attach the label to the compact disc covering the shiny side of the disc.
5. Lay the cardboard paper towel tube on the table and locate the point at the bottom of the tube where the spiral line begins as shown in Figure 6 below.

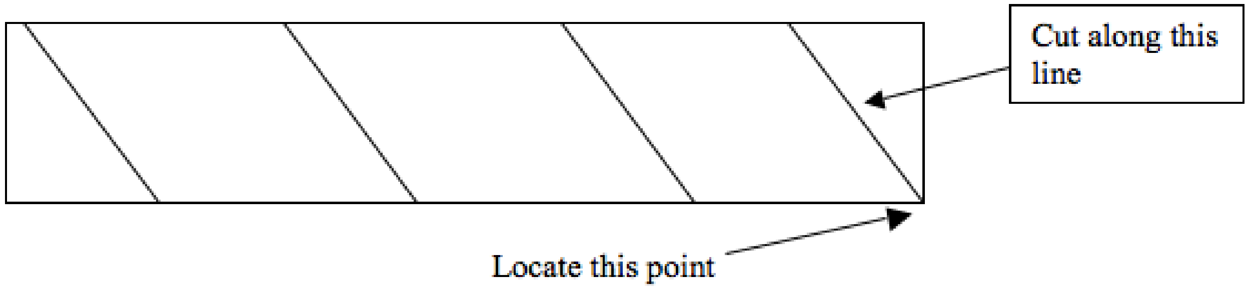

Figure 6. Orienting paper towel tube.

6. Flatten the end of the tube near the selected point, and cut off a wedge from the tube using the spiral line as a guide, forming a tapered end. Rotate the tube so that the tapered part of the tube is on top as you look down at it.
7. Cut a 3 cm slit into the tapered end of the tube and use the slit to cut out a 3 cm x 1.5 cm rectangular window. Add a short piece of transparent tape to the end of the slit to reseal the end of the tube as shown in Figure 7 below.

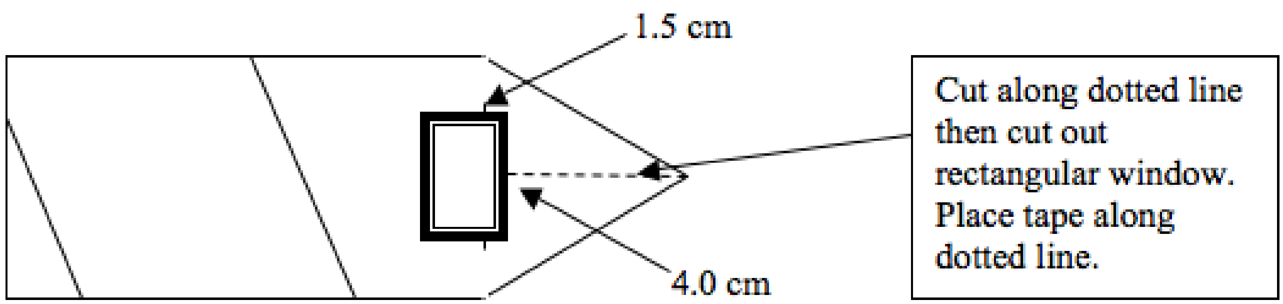

Figure 7. Adding a viewing window (top view).

8. Position the tapered end of the tube over the shiny section of the compact disc and point the other end of the tube toward the fluorescent light source. Look through the window to observe the spectrum. Record what you see in the space below the diagram.

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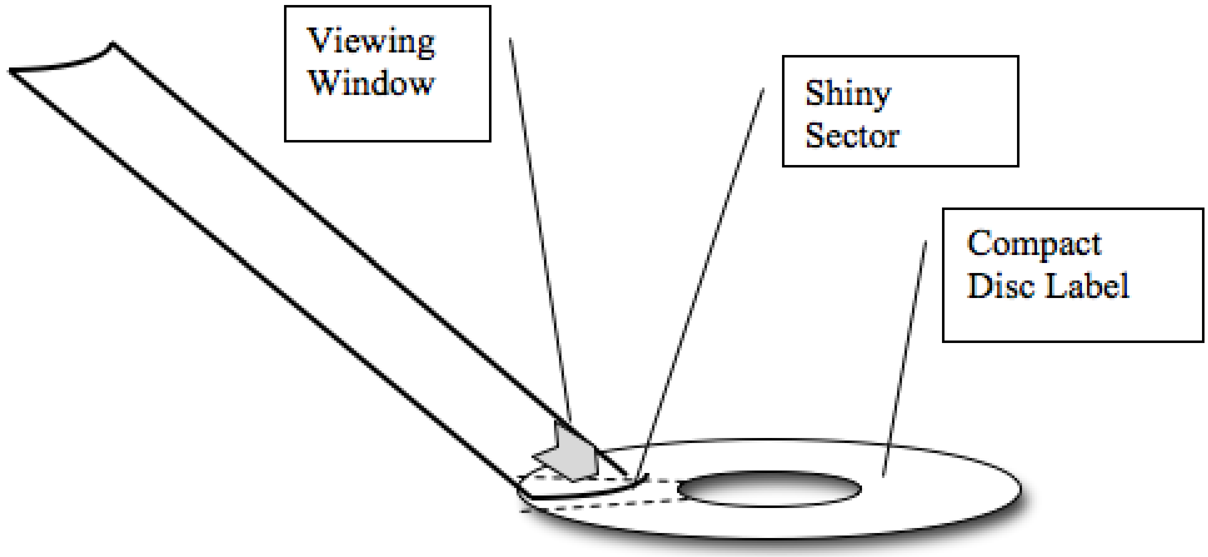

Figure 8. Viewing the spectrum.

Diagram of fluorescent light spectrum

9. Point the tube towards an incandescent light source. Record what you see in the space below.

Diagram of incandescent light spectrum

10. (Optional) If directed by your teacher, observe additional light sources and record what you see on a separate piece of paper.

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EXPLAIN

1. What differences did you see between the spectra observed from a fluorescent light versus an incandescent light?

2. Why do you think that the different lights had different spectra?

3. Based on what you have learned and observed, do you think all green light is composed of blue and yellow light?

EXTEND
Background

Planetary exploration is a major focus of NASA. Launched in 2006, New Horizons is heading towards Pluto to help us understand worlds at the edge of our solar system. It will take more than eight years for this spacecraft to reach Pluto. Pluto, while now being classified as a minor planet, is the last of the former nine planets in our solar system to be visited by a spacecraft. As part of an extended mission, New Horizons will visit one or more objects in the **Kuiper Belt** region beyond Neptune.

Among the many scientific instruments on board New Horizons are spectrometers. Spectrometers will help NASA scientists answer such questions as

- What gases makes up Pluto's atmosphere?
- What does the surface of Pluto look like?
- How do particles ejected from the sun, called the solar wind, interact with Pluto's atmosphere?

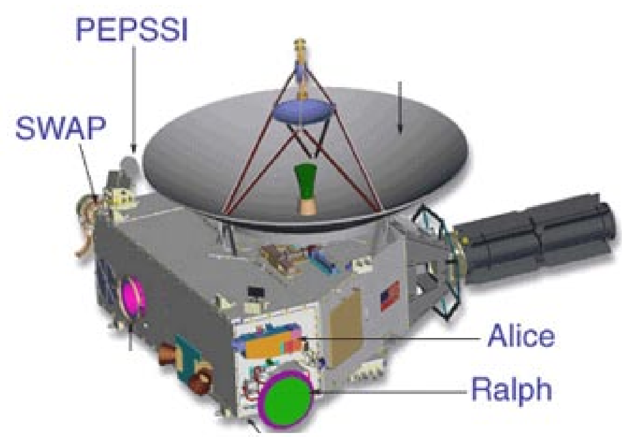

Figure 9. New Horizons baseline spacecraft design. Image Credit: The Boeing Company.

The science payload on New Horizons includes several spectrometers:

Ralph: Visible and infrared imager/spectrometer; New Horizon's main source of sight and provides color, composition and thermal maps.

Alice: Ultraviolet imaging spectrometer; analyzes composition and structure of Pluto's atmosphere and looks for atmospheres around Charon and Kuiper Belt Objects (KBOs). Charon is the largest satellite of Pluto

SWAP: (Solar Wind Around Pluto) Solar wind and plasma spectrometer; measures atmospheric "escape rate" and observes Pluto's interaction with solar wind.

PEPSSI: (Pluto Energetic Particle Spectrometer Science Investigation) Energetic particle spectrometer; measures the composition and density of plasma (ions) escaping from Pluto's atmosphere.

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Resources

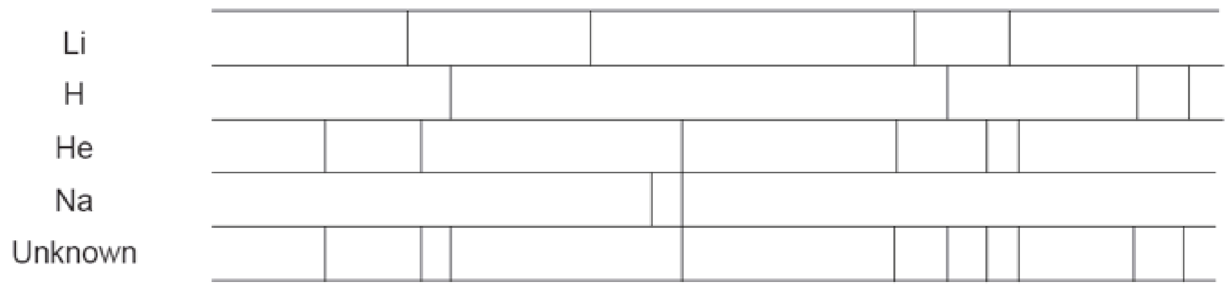
New Horizons Spacecraft and Instruments

http://www.nasa.gov/mission_pages/newhorizons/spacecraft/index.html

New Horizons Overview

http://pluto.jhuapl.edu/spacecraft/overview.html

Below are the emission spectra of four elements and the spectrum of an unknown sample of gas.



1. What elements are found in the unknown sample?

2. How were you able to exclude the other elements?

3. Young stars contain a large amount of hydrogen and a small amount of helium and other elements. Could this be the spectrum of a young star? Why or why not?

EXPLAIN

1. What differences did you see between the spectra observed from a fluorescent light versus an incandescent light?
   (Answers will vary but should include the observation that the fluorescent light appeared as an emission spectrum whereas the incandescent light appears as a continuous spectrum.)

2. Why do you think that the different lights had different spectra?
   (Fluorescent lights produce their light by using the properties of specific elements such as mercury whereas incandescent lights produce light by heating a wire. Therefore the light from the fluorescent light contains the emission spectrum "fingerprint" of the elements in the light. Light produced by heating emits a continuous spectrum.)

3. Based on what you have learned and observed, do you think all green light is composed of blue and yellow light?
   (No. It is possible that a green light source uses substances that emit light mostly in the green portion of the visible spectrum.)

EXTEND

1. What elements are found in the unknown sample?
   (Hydrogen and helium)

2. How were you able to exclude the other elements?
   (By comparing the spectrum of the unknown star with the spectra of the elements. If you are able to match up all the lines to a known spectrum that element is found in the unknown star. If you are unable to match up similar spectrum lines that element is not found in the unknown star.)

3. Young stars contain a large amount of hydrogen and a small amount of helium and other elements. Could this be the spectrum of a young star? Why or why not?
   (It could be the spectrum of a young star. Both hydrogen and helium are present AND there are additional lines in the unknown spectrum indicating that there are other elements present.)

answerkey