Identifying Atomic Spectra

ASTR 1020

Name:

Overview:

In this activity you will explore how different types of spectra are made and get a brief overview of what instrument astronomers use to record spectra. Next, you will explore the atomic structure of hydrogen and the energy levels of electrons. Lastly, you will identify unknown spectra made from the combination of 2 or more elements.

Objectives:

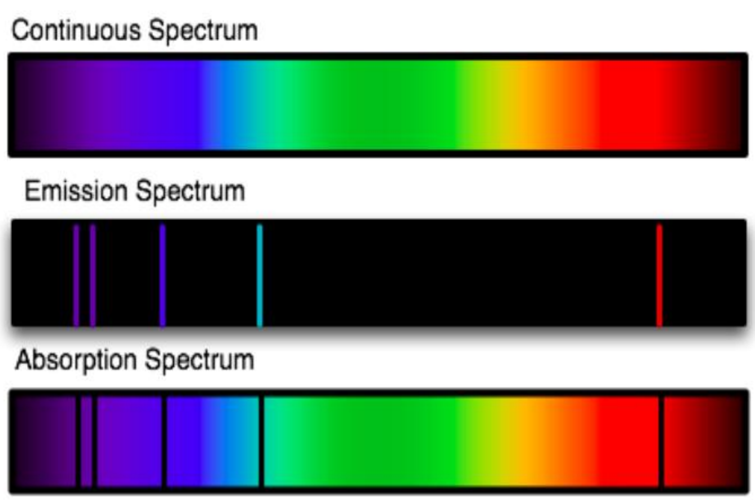
After completing this activity, students will be able to:

- Identify different types of spectra
- Visualize how a spectrograph can be used to create a spectrum.
- Identify the wavelengths of photons produced from transitioning electrons.
- Identify the elements in an unknown sample by comparing it to the spectra of known objects.

Definitions

Here are some terms from lecture that we will be using today in lab:

- **Spectrum** – a band of colors, as seen in a rainbow, produced by separation of the components of light by their different degrees of refraction according to wavelength.
- **Continuous spectrum** – a spectrum that consists of light at all wavelengths without interruption. Hot, dense objects like a light bulb or CORE of a star produce continuous spectra.
- **Emission spectrum** – a spectrum that only emits light at specific wavelengths, forming a pattern similar to a colorful bar code. Hot gases produce emission spectra.

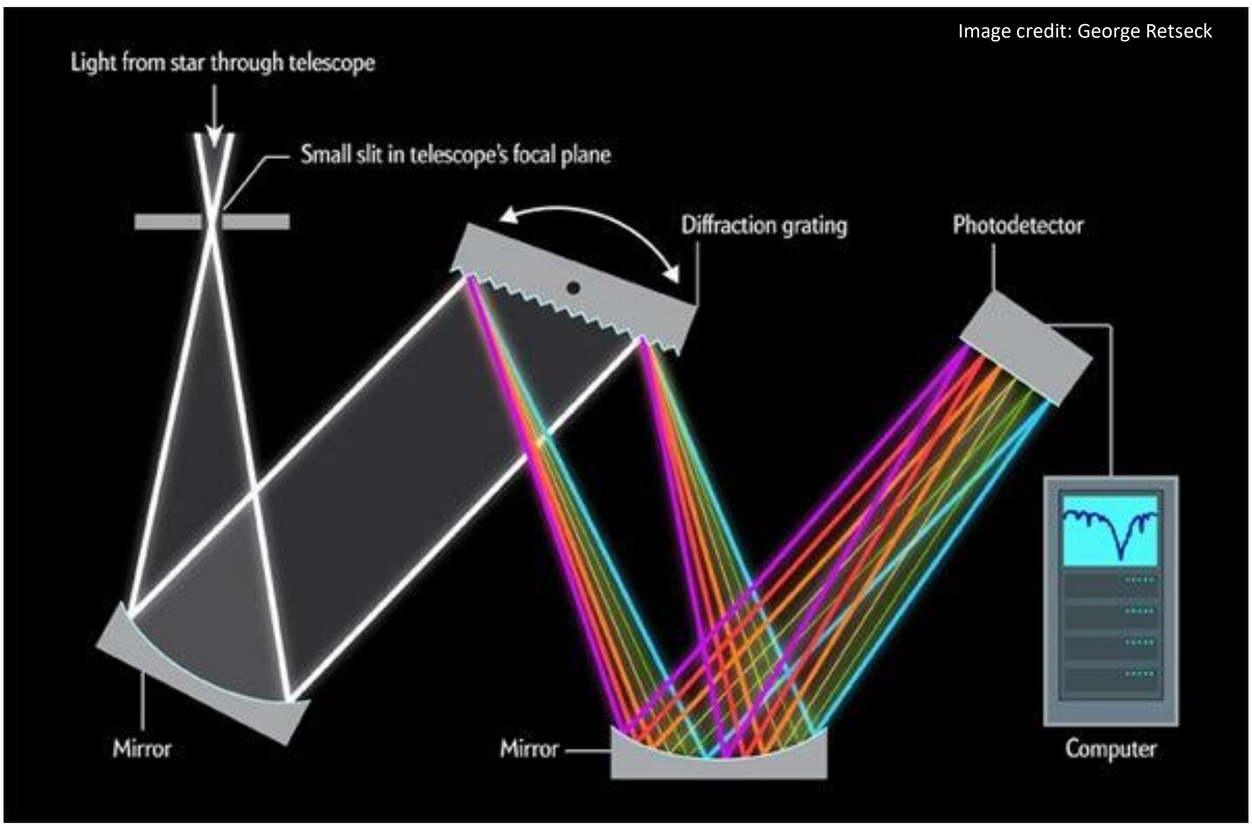


- **Absorption spectrum** – a spectrum that looks like a rainbow with black lines removed at specific wavelengths. They are created when the light of an object that produces a continuous spectrum passes through a cloud of cool gas.

- **Spectrograph** – an instrument that uses a prism or diffraction grating to split light into its component wavelengths.
- **Diffraction grating** – an optical component, typically made of glass or metal, a marked with very close parallel lines. When light hits these lines, light of different wavelengths bounces off in different directions, producing a spectrum.

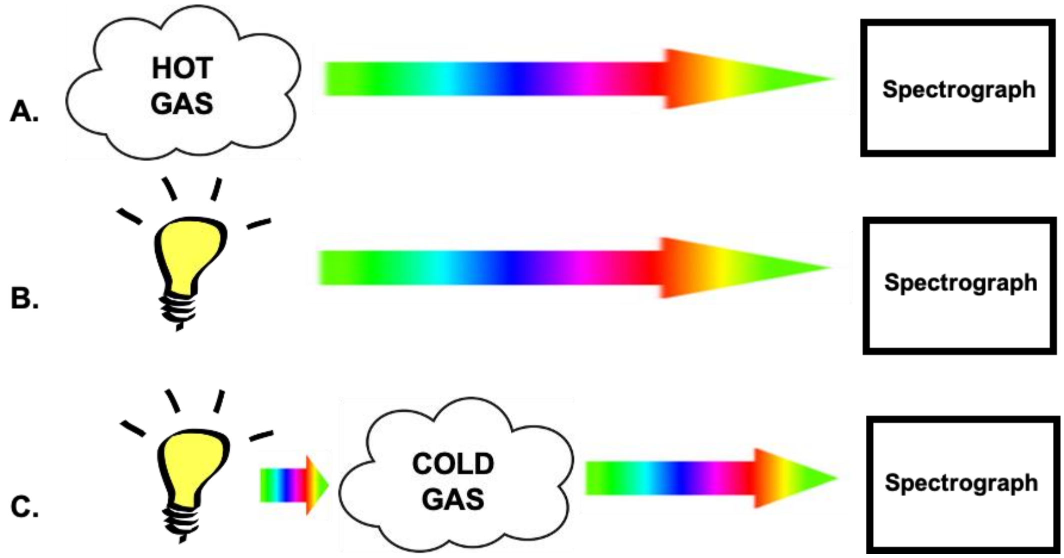
Part 1: Making and Identifying Spectra

In order to observe the spectrum of an object in space, a spectrograph needs to be attached to your telescope. The process begins with light from the star, galaxy, planet, or whatever you are looking at, enters though the telescope. The light is sent through a small slit so the light rays can be collimated (made parallel to each other). The parallel light rays bounce off a mirror and are sent to the diffraction grating. When the light encounters the small groove cut into the grating, lights of different wavelengths bounce off in slightly different directions, separating the light into its component wavelengths. The separated light bounces off another mirror into the detector. You now have a spectrum!



Now that you know how a spectrum is produced, you need to identify what situations create what types of spectra!

Below are three scenarios of light traveling to your spectrograph. Identify what type of spectrum (continuous, emission, or absorption) would be produced in each situation.

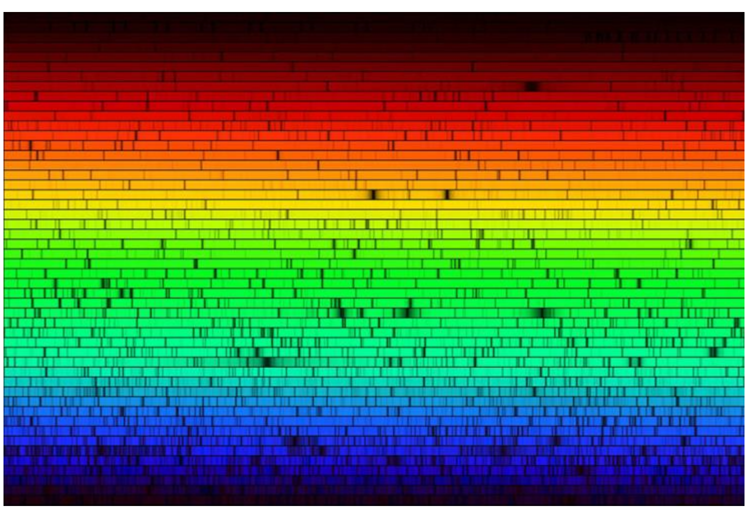


1. In Figure A, light from a hot gas enters a spectrograph. What type of spectrum will it produce?

2. In Figure B, light from a hot dense object enters a spectrograph. What type of spectrum will it produce?

3. In Figure C, light from a hot, dense object that has passed through a cold gas cloud enters a spectrograph. What type of spectrum will it produce?

Here is a spectrum of the Sun (image credit: N.A. Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF).

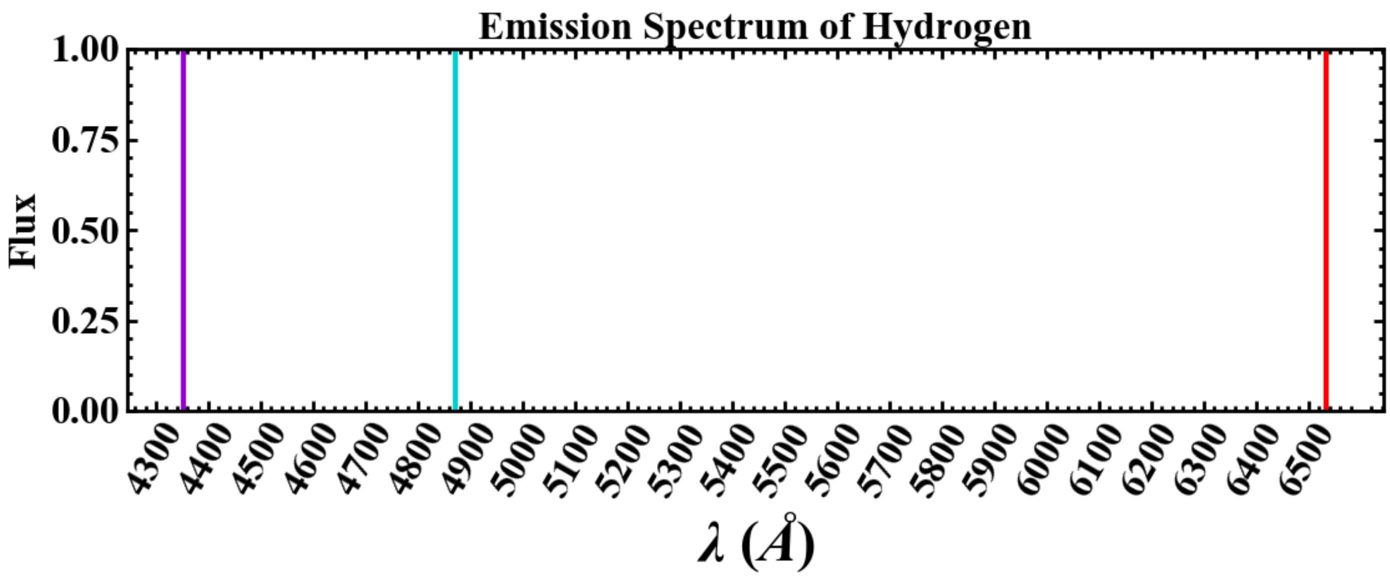


4. What type of spectrum does the Sun produce – emission or absorption?

5. Why do we see this type of spectrum rather than a continuous spectrum?

Part 2: The Hydrogen Atom

Below is the emission-line spectrum of hydrogen. The three distinct emission lines are related to the electron orbitals of the hydrogen atom. When electrons are excited (usually by incoming photons) they jump back and forth between discrete energy levels, like different orbits around a star. Electrons can only orbit the atom at particular distances, or energy levels, so they must give up exactly the difference in energy between any two levels in order to drop from a higher orbit to a lower orbit. The energy lost is shot out of the atom as a photon whose wavelength (color) corresponds to the amount of energy the electron gave up when it jumped down from its energy level. The more energy the electron loses, the more energetic the photon will be, the smaller the wavelength, the bluer the color.



The hydrogen spectrum observed is called the Balmer series. The Balmer lines (shown above) are produced when electron transitions are down to or up from the second-smallest orbit. The radii of this orbit and those above it can be calculated from Equation 1:

$$r_n = \frac{\lambda}{(0.473)\lambda - 1630} \qquad (Equation\ 1)$$

where r_n (n = 2,3,4…) represents the orbital radii of orbits 2, 3, 4, etc., and λ is the wavelength of the corresponding emission line in angstroms (Å). The red, blue-green, and violet emission lines came from an electron moving from a higher orbit, r_n, down to r_2 as given below:

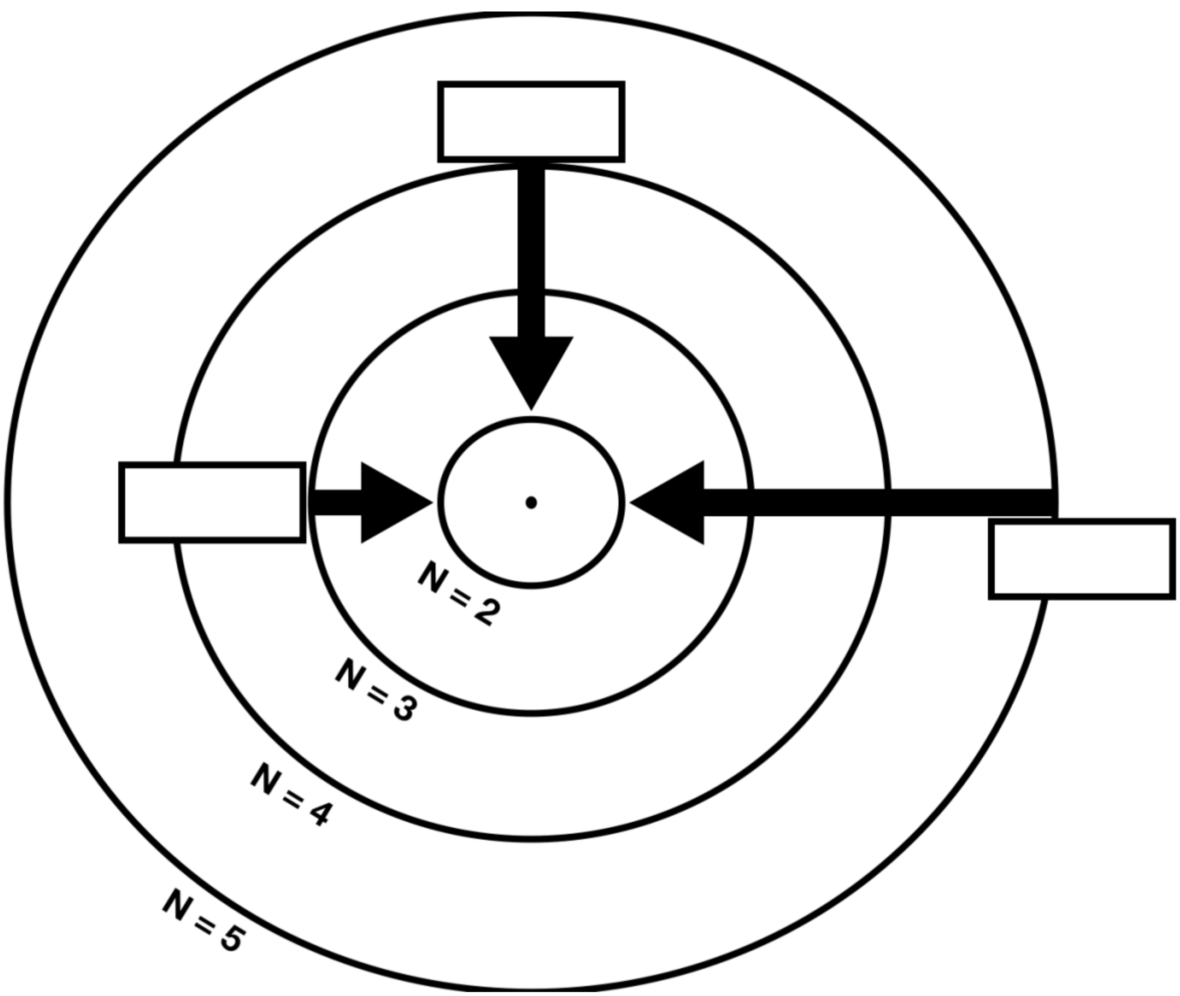
red	$r_3 \rightarrow r_2$
blue-green	$r_4 \rightarrow r_2$
violet	$r_5 \rightarrow r_2$

6. Record the wavelengths of the red, blue-green, and violet emission lines from the emission spectrum of hydrogen above (they do not need to be 100% exact) in Table 1.
7. Use Equation 1 and your measured wavelengths to calculate the radius of the 3rd, 4th, and 5th electron orbits for hydrogen, and record your answers in Table 1.

Table 1: The Hydrogen Balmer Series

Emission Line Color	n	**λ (Å)**	**R_n (Å)**
Red	3		
Blue-Green	4		
Violet	5		

8. Below is a scaled drawing of the electron orbits for a hydrogen atom for *n* = 3, 4, and 5. Arrows have been drawn pointing from each energy level down to *n* = 2. Label each arrow with the corresponding color that would be emitted if an electron fell from that energy level to *n* = 2 (red, blue-green, or violet).



Part 3: Identifying Emission Spectra

Go around the tables and use the diffraction gratings to identify what gas each emission lamp is.

Table 1: ______________________________

Table 2: ______________________________

Table 3: ______________________________

Table 4: ______________________________

Table 5: ______________________________

Table 6: ______________________________