Cosmic CSI – Stellar Fingerprints and Doppler Red Shifts

Suggested Grade Level(s): Grades 9 - 12
Estimated class time: 4 to 6 class periods for the basic lesson; add 1 to 2 class periods if you must teach the Doppler effect. If the Extension is done in class this will extend the lesson time.

Summary

In this activity, students will be introduced to the Doppler effect and learn how it changes our perception of wavelengths of sound (pitch) and light (color). Students will model how astronomers use the line spectra of stars to identify elements in the stars and the speeds of galaxies in the universe.

Objectives

- Students will relate the sound of the Doppler effect for vehicles to the red shift of spectra of stars.
- Students will identify spectra of elements.
- Students will identify spectra of elements when two elements are combined and/or red shifted.
- Students will explore NASA resources to compare the spectra of stars.

National Science Standards

- NS.9-12.1 SCIENCE AS INQUIRY

  As a result of activities in grades 9-12, all students should develop
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- NS.9-12.2 PHYSICAL SCIENCE

  As a result of their activities in grades 9-12, all students should develop an understanding of
  - Structure of atoms
  - Interactions of energy and matter
- NS.9-12.4 EARTH AND SPACE SCIENCE

  As a result of their activities in grades 9-12, all students should develop an understanding of
  - Origin and evolution of the universe
- NS.9-12.7 HISTORY AND NATURE OF SCIENCE

  As a result of activities in grades 9-12, all students should develop understanding of
  - Science as a human endeavor
  - Nature of scientific knowledge
  - Historical perspectives

Knowledge Prerequisite

Students should be familiar with the Doppler effect.

Here is a song about the Doppler Shift
http://www.astrocappella.com/doppler.shtml

If you need to teach the Doppler effect to your students prior to this lesson, there are some excellent resources to help along with the Astrocappella Doppler Song. Look at the activity link "Here It Comes, There It Goes!" and the link "Read about the Doppler Shift."

The activity gives directions on how to make a Doppler Ball which is a great demonstration!

If you don't have a Doppler Ball:

- Hear the Doppler Effect:
  http://library.thinkquest.org/19537/java/Doppler.html
- The lowest plane speed applies to galaxies since no galaxy's motion can match or exceed the speed of light.
  http://www.fearofphysics.com/Sound/dopsounds.html

Teacher Background/Notes

The Science Trek website is located at:
http://www.colorado.edu/physics/2000/quantumzone/index.html

Students can choose which element's spectra they wish to see as well as read background information about spectral lines and quantum models of atoms to be used in the explanation portion of the lesson.

Other excellent teacher sources from NASA:

For spectral analysis:
http://imagine.gsfc.nasa.gov/docs/science/how_l1/spectral.html
http://rst.gsfc.nasa.gov/Sect20/A7.html
http://antwrp.gsfc.nasa.gov/apod/ap040418.html

Logistics:
If you use the Spectrum Tubes, rotate the students through the Exploration with one group working in a dark area while other groups use the Science Trek website. This may take two days for all students to get a chance to see the actual spectra.

Equipment for spectral analysis

Various manufacturers sell complete sets or components of the equipment, for example:
CP87200-00 Spectrum Tube Analysis Set from VWR International (Sargent-Welch)

S43970E Spectrum Tube Power Supply (Fisher) with various gas tubes available.

Science Kit and Boreal sells diffraction grating spectrometers and chemicals for analysis of flame tests based on the IPS curriculum.

WW64799M00 Spectral Analysis Kit (24 student) (A 30-student kit is also available)
- This set introduces the spectroscope as a useful analytical tool.
- Each kit Includes completely assembled diffraction grating spectroscopes and a chemical kit.
- The ten chemicals prescribed for IPS are each packed in a glass vial. A nichrome wire loop is fitted into the stopper on each of the vials.
- Individual components may be bought separately. Chemistry, physics or earth science departments may already have a power supply and a selection of tubes to use.

A dark room is required to view the spectra. Some students may use the computers while another group is using the equipment. Analytical spectrometers give actual wavelengths with the spectral lines, but break easily and cannot be repaired. Tubes with diffraction gratings are more durable, but do not give actual wavelengths with the lines.

Materials

- For the Doppler Ball (if you need to make one):
  - 'splash out' ball** **This toy is made by Galoob and can be bought at your local toy store. For more information, contact Galoob Customer Service at 1-800-442-5662.
  - electronic noise making mechanism with pure tone (from Radio Shack, or other electronics store)
  - 9 volt battery and clip
  - jump rope
  - masking tape
- White paper and colored pencils
- Equipment for spectral analysis – see teacher notes
- A dark room
- computers

Procedure:

I. Engagement – one class period

Have students sit or stand in the room and cover their eyes.
Walk around the room and make a discrete noise – hit a wooden block with a stick or blow a whistle or such.
Ask students to point to the direction that the sound is coming from.

Students should have no difficulty locating a sound with their eyes closed.

Can you tell where a siren is just by listening to the siren?

Yes – students can tell if the sound is coming from the right, left or front or back just like the noise you just made.

Can you tell if it is coming toward you or moving away from you?

Yes, they should be able to tell you yes even if they cannot articulate the reason.

Ask students what they hear when a police car or ambulance with a siren passes in front of them as they stand alongside a road.

Ans. Higher pitch then lower pitch. Some will be able to demonstrate the sounds for you.

Ask students to read the article "Universe is Expanding -- 'Red Shift' is Proof of Einstein's General Theory."

Explain that the Red Shift of galaxies is just how we **see** Doppler Shift of the siren but for light waves instead of sound waves.

- Red shifted light is the same as lower pitch – the source is moving away from us.
- Blue shifted light is the same as higher pitch – the source is moving toward us.

Play the song "Doppler Shifting" by Astrocappella (see teacher notes for permissions and source.)

By the end of this lesson, students will be able to

- explain the red shift of galaxies with the Doppler effect
- identify spectra of an element by comparison with known spectra
- compare stationary spectra to moving spectra.

II. Exploration – one or two class periods

Two periods may be needed if you have only one set of spectral tubes for student use. Rotate through with one group at a time looking at spectra.

Equipment needed: White paper and colored pencils to draw spectra.

1. **Explain**: Individual elements emit light in different colors. The light emitted can be broken up by a prism or diffraction grating into a series of lines. These lines that act as a fingerprint for the elements. No two elements emit exactly the same lines of light.

   However, as the light source approaches us, the wavelengths get bunched up and shorter in front of the source. Short wavelengths are bluer light.
   As the light source moves away from us, the wavelengths get spread out and longer behind the source. Long wavelengths are redder light.

   Students may work individually or in groups.
   Students will investigate the spectra of individual elements to see how they compare.
   Students will draw the spectra of some elements side by side and determine which lines are the best for identification.

2. Students should use a spectroscope to view the excited gases in spectrum tubes and draw the spectra that they see (See equipment list on teacher page). They will draw what they see in color.

3. Have students visit the Science Trek website:
   http://www.colorado.edu/physics/2000/quantumzone/index.html
   Scroll down to where you see the illustration of a white light spectrum that looks like a rainbow. The pull down menu above the spectrum will allow students to view spectra of different elements.
   Students will copy and compare the colored spectra of elements.
   (Students will read and explore this website in more depth later in the lesson.)

4. Ask students to write how they identify the various spectra.
   Students should share their key to identification with their group or with the whole class.

The class and teacher, without comment or clarification, should receive the methods of identification since the student will be using his/her rubric in the next step for identification of spectra. Following that activity, students will be given the opportunity to revise their thought processes.

III. Explanation – two class periods

Day 1

1. Have students visit the Science Trek website:
   http://www.colorado.edu/physics/2000/quantumzone/index.html
   Students will read about the spectral lines and quantum model of the atom.

2. Present students with the black and white pictures representing the spectra of various elements that might appear in stars. (pages 1 and 2 of the PDF handout)

3. Give students a few of the same pictures – mixed up and without identifying information (page 3 in the PDF handout – key is on page 5). Have the students match the spectra to identify the unknown spectra.
   This can be done either individually or in groups.

4. Review the correct answers so students can reflect and adjust their method of identifying spectra.

   Explain to the students that this is the process that astronomers use when looking at information from various stars. If the line spacing in the spectra is right, but too far right or left, they know that the galaxy is moving away or toward us.
   (See page 6 of PDF handout for information from Astrocappella website)

5. Ask students to predict what the spectra would look like:
   a. if two elements were combined.
   b. if the spectral lines were redshifted.
      (All the lines would be moved toward the left of the drawing.)
   c. if the spectral lines were blueshifted.
      (All the lines would be moved toward the right of the drawing.)

Day 2

6. At this point if you have the time and computers available, allow students to explore the information and actual images from NASA relating to spectral analysis at the websites listed in the teacher notes. Some of this material will be a challenge to your class but the IMAGINE website is appropriate for all levels of a high school physics class.

   The IMAGINE website has basic science, advanced science, quiz questions and links for further research.

OR

The teacher can present some of this material to the class as a whole.

IV. Extension

This may be used as:
- An anchor to challenge students who finish early in a differentiated classroom
- An out of class assignment for selected students
- An additional day or two in class

Students who wish to expand their understanding might:
- Write their own song about the redshift of galaxies
- Research how scientists have learned about quasars

- Research into how Doppler Radar works for meteorologists or speed traps
- Research more about the quantum models of the atom

V. Evaluation – one class period

Students should either:

Identify the spectra on page 4 of the PDF handout. (Key is on page 5)

Or

Draw individual combined, red-shifted and blue-shifted spectra.
These can be presented as a challenge to their classmates.