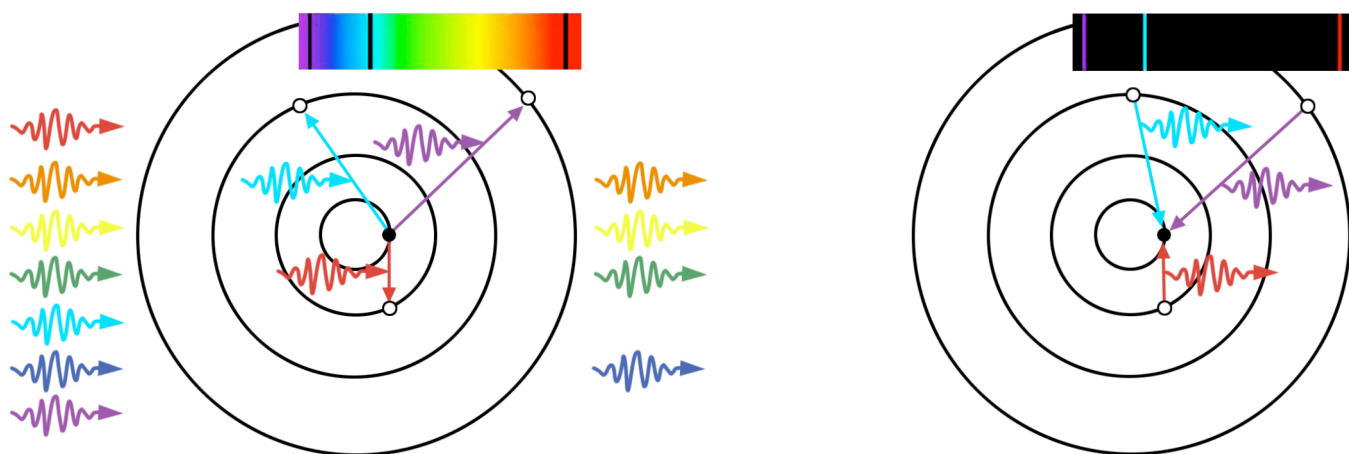


Atoms are very small. Take a hydrogen atom, the simplest of atoms: if the atom were the size of a football field, the nucleus would be a large grain of sand (1 mm across!). In terms of mass, the nucleus has it all; but in terms of interacting with light, the electrons are the major players.

### How do atoms interact with light?

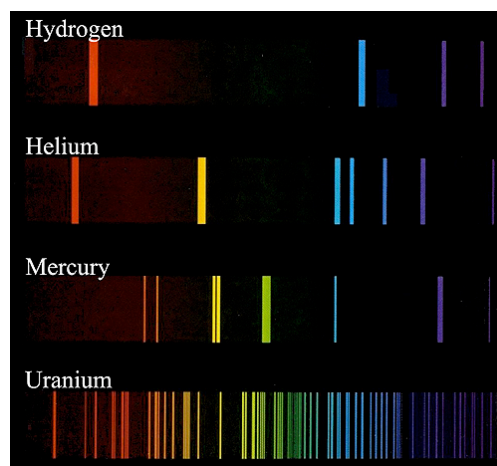
To learn how gas interacts with light, we have to know how electrons in atoms interact with light. Electrons are only allowed to exist in special energy levels around an atom (like cars in lanes on a highway). Each element has a unique pattern of energy levels. What sets the pattern? The number of protons in the nucleus defines each element, so the number of particles (protons and neutrons) in the nucleus determines the pattern of energy levels.

Electrons can change levels (like cars can switch lanes) but electrons may not carry extra energy in their pockets or jump halfway between levels (like cars **shouldn't** drive halfway between lanes). If an electron jumps to a higher level, it has to absorb energy to match the higher level (**below left**); if to a lower one, it must radiate energy to match the lower level (**below right**).



Where does an electron get energy? It can collide with other atoms and get kicked to higher levels, or it can absorb a packet of energy known as a photon --- this is light! A photon's energy determines its color: the more energy, the shorter the wavelength, the 'bluer' the color.

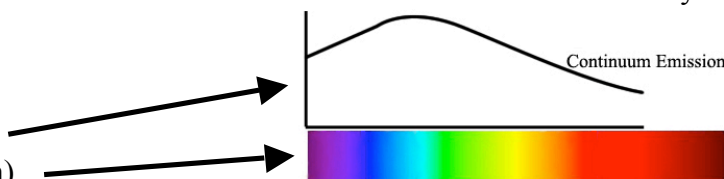
An electron can only absorb or emit energy that lets it change levels, so it can only interact with certain colors of light. Each element has a unique energy level pattern, so each element interacts with a unique pattern of colors.



### How do dense objects give off light?

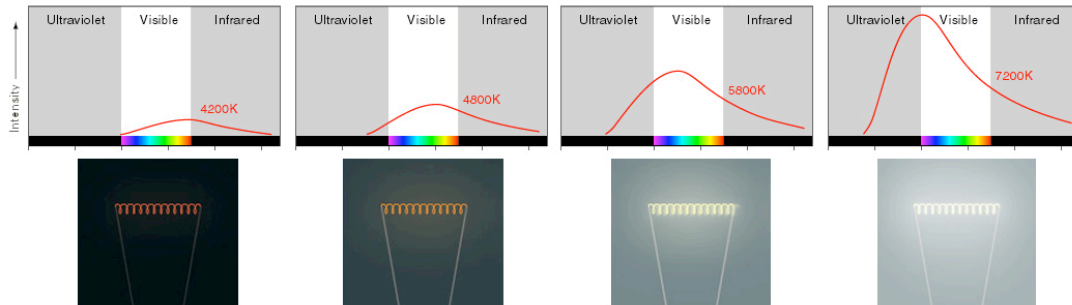
Dense objects (like people, planets, and the insides of stars) emit light at lots of wavelengths like a rainbow. If you plotted how much light is emitted at each wavelength, you would get a curve with a peak. That peak is the wavelength at which the object is emitting the most light. If you took any gas and made it denser and denser, eventually the emission lines would blend to form this curve called a "blackbody spectrum" or "continuum emission".

We can look at spectra in different ways:  
as a graph of how bright it is at that color (top)  
as what you see through a spectrograph (bottom).



## How does the blackbody curve change with temperature?

The blackbody curve for a temperature will have a unique shape and peak wavelength. The hotter the object, the shorter the peak wavelength and the more energy emitted at shorter wavelengths. The cooler the object, the longer the peak wavelength and the more energy emitted at longer wavelengths. Humans are not very hot and peak in infrared, while the Sun is hotter and peaks in visible light.

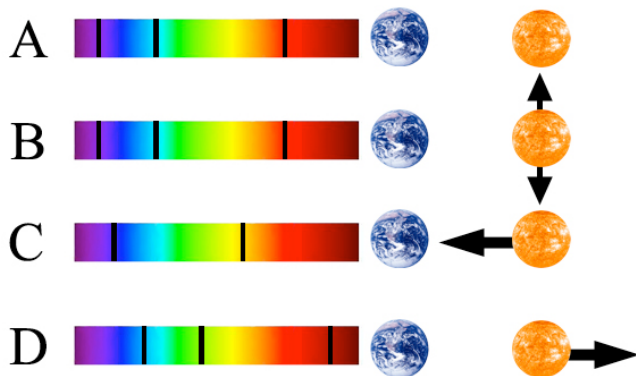
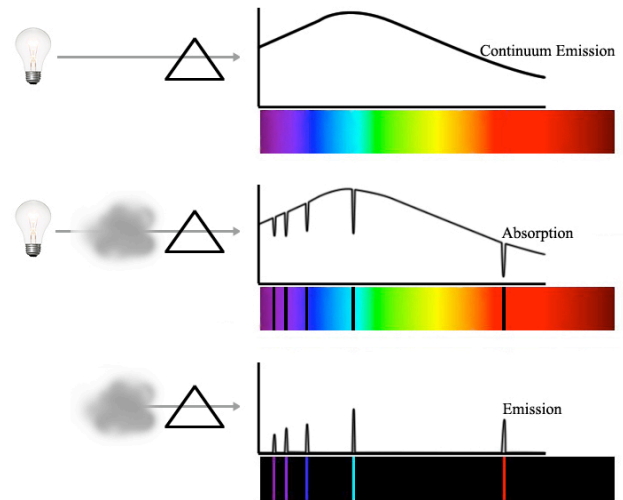


## What kinds of spectra will I see?

A dense object will emit a blackbody spectrum.

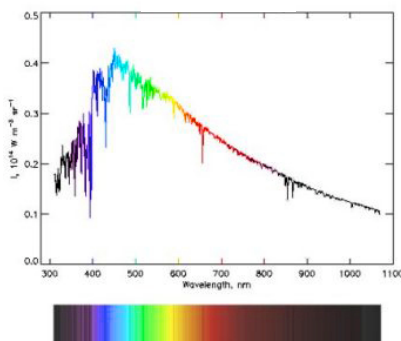
If we shine the blackbody spectrum through a gas, then the atoms in the gas absorb light at the special colors associated with the element. The spectrum will have dips at those special wavelengths. These dips are called absorption lines.

If the gas is hot, or light shines through from an angle that we can't see, the atoms in the gas emit light at the colors associated with the element. The spectrum will have bright peaks at those special colors. These bright peaks are called emission lines.



## What else can we learn from light?

An object's radial motion causes the light it emits to shift in wavelength, just like how an ambulance siren is Doppler shifted to higher or lower frequencies as it moves toward or away from you. The star in (A) is not moving relative to the Earth, so its lines appear in at the same wavelength as on Earth. If the star moves side-to-side, you won't see any shift (B). If a source moves toward or away from you, the light it emits will be shifted in color. If it moves toward you, the light will appear shifted to the blue end of the spectrum (C); if away, it will be shifted to the red end (D). The faster the motion, the greater the shift.



## In summary what does light tell us about stars?

A star is like a blackbody with a thin shell of gas around it, so it has a blackbody spectrum with some lines. What can we learn?

- 1) The blackbody spectrum tells us the star's temperature.
- 2) Emission and absorption lines tell us the star's composition.
- 3) Any Doppler shift of the lines tells how fast the star is moving toward or away from us.
- 4) Distance ---- nope, we can't tell the distance to the star.