

# Teacher Guide: Star Spectra



## Learning Objectives

Students will...

- Determine the elements that are present in the spectrum of a star.
- Use this information to infer the approximate temperature of the star.
- Classify stars.
- Use other aspects of spectra to find nebulae, variable stars, binary stars, giant stars, and other unusual stars.



## Vocabulary

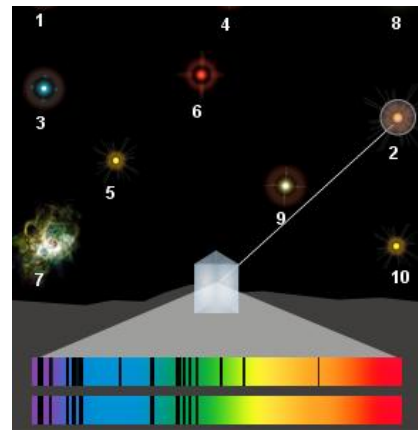
absorption spectrum, binary star, blueshift, Cepheid variable, emission spectrum, giant star, nebula, redshift, spectrum, star



## Lesson Overview

Astronomers spend their time gathering information about objects that are trillions of kilometers away. One of the most useful ways to investigate a star is to look at its spectrum—the combination of colors found in its light. Every star has a unique spectrum that yields clues about the star’s surface temperature, motion, and composition.

The *Star Spectra Gizmo*™ allows students to examine simplified stellar spectra. After determining which elements are present in the spectrum, students can use the Harvard Classification Scheme to classify the star and estimate its surface temperature.



Do the spectral lines match up?

The Student Exploration sheet contains two activities:

- Activity A – Students find the elements present in stellar spectra, then classify the stars.
- Activity B – Students observe unusual characteristics in stellar spectra and match these traits to unusual stars.



## Suggested Lesson Sequence

### 1. Pre-Gizmo activity: Flame tests (🕒 10 – 20 minutes)

When heated, any element will release light in specific colors called an *emission spectrum*. You can observe these spectra by heating substances in the flame of a lab burner. First, obtain a variety of salts such as sodium chloride (NaCl), lithium chloride (LiCl), potassium chloride (KCl), calcium chloride (CaCl<sub>2</sub>), barium chloride (BaCl<sub>2</sub>), copper sulfate (CuSO<sub>4</sub>), and lead nitrate (Pb(NO<sub>3</sub>)<sub>2</sub>). You will also need a Bunsen burner, clean wire loops (wet Q-tips work as well), and student spectroscopes (optional).

To perform a flame test, first light the Bunsen burner. Dip a wire loop in water, then in the test substance. Place the wire over the hottest part of the flame to see a bright color. Have students observe each flame both with the naked eye and through a spectroscope.

2. **Prior to using the Gizmo** (🕒 10 – 15 minutes)  
Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.
3. **Gizmo activities** (🕒 15 – 20 minutes per activity)  
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.
4. **Discussion questions** (🕒 15 – 30 minutes)  
As students are working or just after they are done, discuss the following questions:
  - What does the spectrum of a star tell you about the star? [Note: The spectrum does *not* indicate the composition of the star. Most stars are made of hydrogen and helium. Instead, the spectrum indicates the surface temperature of the star.]
  - How do the spectra of cooler stars compare to the spectra of hotter stars?
  - What are some possible reasons for a star’s spectrum to change over time?
5. **Follow-up activity: Real stellar spectra** (🕒 5 – 10 minutes)  
The **Selected Web Resources** on page 3 of this document contains several links to Web sites that contain pictures of actual star spectra. Show these pictures to your students and ask how the actual spectra are different from the simplified spectra shown in the Gizmo. As it turns out, the real thing is very complex!



### Scientific Background

What we hear as sound is really a disturbance in the air caused by motion of some distant object, say a guitar string vibrating. What we see as light is a disturbance caused by the motion of charged particles.

Atoms are electrically neutral, having no total charge, but they do include charged regions. Their exteriors are negative; their interiors, positive. These charged components are constantly moving because the atoms themselves are moving. Hence, all objects emit a kind of light. Our eyes, however, are not sensitive enough to see most of this light, just as our ears are not sensitive enough to detect all sounds.

Stars are very hot, so the matter inside them moves much faster than matter at room temperature. This produces light at higher frequencies, some of which we see. Because a star’s protons and electrons have a variety of speeds, it emits a wide *spectrum* of light, just as an orchestra produces a wide array of tones.

But there is a second way charged particles move. An electron can undertake a *quantum leap* from one orbital of an atom to another. If it jumps from a high-energy orbital to a lower one, it emits a *photon* of light with energy equal to the difference—energy is conserved. Remarkably, the *opposite* can happen. Just as certain materials can muffle sound or negate it, an electron can jump *up* from one orbit to a higher one and *absorb* a photon when doing so!

Atoms cannot absorb just any photon. They can only absorb photons whose energies match the steps between the atom's energy levels. These differ from one element to another, so each element has a characteristic *absorption spectrum*, the specific frequencies it can absorb.

The light given off by chaotically moving matter on a star's surface must pass through gases in its *photosphere*. These gases absorb light at certain frequencies, and we can figure out which gases are present by examining which frequencies were absorbed.

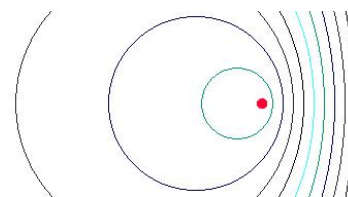
This absorption spectrum only indicates what elements are present in the *photosphere*. It does not indicate the composition of the star itself. Helium and hydrogen are the main constituents of almost all stars, and the light emitted by the star's surface only indicates its temperature.



### Astronomy connection: Redshift

In the *Star Spectra Gizmo*, one of the stars exhibits a *redshift*, a shifting of spectral lines that indicates the star is moving away from the observer. There are several types of redshift, including *Doppler* redshift and *cosmological* redshift.

Doppler redshift occurs because waves in front of a moving source are compressed, while the waves behind the source are stretched out. For a light wave, a shorter wavelength corresponds to a shift towards the blue-violet end of the spectrum (blueshift), while a longer wavelength corresponds to a shift towards the red end of the spectrum (redshift).



Doppler effect

Cosmological redshift occurs when light passes through space that is expanding, causing wavelengths to be stretched and shifted towards the red end of the spectrum.

In the 1920's, the American astronomer Edwin Hubble observed that light from distant galaxies was redshifted. Hubble and his partner, Milton Humason, found that as the distance to a galaxy increases, so does the observed redshift. This discovery, called *Hubble's Law*, revealed that the universe is expanding. It also suggested that the universe originated in a gigantic explosion that was dubbed "the Big Bang."



### Selected Web Resources

Flame tests: <http://www.800mainstreet.com/spect/emission-flame-exp.html#Anchor-flame-head>,

Real stellar spectra: [http://spiff.rit.edu/classes/phys230/lectures/spec\\_interp/spec\\_interp.html](http://spiff.rit.edu/classes/phys230/lectures/spec_interp/spec_interp.html),

<http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit1/SpTypes/index.html>,

Spectral lines: <http://www.colorado.edu/physics/2000/quantumzone/index.html>

Astronomical color effects: <http://www.webexhibits.org/causesofcolor/18A.html>

Stars great and small: <http://www.webexhibits.org/causesofcolor/18B.html>

Stellar spectra: <http://cass.ucsd.edu/public/tutorial/Stars.html>

Stellar spectra activity: <http://www.learner.org/teacherslab/science/light/color/spectra/index.html>

Expanding universe: <http://skyserver.sdss.org/dr1/en/astro/universe/universe.asp>

Related Gizmos:

*H-R Diagram*: <http://www.explorelarning.com/gizmo/id?429>

*Bohr Model of Hydrogen*: <http://www.explorelarning.com/gizmo/id?506>

*Doppler Shift*: <http://www.explorelarning.com/gizmo/id?363>