

FYI

Spectral Lines

By passing light from an astronomical object through a spectroscope, astronomers measure how much light of each wavelength is being emitted. They may use that information to determine the composition of the star and its surroundings.

Any hot, dense gas, such as the interior of a star, emits a **continuous spectrum** of light. That is, it emits electromagnetic radiation at all wavelengths. Because the gas is dense, the atoms are closely packed together. Because the gas is hot, the atoms are moving quickly and frequently collide with one another. These collisions release energy in the form of electromagnetic radiation. The energy released depends on differences in the motion of the colliding atoms so there is a broad range of wavelengths of electromagnetic radiation produced. In visible light, this has the effect of looking like a rainbow, a continuous distribution of all the colors of light, but a continuous spectrum may include all the other forms of electromagnetic radiation as well.

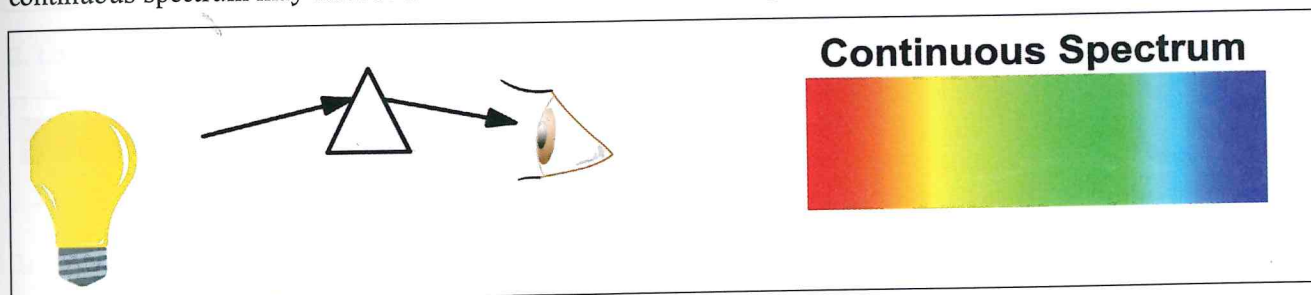


Figure 4-10: Diagram illustrating the formation of a continuous spectrum

In lower-density hot gases, such as some nebulae, electromagnetic lines are produced by the changes in position of the electrons around the gas atoms. This results in the emission of spectral lines, called **emission lines**. The electrons that surround the nucleus of each atom are in **quantized** shells, meaning that the electrons can only exist at very specific distances from the nucleus of the atom. When the gas receives energy from another source, such as a nearby star, the atoms absorb energy and the electrons are able to move farther away from the nucleus.

Because everything in nature strives to be in its most stable, lowest-energy state, “excited” electrons will move back downward toward their stable shell in small jumps, sometimes falling the entire distance at once. Each time the electron moves to a more stable shell, it emits energy in the form of electromagnetic radiation. The wavelength of the emitted electromagnetic radiation depends on the energy difference between the electron shells. A larger gap between shells will produce a higher-energy, smaller-wavelength photon than will a small gap. Each chemical element has a unique electron shell structure and, therefore, a unique emission line spectral “fingerprint.” These characteristic patterns enable astronomers to identify the presence of different chemical elements in distant objects.

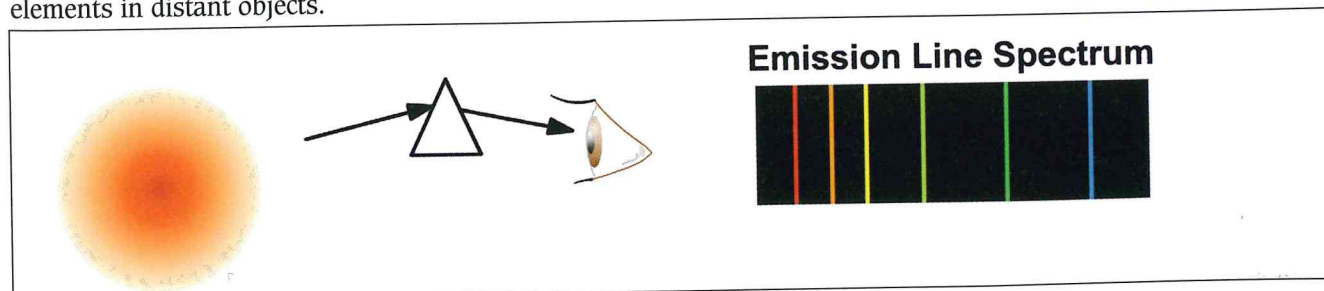


Figure 4-11: Diagram illustrating the formation of an emission line spectrum

In hydrogen gas, visible light photons are produced by electron transitions from higher states down to the shell $n = 2$. **Photons** are units or “particles” of electromagnetic radiation, which carry an exact amount of energy that is characteristic of that particular type of radiation. Figure 4-12 shows the visible light emission spectrum of hydrogen gas. Transitions down to $n = 1$ result in the emission of higher-energy ultraviolet photons. The mercury gas inside an overhead fluorescent light and the neon gas inside a store-front sign produce emission line spectra.

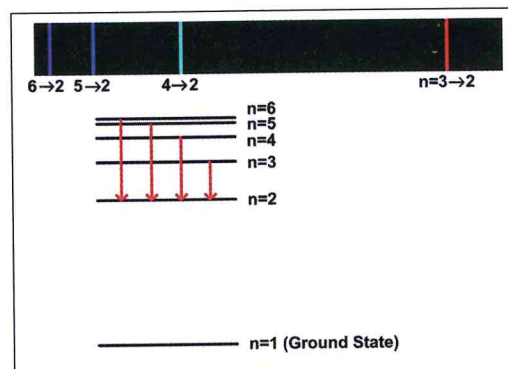


Figure 4-12: Diagram of a hydrogen emission spectrum

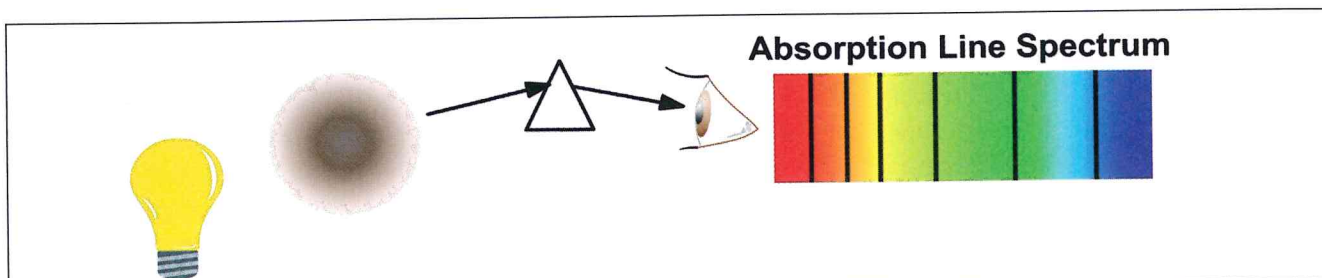


Figure 4-13: Diagram illustrating the formation of an absorption line spectrum

When continuous electromagnetic radiation from a star or other hot glowing object passes through a cloud of cooler gas, some of the radiation is absorbed by the gases in the cloud, creating dark lines. Called **absorption lines**, they show up as gaps in the continuous spectrum. In a relatively cool gas, electrons are in their stable, low-energy configuration. If that cool gas is in between an observer and the glowing object, the observer will see the continuous rainbow spectrum of the background source, interrupted by dark lines. The missing wavelengths form a pattern that is unique to the chemical composition of the cooler, foreground gas. Note that the positions of the absorption lines are identical to the positions of emission lines for the same chemical element. Therefore, absorption lines can also be used to identify the composition of objects in the universe.

Stars are huge balls of gas, but their structure is a little more complicated than this simple picture. Stars have hot, dense centers, but they also have atmospheres—cooler outer layers of gas. When examining the spectrum of electromagnetic radiation received from a star such as the sun, you will see a continuous spectrum superimposed with dark absorption lines corresponding to chemical elements present in the star’s atmosphere.

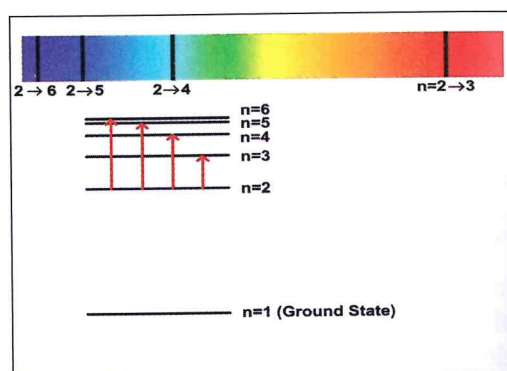


Figure 4-14: Diagram of a hydrogen absorption spectrum

Checking In

1. How is a continuous spectrum different from an emission line spectrum?
2. Why are spectral lines called the “fingerprint” of an astronomical object?