As you come into class make sure to pick up a Linear Diffraction Grating!

Make sure it says 500 lines/mm.

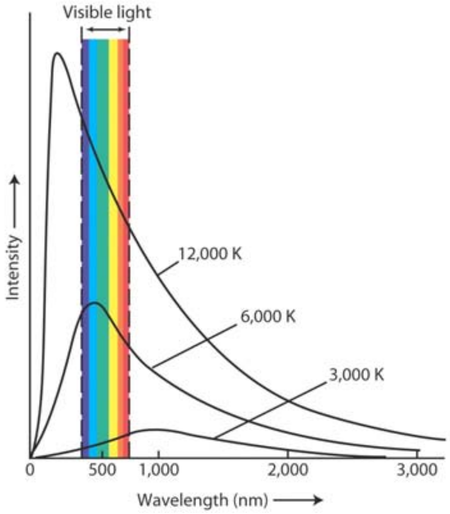
- Next homework is #6– due Friday at 11:50 am.
- There will be another make-up nighttime observing session in November. Stay tuned.

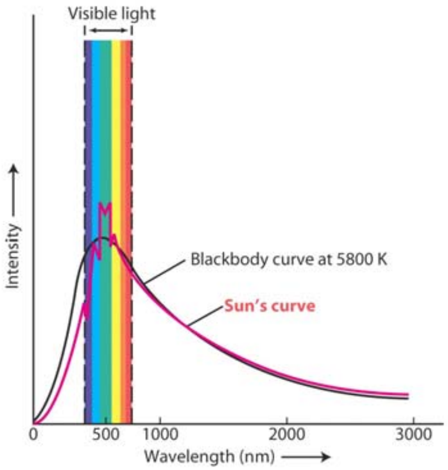
Outline

- Have we said enough about Blackbody radiation yet?
  - Wein's Law
  - Stephan-Boltzmann Law
- Back to atoms– again
- Quantum mechanical properties of the Atom– things get quantized
- How atoms absorb and emit light– Quantum Leaps
- Looking at atoms emit in class– Voyeurism
- The fingerprints or barcodes of atoms
- The Doppler effect– weeee weee

The Spectrum of Blackbody Radiation

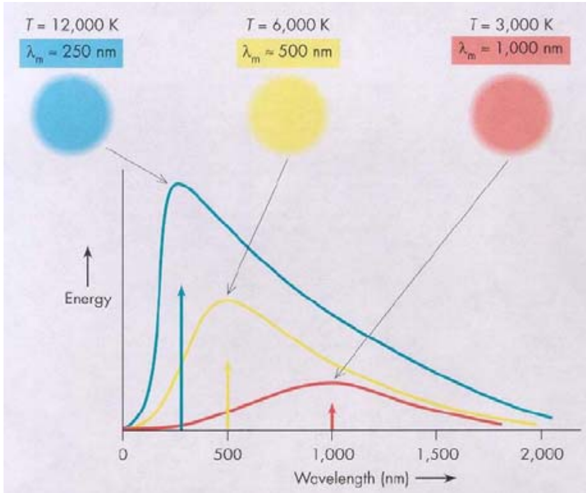
- As temperature increases, peak shifts to shorter wavelengths
- The Sun's spectrum looks almost like a 5800 K blackbody





Wein's Law

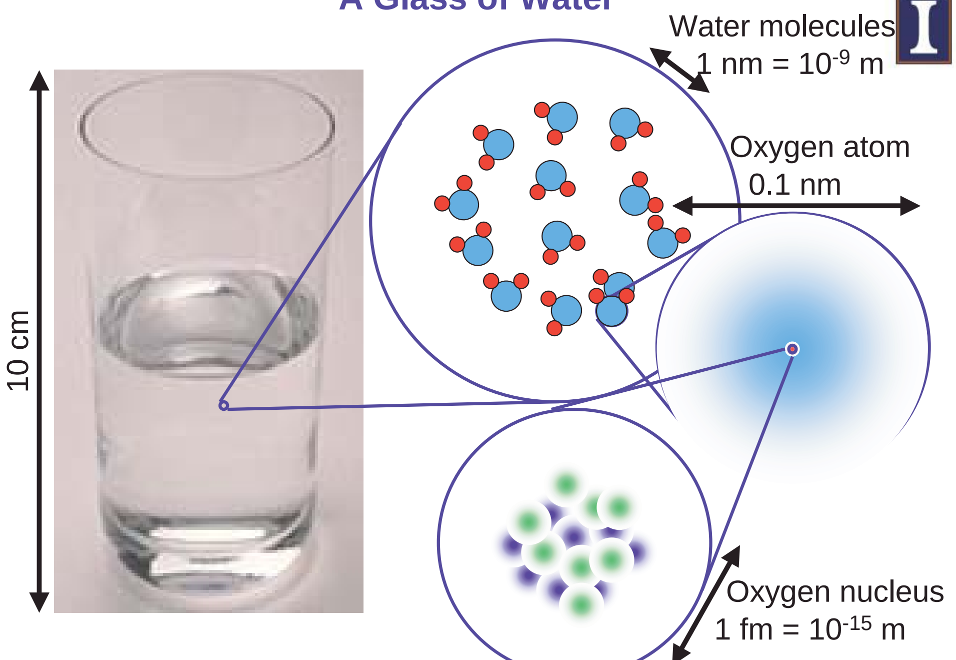
- The peak of the blackbody emission is inversely related to the temperature
- The hotter the object, the stronger it emits light in the shorter wavelengths.
- The Sun's Photosphere is around 5800 K
- Red hot? Or Blue hot? Color of stars?



Stephan-Boltzmann Law

- For blackbodies, the brightness, or intensity, or output energy, is proportional to T^4 (in Kelvin).
- If a star was the same size as the Sun, but was twice as hot, it would be <u>16 times</u> as bright.

A Glass of Water



Protons, neutrons, and electrons

- **Electrons**
  Negatively charged (charge -1)
  Lightweight (mass 9.110 x 10^{-28} g)
- **Protons**
  Positively charged (charge +1)
  1832 times as massive as an electron (mass 1.673 x 10^{-24} g)
- **Neutrons**
  No electric charge
  A little more massive than a proton (mass 1.675 x 10^{-24} g)

The Periodic Table of the Elements

1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Cesium	56 Ba Barium	57 La Lanthanum	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89 Ac Actinium	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110	111	112		114		116		

58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

The number of protons in an atom determines the type of element

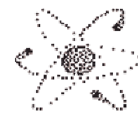
Quantum Atoms

At small distances– the size of atoms

- <u>Newton's laws ***fail***</u>
- Atoms & light obey ***quantum mechanics***

Electron orbits nucleus + electron: like solar system?

- No: in quantum mechanics electrons are not really like a planet. It isn't gravity.
- In atom, the electron acts like wave !?!
- And not all orbits are allowed



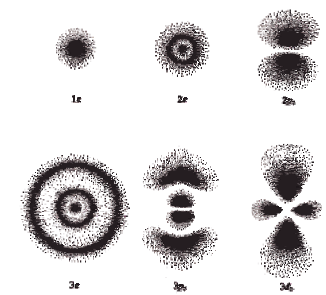
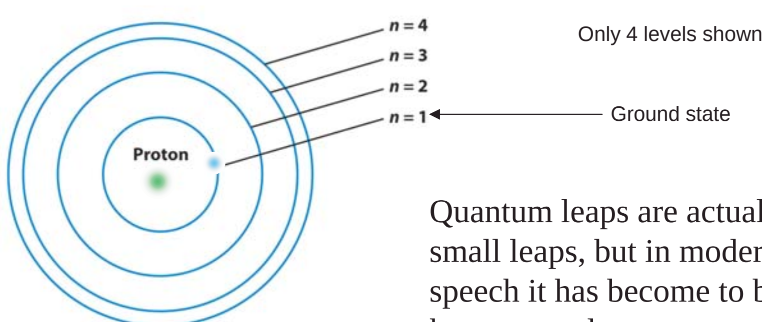


Figure 6-12. Probability density plots of some hydrogen atomic orbitals. The density of the dots represents the probability of finding the electron in that region.
© 1983 University Science Books; "Quantum Chemistry" by Donald A. McQuarrie

Quantum Atomic Structure

Allowed orbits → energy levels
- Lowest energy → stable orbit
- Closest to nucleus
- ***Ground state***



Hydrogen atom

Quantum leaps are actually small leaps, but in modern speech it has become to be known as a large step.

Question 1

Today, we are going to look at different emissions. What does the heater do?

1. Emits a continuous spectrum of light
2. Emits discrete colors of light
3. Emits only reddish color light

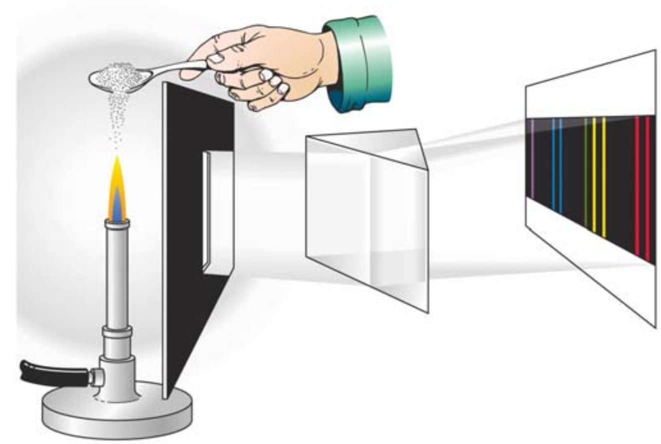
Question 2

Today, we are going to look at different emissions. What does atom lamps do? These are “Neon” lamps with electrified gas and energized (“excited”) atoms.

1. Emit a continuous spectrum of light
2. Emit discrete colors of light
3. Emit only white light

Emission Lines in the Laboratory

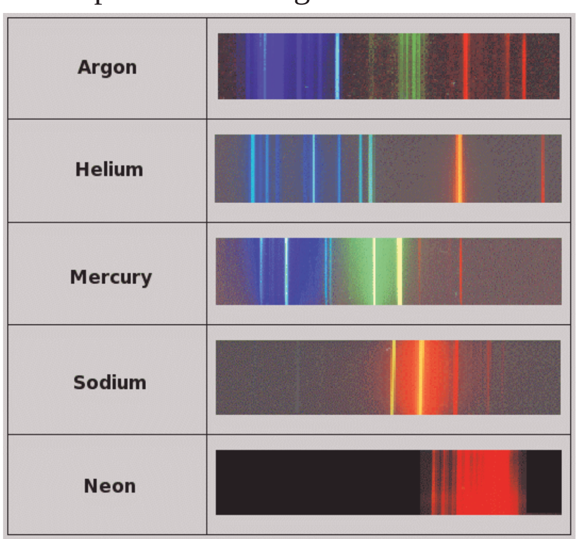
- Spectral lines produced and studied in the laboratory by Robert Bunsen and Gustav Kirchhoff beginning around 1857
- Discovered that burning different chemical elements produced different patterns of lines



The Spectrum is a fingerprint!

The pattern of spectral lines produced by (or absorbed by) a gas depends on the chemical composition of the gas.

Or a barcode!

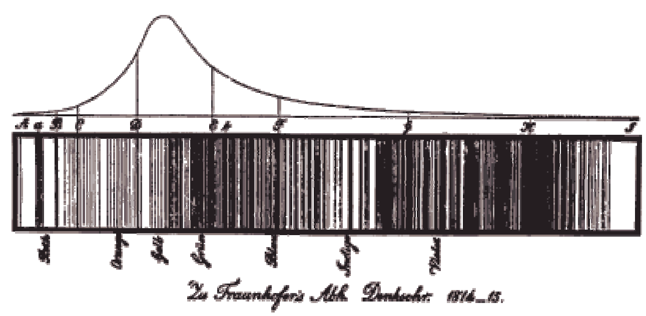


Emission spectrum

http://www.astro.washington.edu/astro101v

Fraunhofer and Spectral Lines

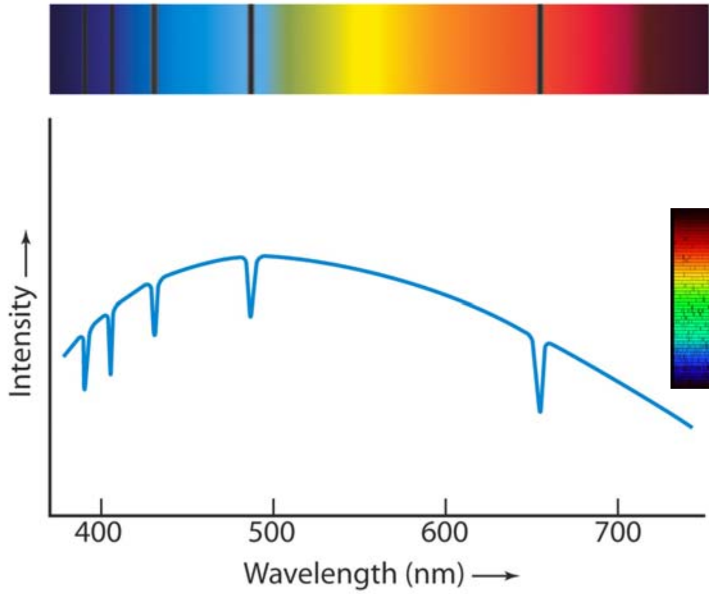
Discovered that Sun’s spectrum contained narrow gaps (**spectral lines**) when viewed at high resolution (1814)

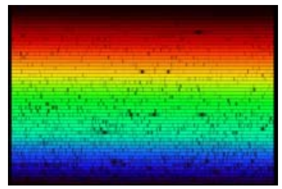


Joseph von Fraunhofer (1787-1826)

Prism spectrograph

Absorption Spectrum of the Sun





Quantum Light: Photons

As we discussed before, just as electrons can sometimes act like waves light can sometimes act like particles– Photons

On small scales or low intensities

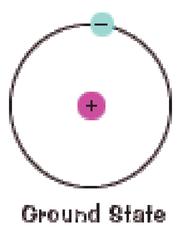
- Light acts like particle: ***"photon"***
- Discrete "packet" of energy"
- Different colors ⇨ different energies
- Smaller λ, higher E

- These packets of energy can effect the electron in an atom.

Light and Atoms

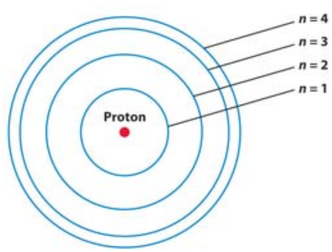
If light hits an atom in ground state
and photon energy = atom energy level ***exactly***

1. atom absorbs photon
2. Electron jumps to higher level
3. Atom in "excited" state



But excited = unstable
And after time,

1. Electron jumps back to ground state
2. Emits photon with energy =difference between levels



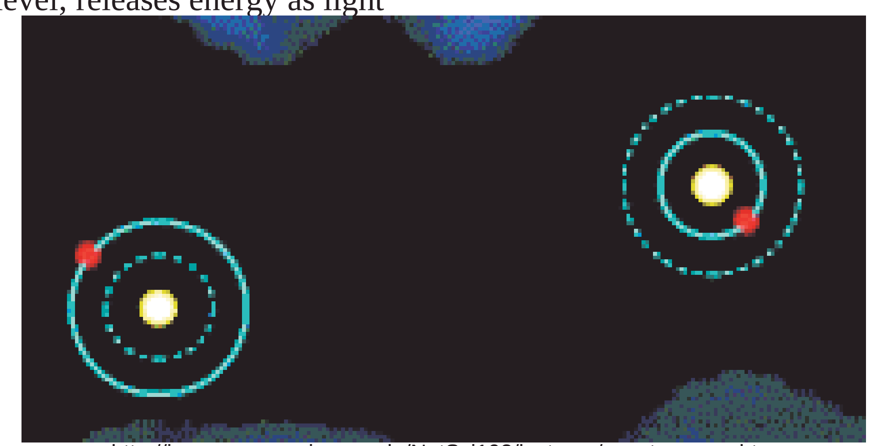
Online demo

Atoms absorb/emit light

- atom structure sets energies

Atomic Interpretation of Spectral Lines

- Spectral lines correspond to transitions between levels in an atom
- **Absorption:** light energy absorbed by atom, electron jumps to higher energy level
- **Emission:** electron spontaneously drops down to lower energy level; releases energy as light

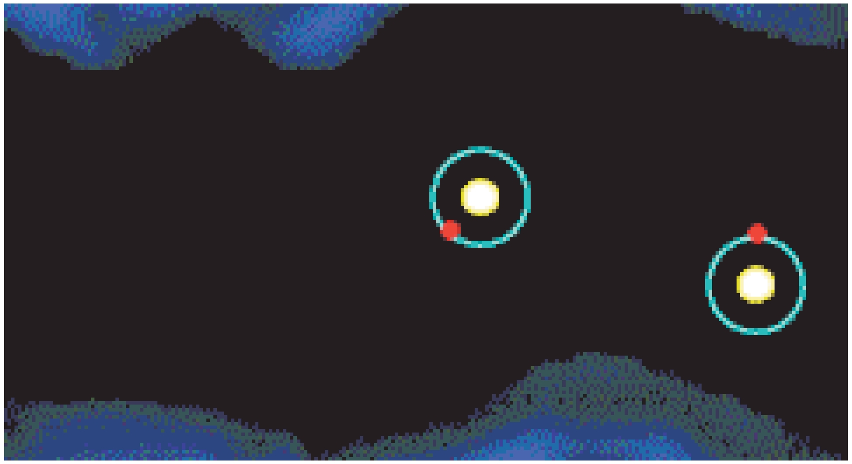


http://ircamera.as.arizona.edu/NatSci102/lectures/spectroscopy.htm

Collisional Excitation of Atoms

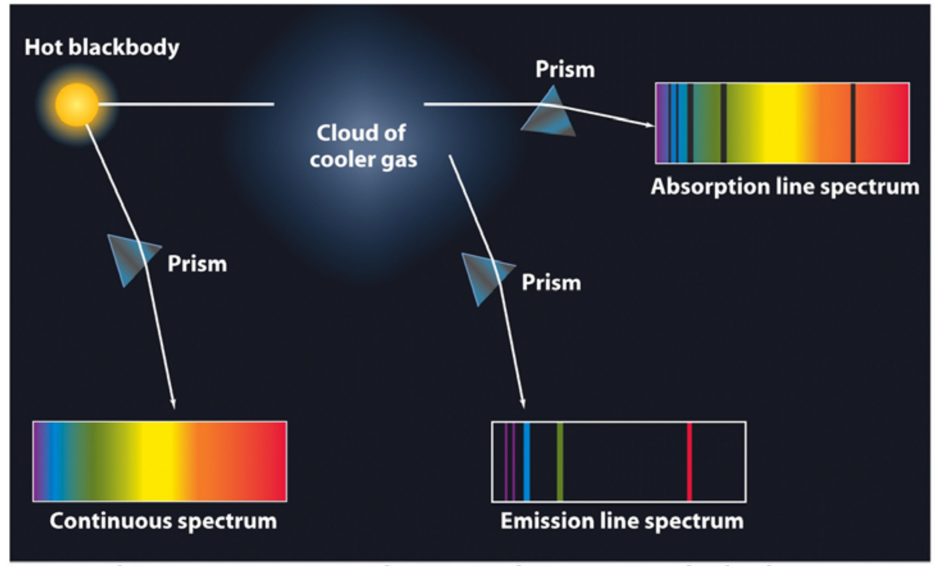
How do atoms get excited in the first place?

- By **absorbing** photons; or
- By **colliding** with other atoms



http://ircamera.as.arizona.edu/NatSci102/lectures/spectroscopy.htm

Connection between Lines and Continuous Spectra



http://www.astro.uiuc.edu/projects/data/Spectra/index.html

Implications: Spectra

Light spectrum gives atom "fingerprint" or "barcode"

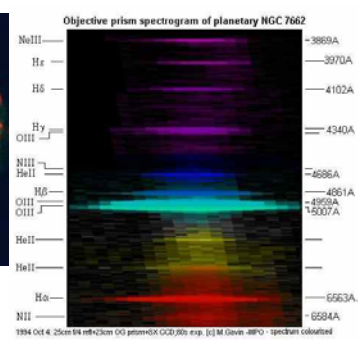
So, the spectrum gives atomic composition

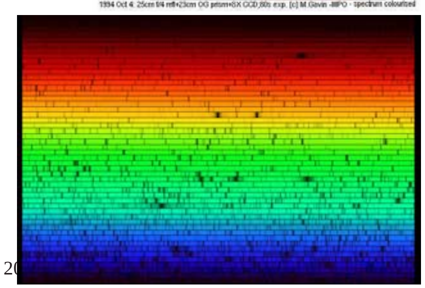
Planetary nebula:

- Colors: *lines=elements*
- See newly created material!

Solar spectrum:

- Dark lines: elements
- Tells *composition* of Sun



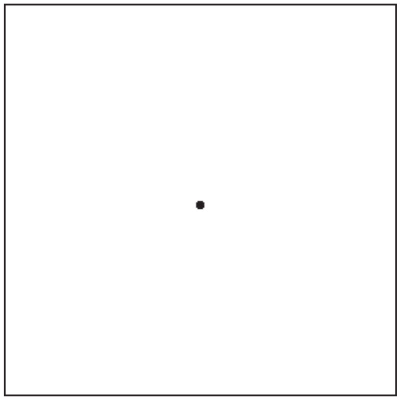


Doppler Effect

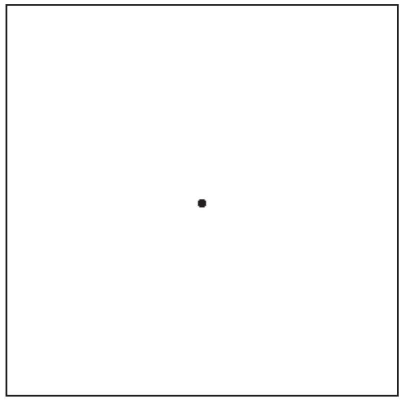
Those of you use to racing events like the Indy 500, or the sound of a police siren, are use to the Doppler effect.

The Doppler Effect

The effect arises from the relative motion of the observer and the source of light, sound, etc. The waves get squashed in the direction of motion and stretched in the opposite direction.



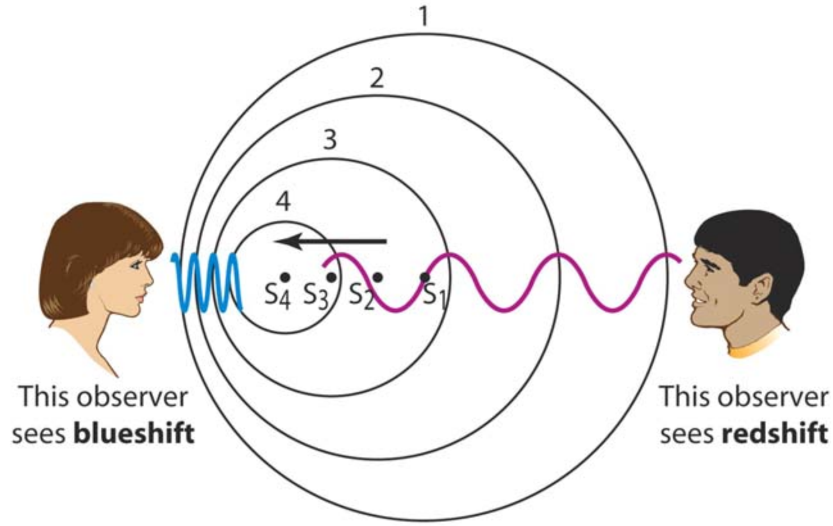
Source standing still



Source moving to right

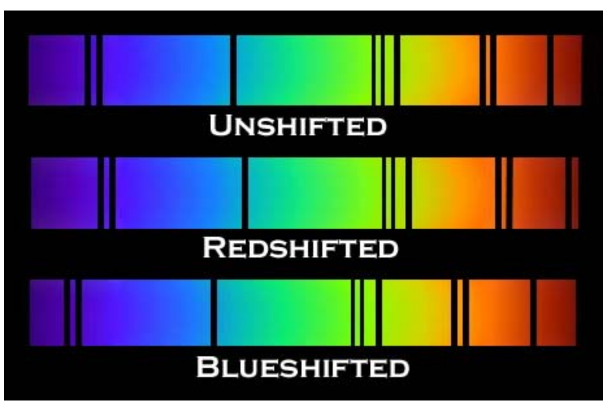
The Doppler Effect

The amount of the shift in wavelength depends on the relative velocity of the source and the observer

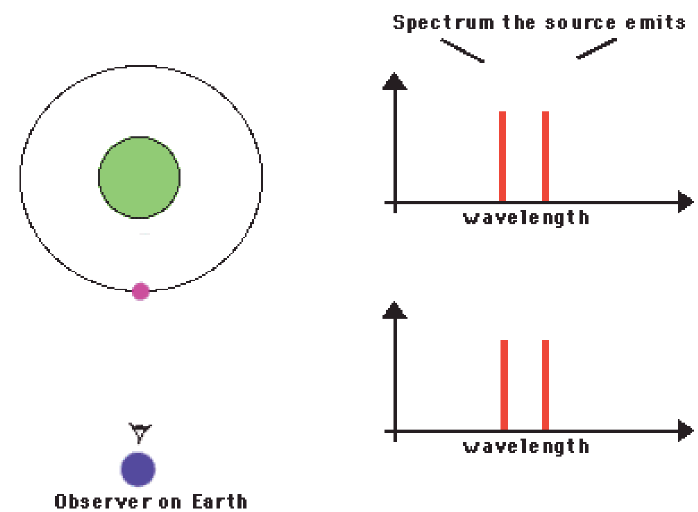


Applying Doppler Shift to Light

We can use the Doppler shift as a shift in the wavelength of spectral lines to determine the speed of the source of light– either **toward** or **away** from us.



Using Spectral Lines to Detect Line-of-Sight Motion



http://cosmos.colorado.edu/astr1120/lesson1.html

Proper Motions vs. Radial Motions

- **Proper motion** is the part of an object's velocity perpendicular to the line of sight
- The Doppler shift only gives us the line-of-sight motion, not the proper motion