1 Starlight and Atoms

Where does light come from? Where is its origin?

1.1 Temperature Scales

Fahrenheit - Water freezes at 32 °F and boils at 212 °F, pronounced 212 degrees Fahrenheit

Celsius - Water freezes at 0 °C and boils at 100 °C, pronounced 100 degrees Celsius

Kelvin - Absolute zero, lowest possible energy that an atom can theoretically be, water freezes at 273 K and boils at 373 K, pronounced 373 Kelvin.

1.2 Blackbody Radiation

Black absorbs radiation, white reflects radiation

Black emits radiation, white does not

Emissivity, e - Blackbody or not; $0 < e \leq 1$, $e = 0$ for a mirror and $e = 1$ for a perfect blackbody

1.2.1 Two Radiation Laws

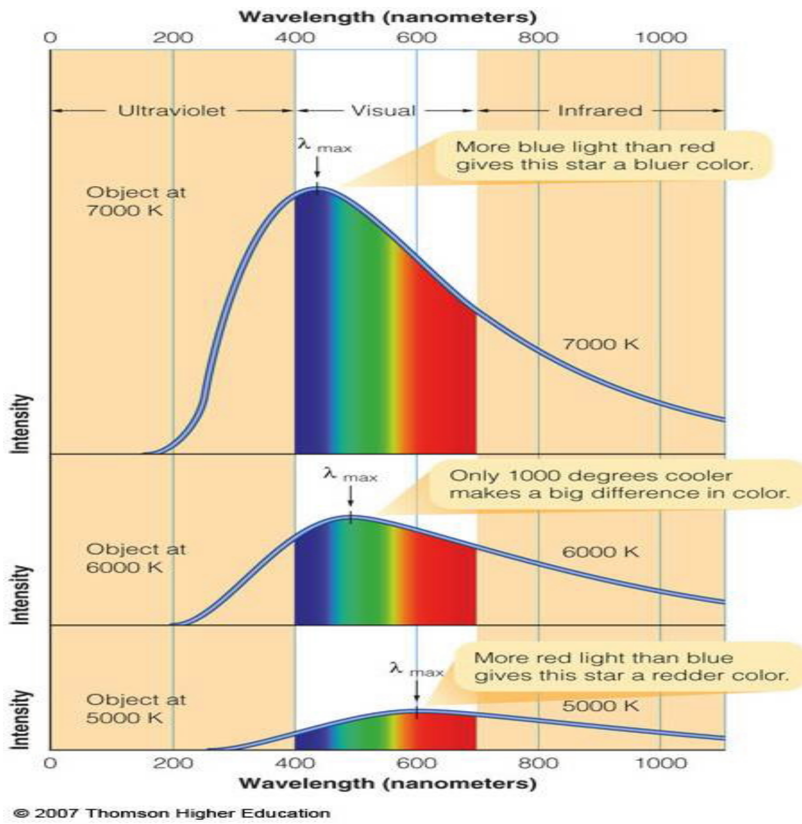
Stefan - Boltzmann Law The energy emitted in one second, Joules J/s, by an object such as a star that is at a certain temperature depends on the radiating surface area, emissivity (very close to 1), the temperature to the fourth power, and a constant of proportionality, σ.

$$\frac{E}{t} = \sigma e A T^4$$

Wien's Law The wavelength of maximum, $\lambda_{\max}$, depends inversely to the temperature of the object

$$\lambda_{\max} = \frac{3,000,000}{T}$$

This gives the wavelength at which the intensity is at its maximum level.



1.3 Color Index

Color is an indication of temperature

Blue stars are hot, hot stars radiate mainly in the UV or violet

Red stars are cool, cool stars radiate mainly in the red and IR

Two filters -

A B filter, passes 400 nm to 480 nm

A V filter passes 500 nm to 600 nm

Measure the magnitude through each filter

$$\text{Color Index } = B - V$$

A hot star emits mainly in the violet part of the spectrum so its $B - V$ will be negative $\sim -0.4 \Longrightarrow T \sim 50,000\,\text{K}$

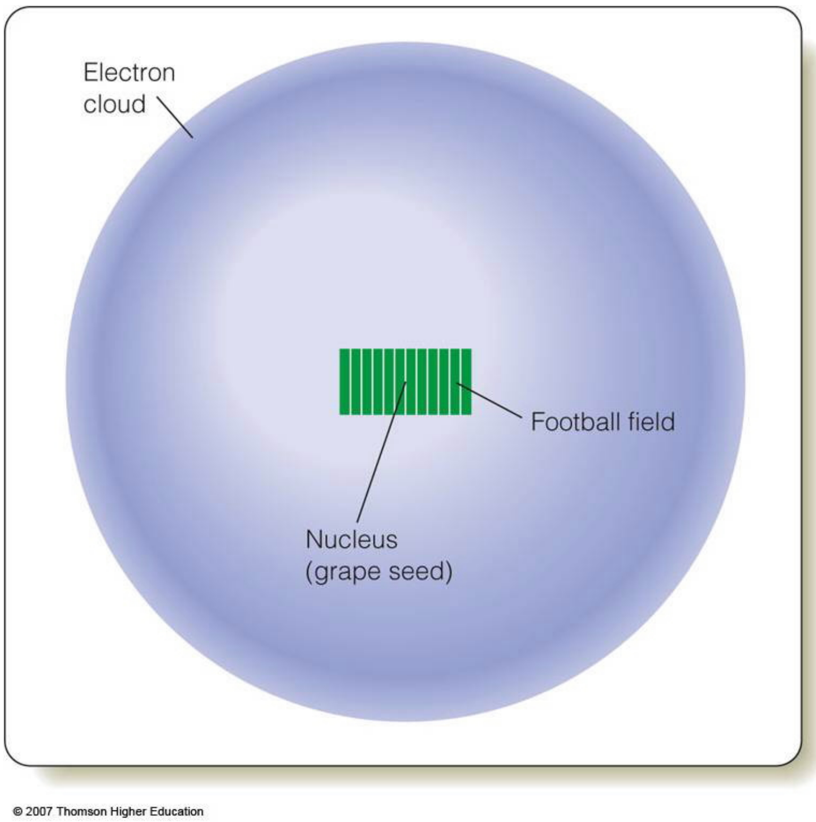
A cool star emits mainly in the red part of the spectrum so its $B - V$ will be positive $\sim 2 \Longrightarrow T \sim 2,000\,\text{K}$

Remember, the smaller the value of the magnitude, the brighter the star

1.4 Atoms

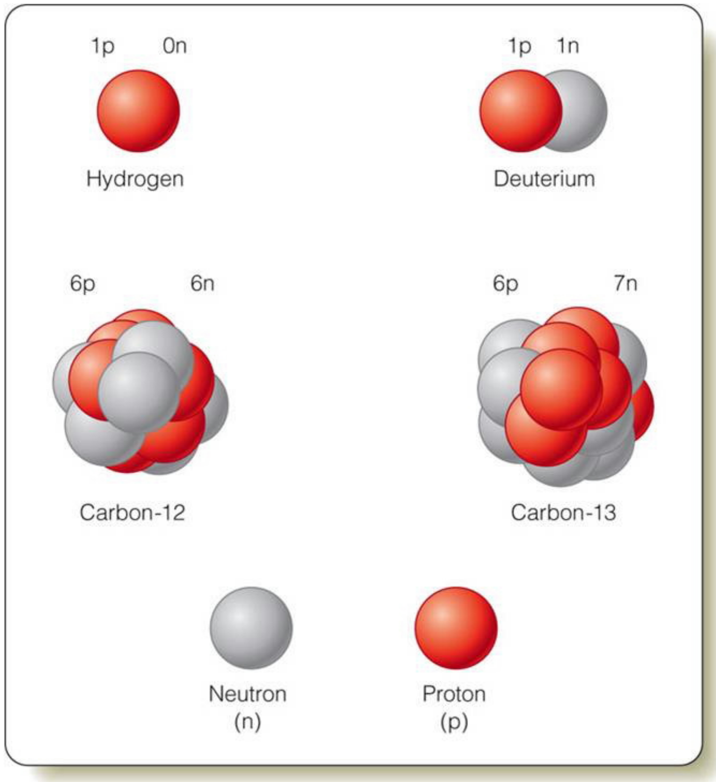
nucleus - protons and neutrons, $\sim 10^{-15}$ m in diameter

electrons orbit the nucleus, size of the atom is $\sim 10^{-10}$ m



mass of proton is 1836 times greater than the mass of the electron

isotopes



ions and ionization
molecules

1.4.1 Electron shells

binding energy
quantum mechanics
energy levels
energy level diagrams

1.4.2 Matter and Energy Interactions

Electron absorbs a photon, electron moves to a higher energy level

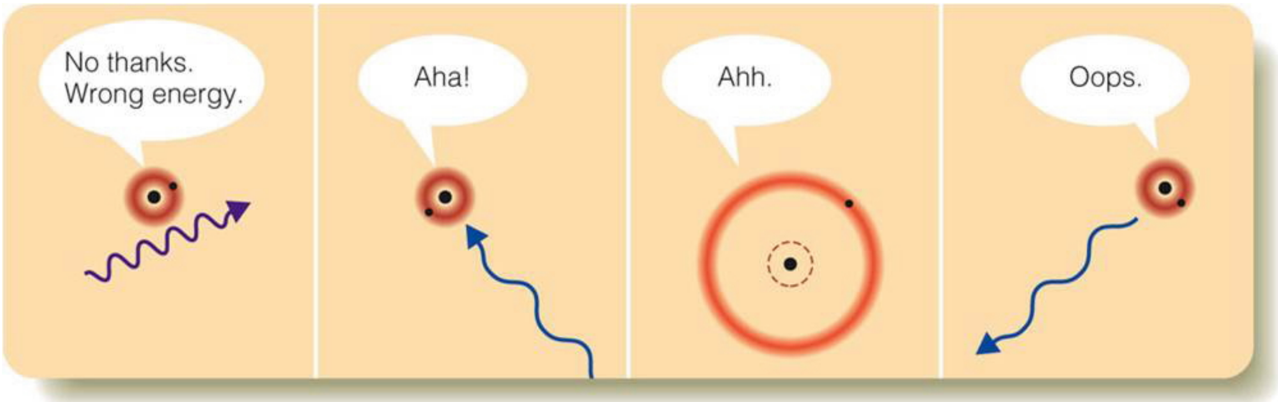
Electron absorbs energy for another atom during a collision and moves to a higher energy level

Electron drops from high energy level to a lower energy level and emits a photon

Energy of the emitted photon is

$$E_{ph} = \Delta E_{h \to l}$$

Lowest energy level - ground state

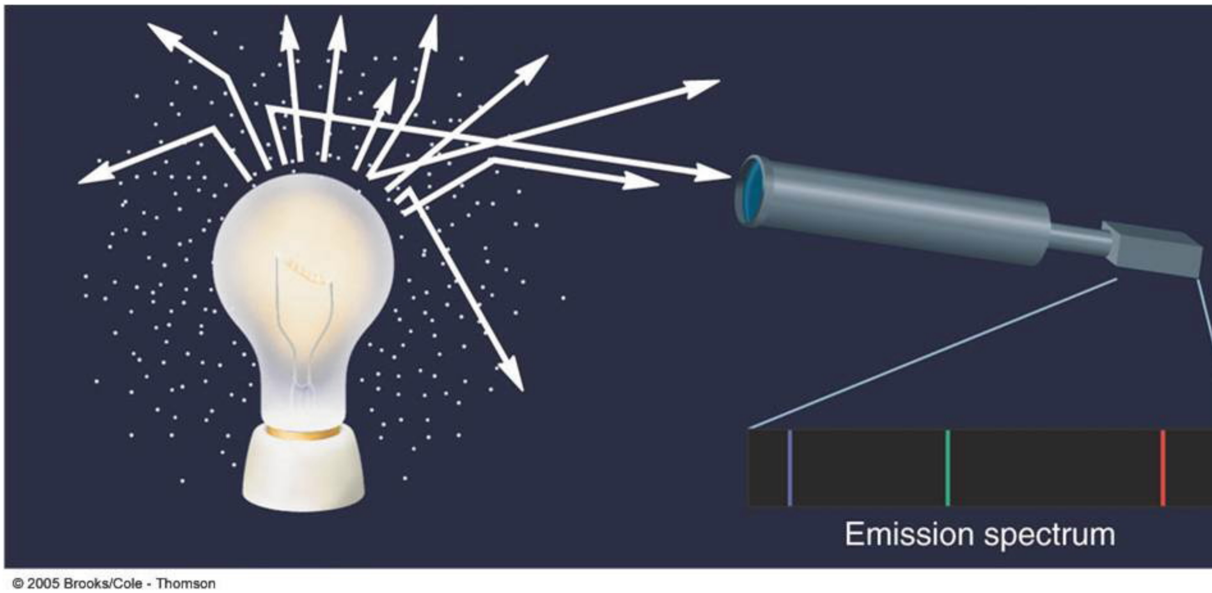


1.5 Formation of Spectra

1.5.1 Kirchoff's Laws

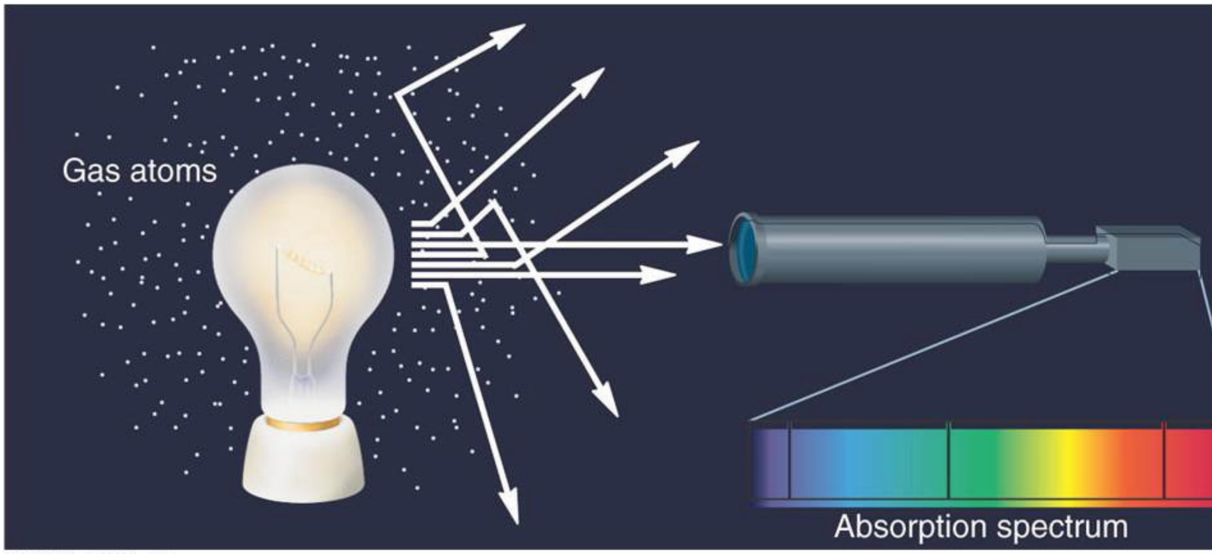
Emission Spectra - bright line spectrum

- A low-density gas excited to emit light will do so at specific wavelengths and produce an emission spectrum.



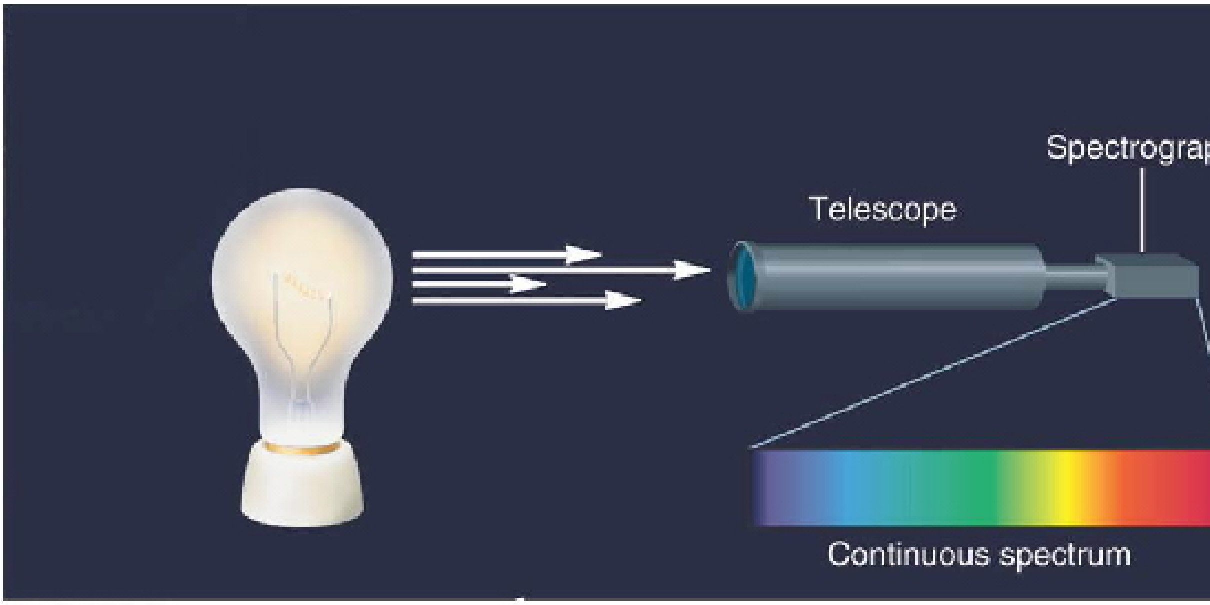
Absorption Spectra - dark line spectrum

- If light comprising a continuous spectrum is allowed to pass through a cool low density gas the resulting spectrum will have dark lines at certain wavelengths.

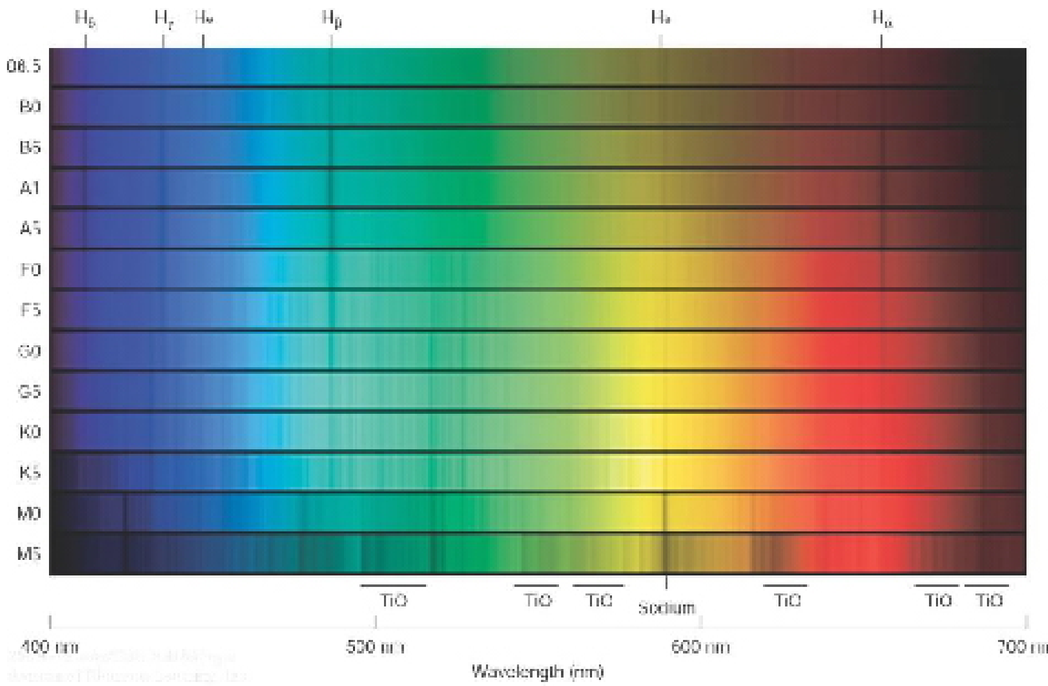


Continuous Spectra

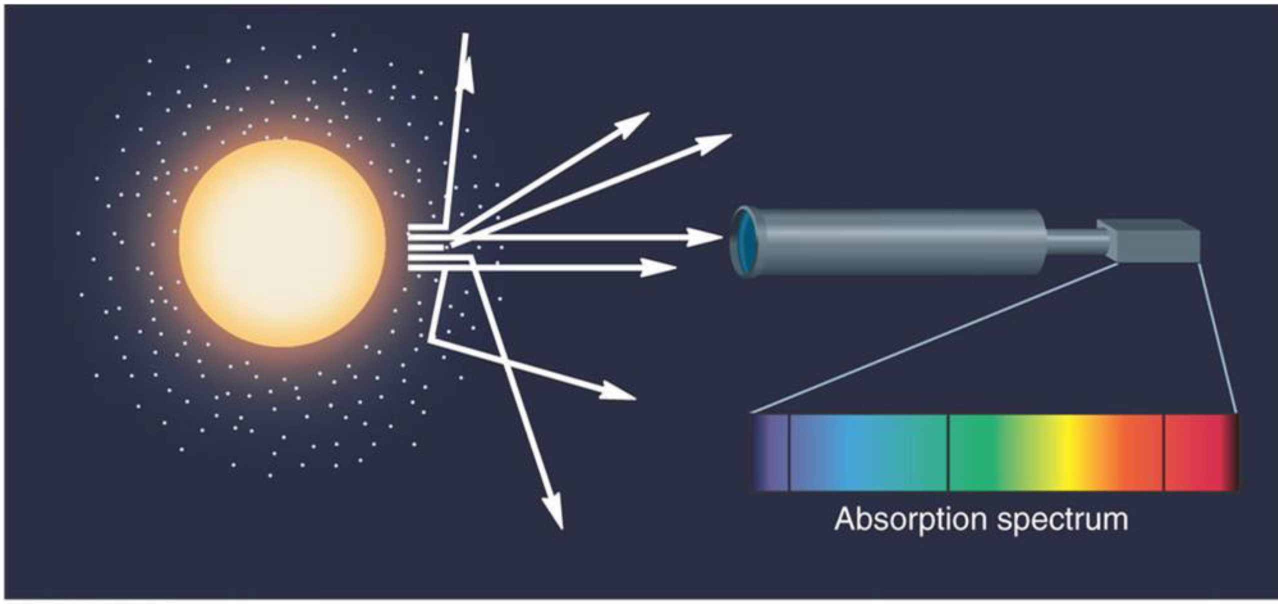
- A solid, liquid, or dense gas excited to emit light will radiate at all wavelengths and produce a continuous spectrum.



1.5.2 Stellar Spectra (old style)



How it forms



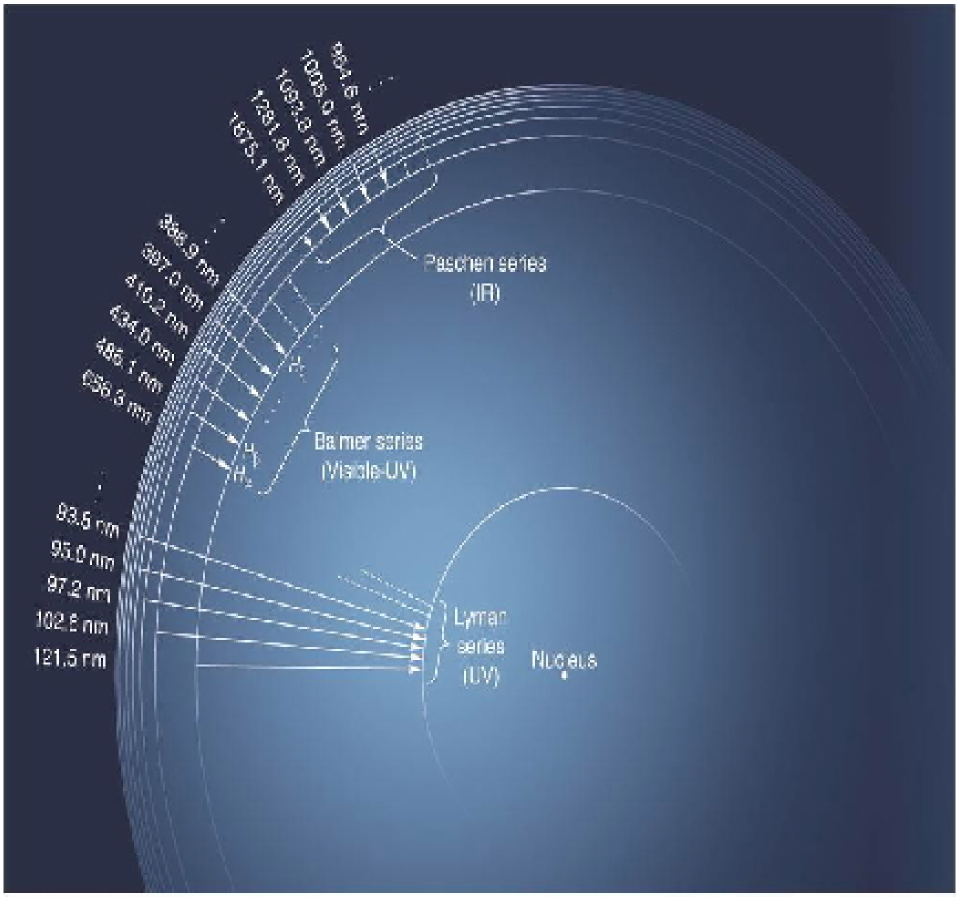
1.5.3 The hydrogen spectrum

Energy levels

Lyman Series

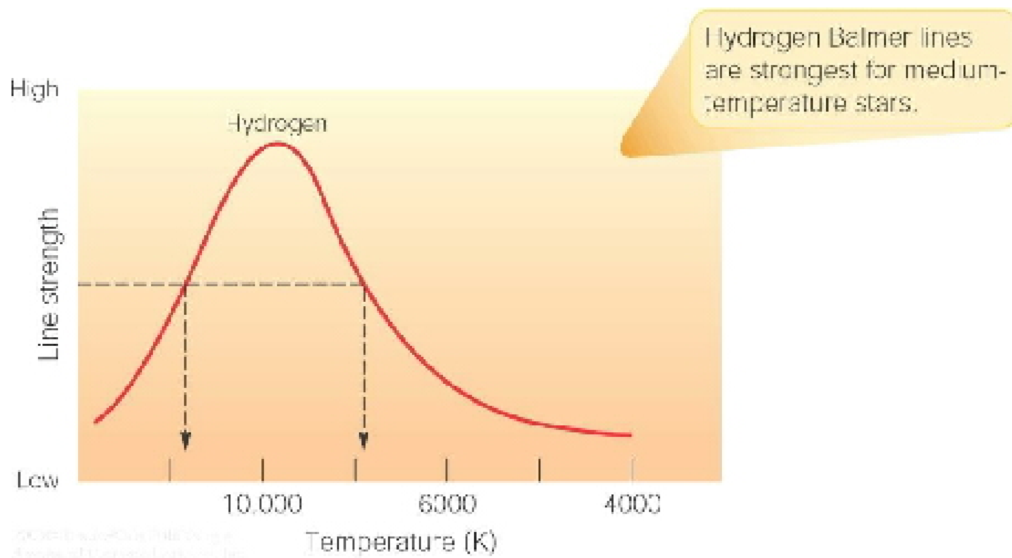
Balmer Series

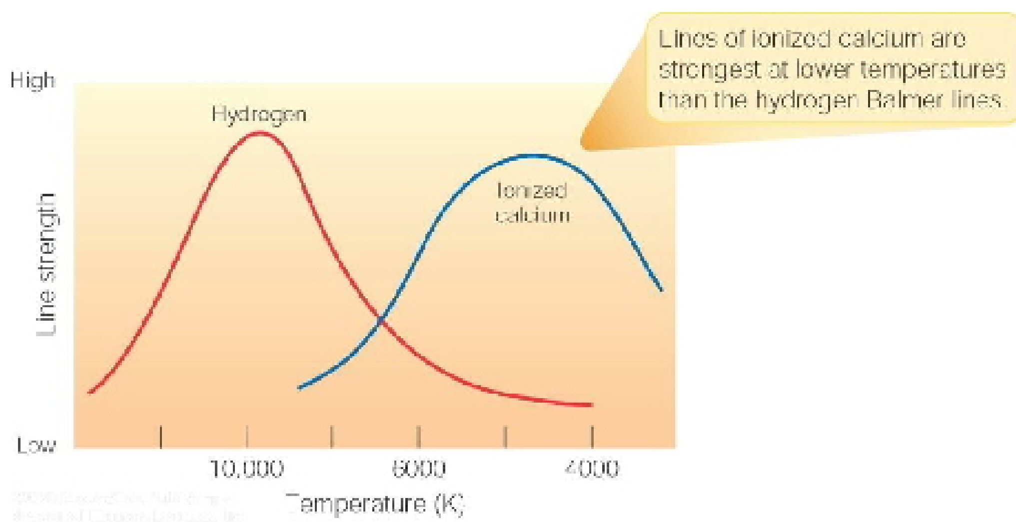
Paschen Series

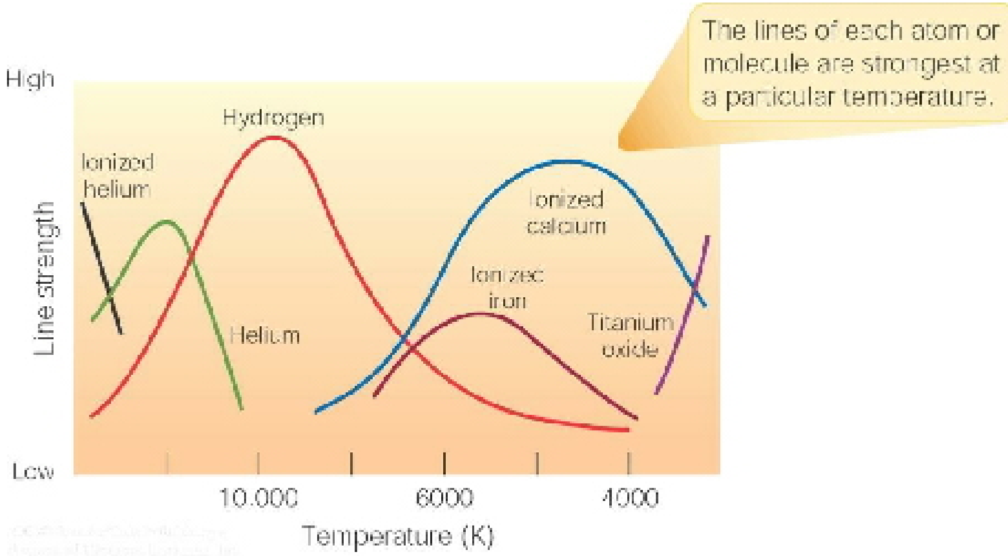


1.6 Stellar Spectra

The Balmer thermometer


Hydrogen Balmer lines are strongest for medium-temperature stars.
High
Hydrogen
Line strength
Low
10,000
6000
4000
Temperature (K)


Lines of ionized calcium are strongest at lower temperatures than the hydrogen Balmer lines.
High
Hydrogen
Ionized calcium
Line strength
Low
10,000
6000
4000
Temperature (K)



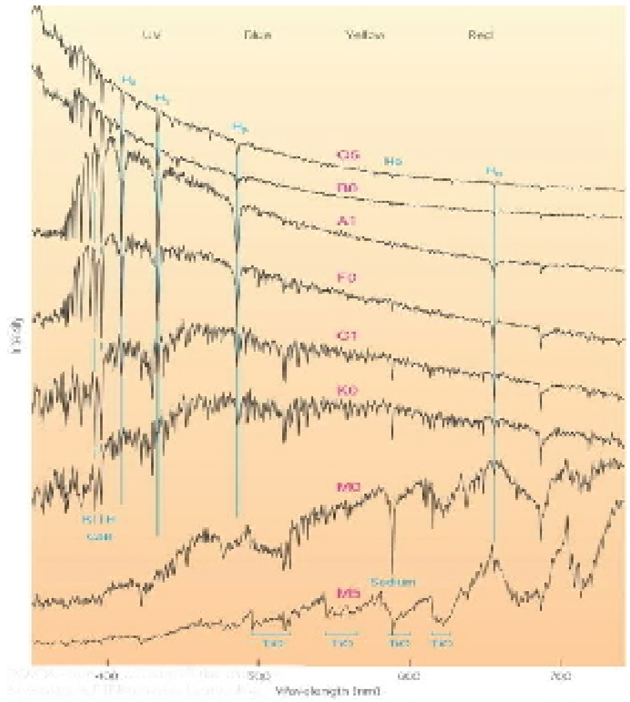
1.6.1 Spectral Classes

O, B, A, F, G, K, M

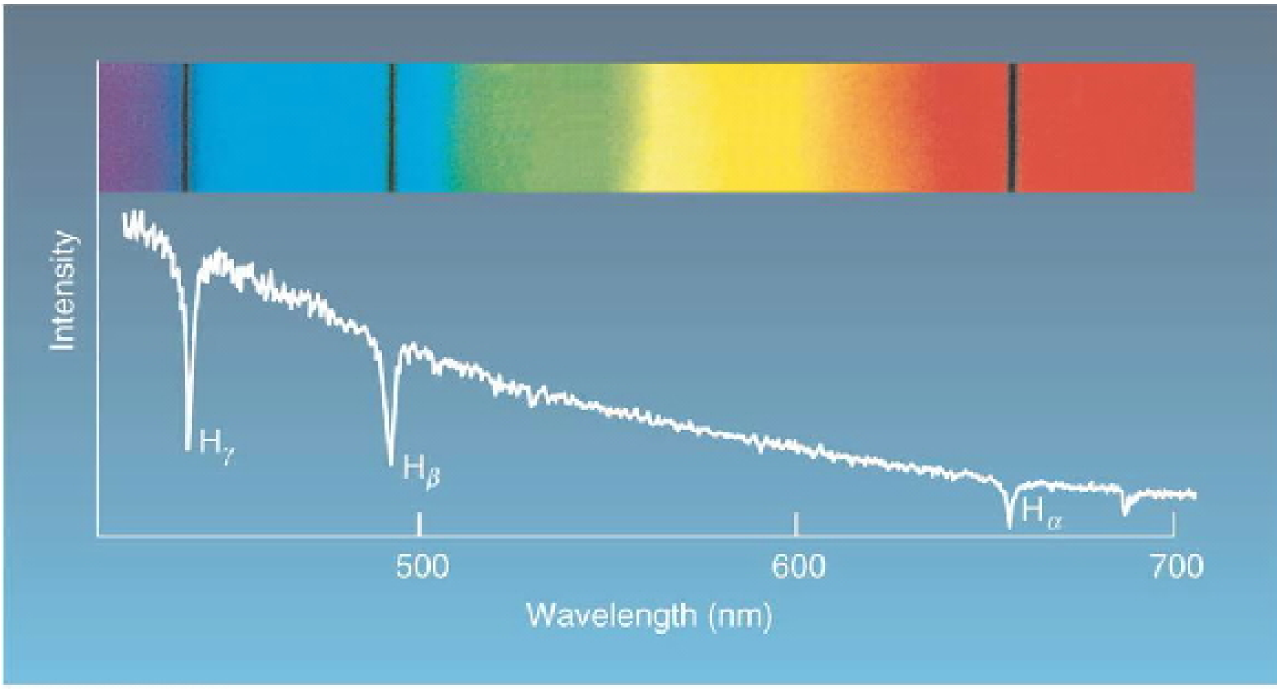
Table 7-1 | Spectral Classes

Spectral Class	Approximate Temperature (K)	Hydrogen Balmer Lines	Other Spectral Features	Naked-Eye Example
O	40,000	Weak	Ionized helium	Meissa (O8)
B	20,000	Medium	Neutral helium	Achernar (B3)
A	10,000	Strong	Ionized calcium weak	Sirius (A1)
F	7,500	Medium	Ionized calcium weak	Canopus (F0)
G	5,500	Weak	Ionized calcium medium	Sun (G2)
K	4,500	Very weak	Ionized calcium strong	Arcturus (K2)
M	3,000	Very weak	TiO strong	Betelgeuse (M2)

1.6.2 Modern spectra



1.6.3 New from Old Spectra



1.7 What can spectra reveal about stars?

1.7.1 Composition

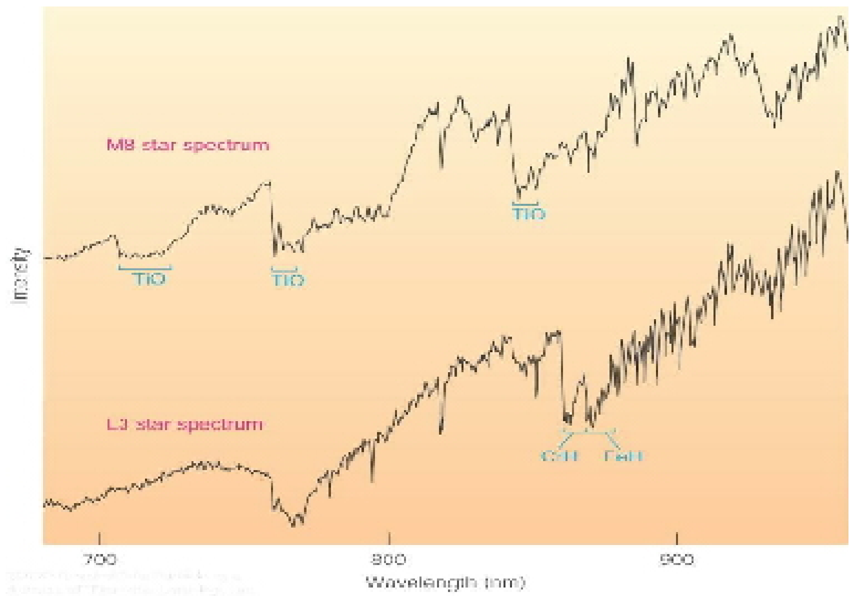
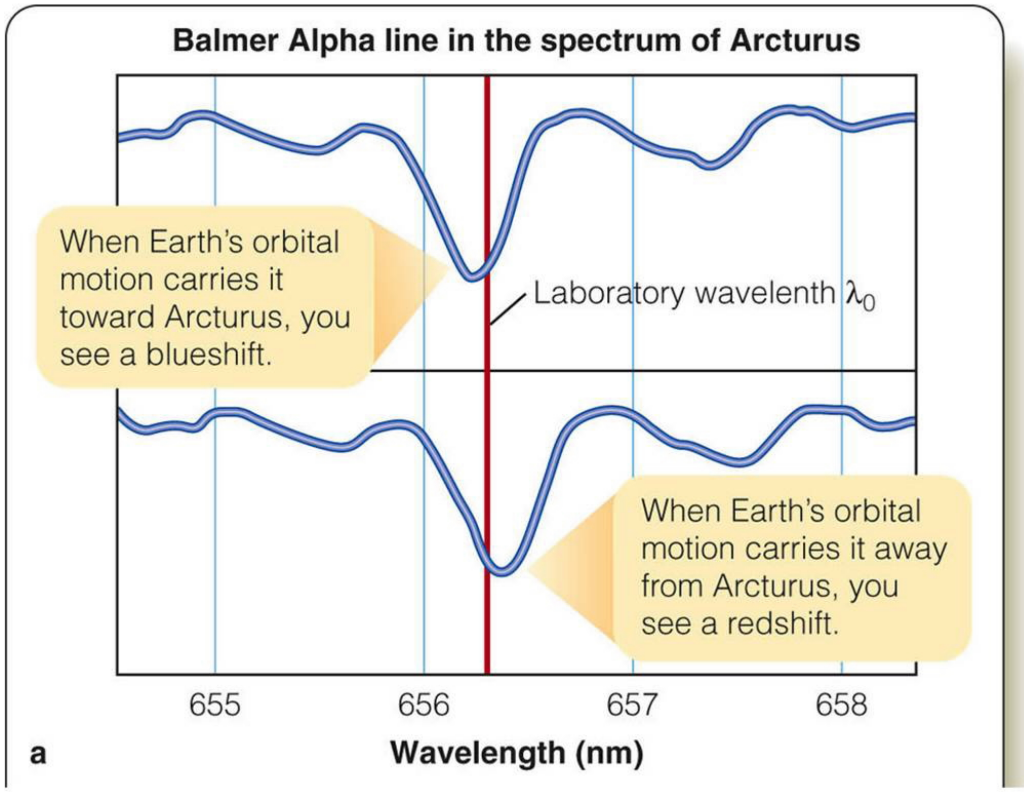
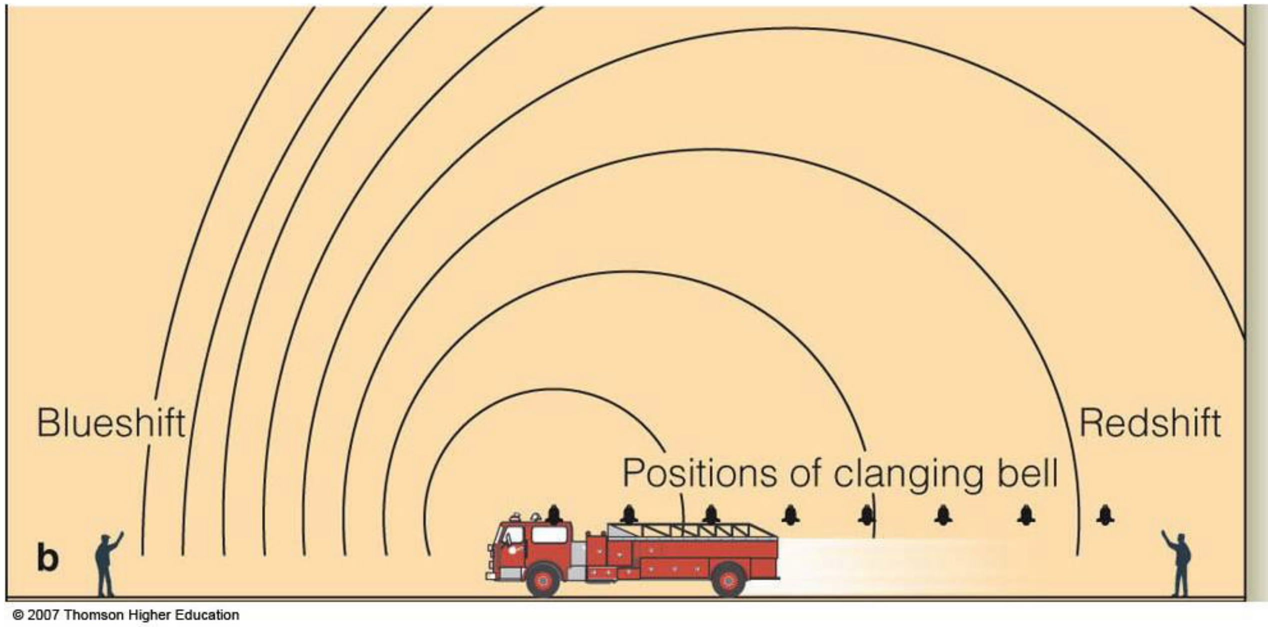


Table 7-2 | The Most Abundant Elements in the Sun

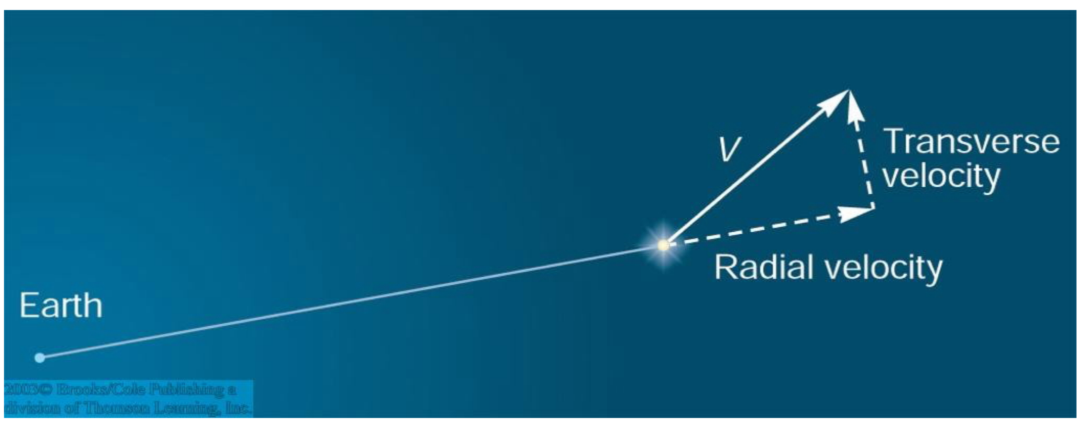
Element	Percentage by Number of Atoms	Percentage by Mass
Hydrogen	91.0	70.9
Helium	8.9	27.4
Carbon	0.03	0.3
Nitrogen	0.008	0.1
Oxygen	0.07	0.8
Neon	0.01	0.2
Magnesium	0.003	0.06
Silicon	0.003	0.07
Sulfur	0.002	0.04
Iron	0.003	0.1

1.7.2 Radial Velocity - Doppler Effect


Balmer Alpha line in the spectrum of Arcturus
When Earth's orbital motion carries it toward Arcturus, you see a blueshift.
Laboratory wavelenth λ_0
When Earth's orbital motion carries it away from Arcturus, you see a redshift.
655
656
657
658
a
Wavelength (nm)



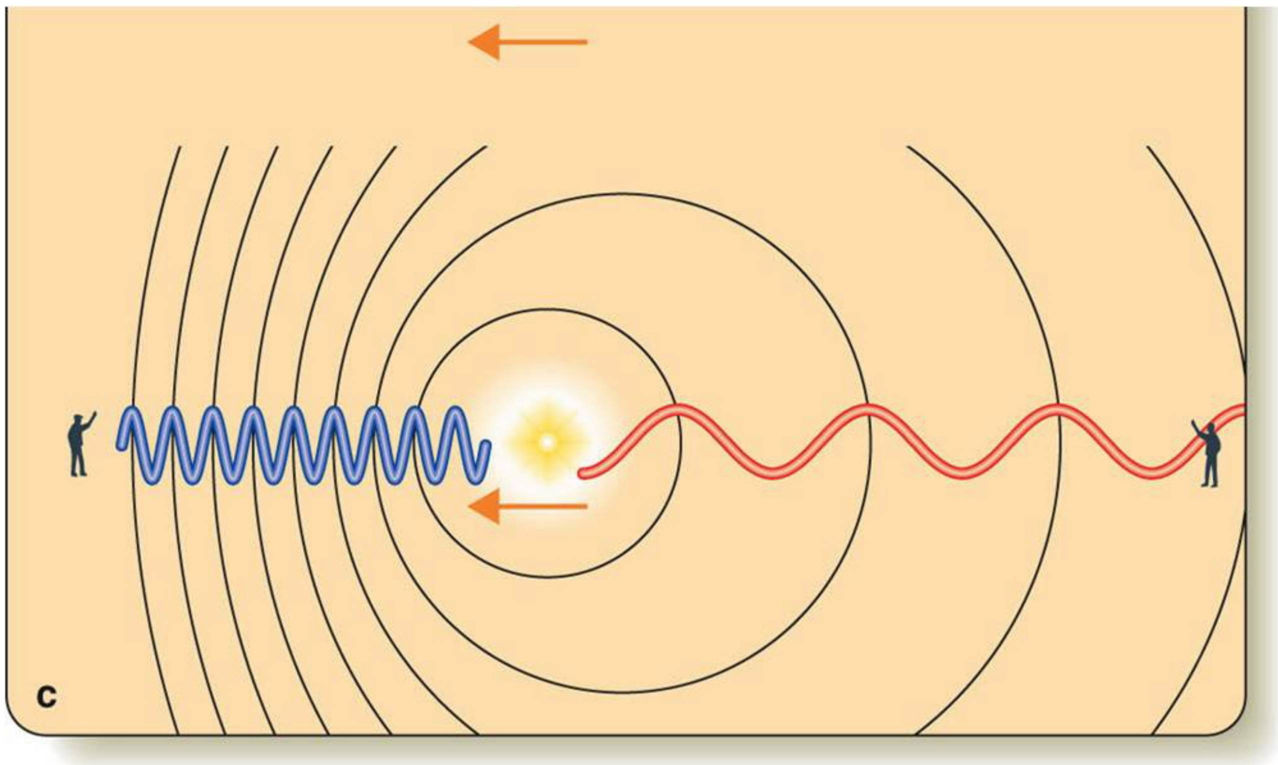
Stellar Motion in general



1.7.3 Radial velocity

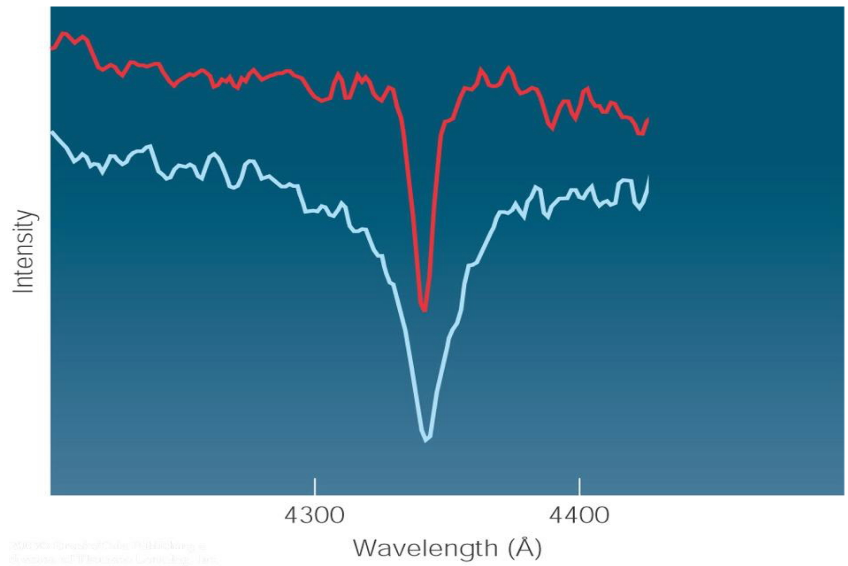
$$\frac{V_r}{c} = \frac{\Delta\lambda}{\lambda_o}$$

Transverse velocity - use small angle formula



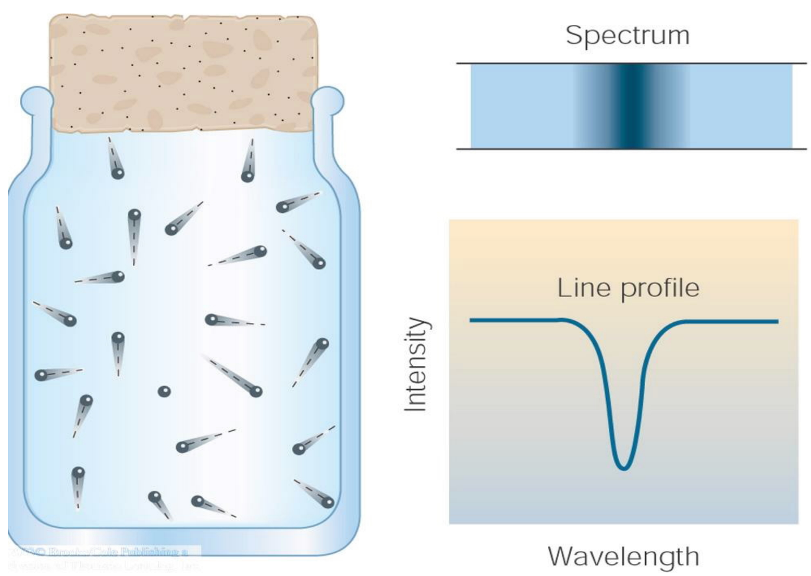
Before we can investigate anymore information from light we need to discuss the shapes of spectral lines.

1.8 Line profile



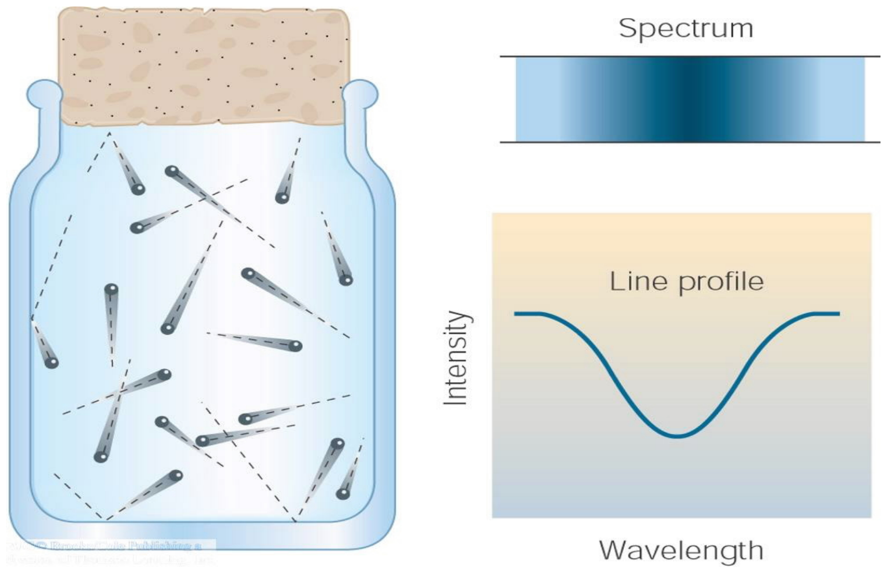
1.8.1 Broadening Mechanisms

Doppler Broadening Natural Broadening - natural line width



Doppler Broadening will occur in the hottest of stars. The hotter the star the wider the line profile

Collisional Broadening



The denser the gas the higher the probability of the atoms colliding therefore the wider the spectral lines. This tells us something about the density of the gas of the star. Red giants have low densities therefore would not show spectral lines broadened by collisions. White dwarfs have high densities and therefore would show lines broadened by collisions.

Here is a link to check out if you want to know **everything** about spectral classifications. Wow!

http://ned.ipac.caltech.edu/level5/Gray/Gray_contents.html**??**
(http://ned.ipac.caltech.edu/level5/Gray/Gray_contents.html)