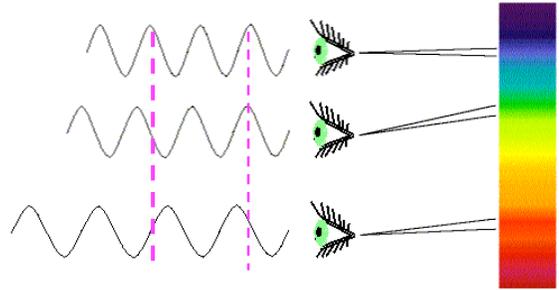


What is Spectroscopy?

Spectroscopy is one of the most important tools in a scientist's tool-kit. Astronomers use spectroscopy to study light from different objects in the Universe. Light is energy and can be thought of as either waves or particles.

Wavelength:

If you think of light of a particular color as a wave, then the distance between the peaks in the wave is its "wavelength." *Does yellow light have a wavelength that is longer or shorter than red?*



Light of each color has a different wavelength - blue light has a shorter wavelength than red light. Blue light therefore has a larger number of peaks per unit of length (e.g. in the picture above the wave at the blue end of the rainbow has 3 peaks between the two dashed lines, while the wave at the orange end of the rainbow has only 2 peaks). A wave with more peaks per unit length has more energy than a wave with fewer peaks. *Which has more energy: red or yellow light?*

Infrared light has longer wavelengths than red and *ultraviolet light* has shorter wavelengths than purple. Light from the sun or a car's headlight is a mixture of light of different wavelengths of light.

Spectrograph:

A *spectrometer* (or a *spectrograph*) is an instrument that can spread light out into its different colors. This week you will do a number of different experiments where you will use spectrographs and even build your own! When light from a star or a galaxy or lamp is spread out it is called a "spectrum."

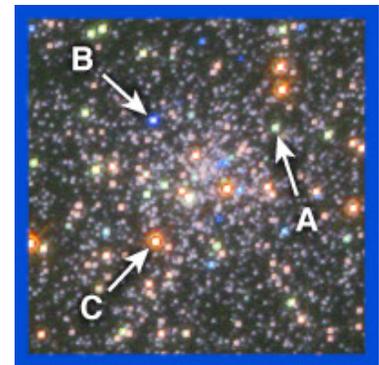
Continuous and Discrete Spectra:

There are different kinds of spectra. A rainbow like the one below is called a "*continuous*" spectrum:

Hot things produce continuous spectra. The temperature of an object is what decides what color in the spectrum is most prominent. A star that is about 5600° Celsius is yellow like our sun; a star that is only 3500° Celsius is red like the star Antares, while a blue star like Sirius is about 40,000° Celsius!



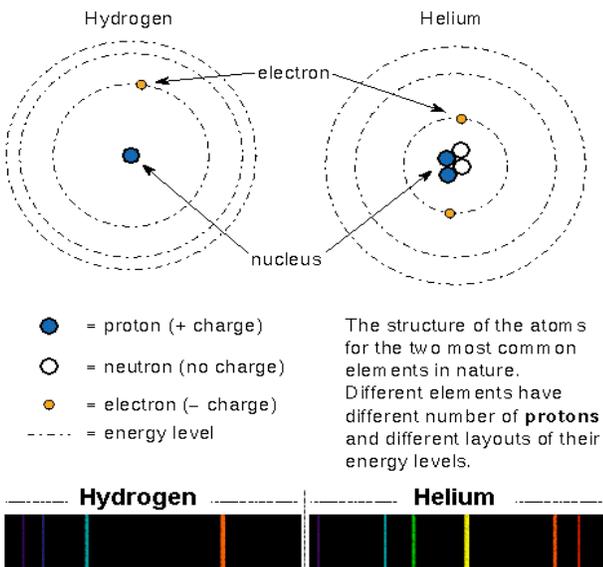
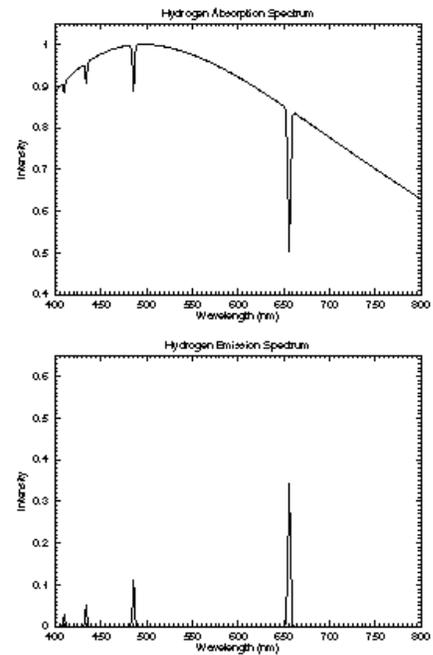
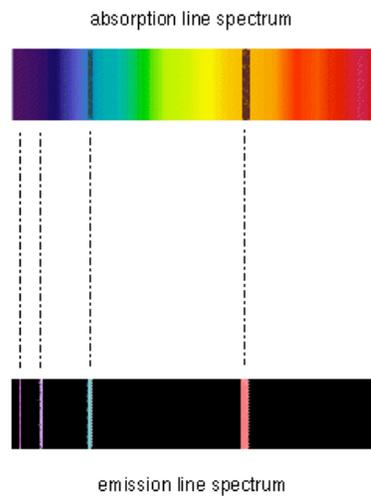
The image to the right was taken by the Hubble Space Telescope and is a photograph of the globular star cluster M15. Can you tell which of the stars A, B or C is the hottest and which is the coolest in the image?



Astronomers also use spectrographs to look at objects in the Universe that have spectra that look more like a bunch of lines. These are called "*discrete*" spectra. Discrete spectra are produced by gases (of either atoms or molecules). Below are two spectra – both of hydrogen. In the spectrum on top the hydrogen gas is "*absorbing*" or taking away the light from a hot object behind it (and making the black lines), while in the spectrum below hot hydrogen gas is "*emitting*" or giving out light at very specific wavelengths (or colors).

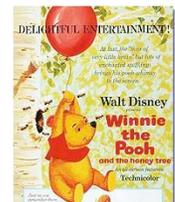
Astronomers study “emission lines” and “absorption lines” in a spectrum of a star because these are the fingerprints of the atoms and molecules that make up the star. Every atom or molecule has a very precise “fingerprint” of lines of different wavelengths that allows astronomers to figure out what a star is made of. Astronomers also use the information in a spectrum to learn about how hot a star is and how fast it is moving.

Why does each atom or molecule have a specific “fingerprint” of lines in its spectrum?



You probably know that an atom consists of a nucleus surrounded by electrons that swarm around it like very organized bees around a hive. The electrons are forced to stay in tracks (called energy levels) at specific distances from the nucleus, but every now and then they will jump from an outer track to an inner track and give out a photon (a particle of light energy) – this makes an “*emission line*.” If they jump from an inner level to an outer level they make an “*absorption line*.”

Do you remember the children’s story of Winnie-the-Pooh and the honey tree? Pooh found an old oak tree in the 100-acre wood that had a beehive at



the top, so he borrowed a balloon from his friend Christopher Robin and floated up in the air to reach the honey. Imagine a bigger honey-tree with 5 different beehives at different heights (10 feet apart). Also imagine an industrious Pooh starting to gather honey at the top buoyed by 5 borrowed balloons. When he is done eating honey at the top hive, he lets go of one of his balloons and then suddenly drops down 10 feet to just the right height to get to the next hive. Each time he finishes eating the honey from a hive he can let go of another balloon till he is finally down on the ground. If you think of the balloons as having energy that holds Pooh up in the air and prevents him from falling due to the gravity, then each time he lets go of a balloon (one packet of energy) he falls to the next level (and down to another beehive). This is exactly what happens to an electron when it jumps from an outer level to an inner level – it can only do so if it lets go of some energy and since light has energy each time an electron jumps down to a lower level it gives off (emits) light. Every atom has a unique spacing between the levels (like every tree might be unique in the number of hives it has and how far apart they are) – so as an electron jumps from one level to another it gives off specific packets of light (photons) that tell astronomers at which kind of atoms (or molecules) they are looking.