Why is Light so useful in Astronomy?

- It can tell us many properties of planets and stars:
  - How warm / hot they are (Surface temperature)
  - What they're made of (Chemical Composition)
  - How they're moving (Radial Velocity and Spin)

Interaction of Light and Matter: Four Ways

1. **emission –** matter releases energy (E) as light
2. **absorption –** matter takes E from light
3. **transmission –** matter allows light to pass
4. **reflection –** matter repels light in another direction

CONSERVATION OF ENERGY

Emission - Continuous

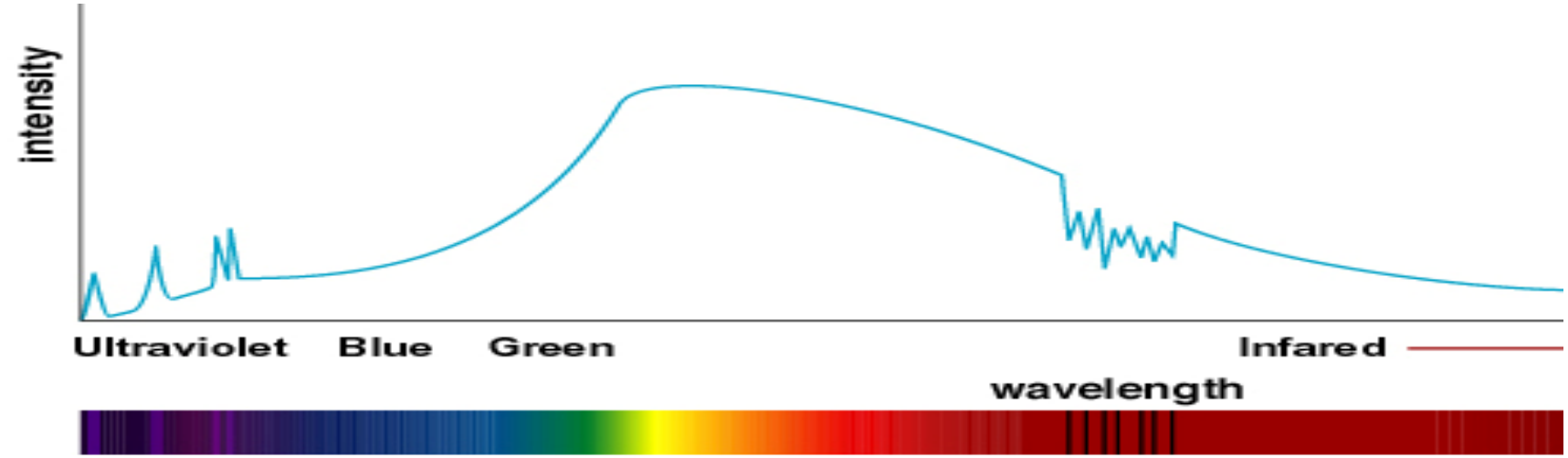
- Hot, dense objects give off continuous thermal blackbody radiation
  - Warm objects emit infrared
  - Hotter ➔
    - More light
    - Shorter wavelengths
    - e.g. Stars emit visible light!

- IR Spectrum ➔ We can measure planet's surface temperature!

Reflection: Application

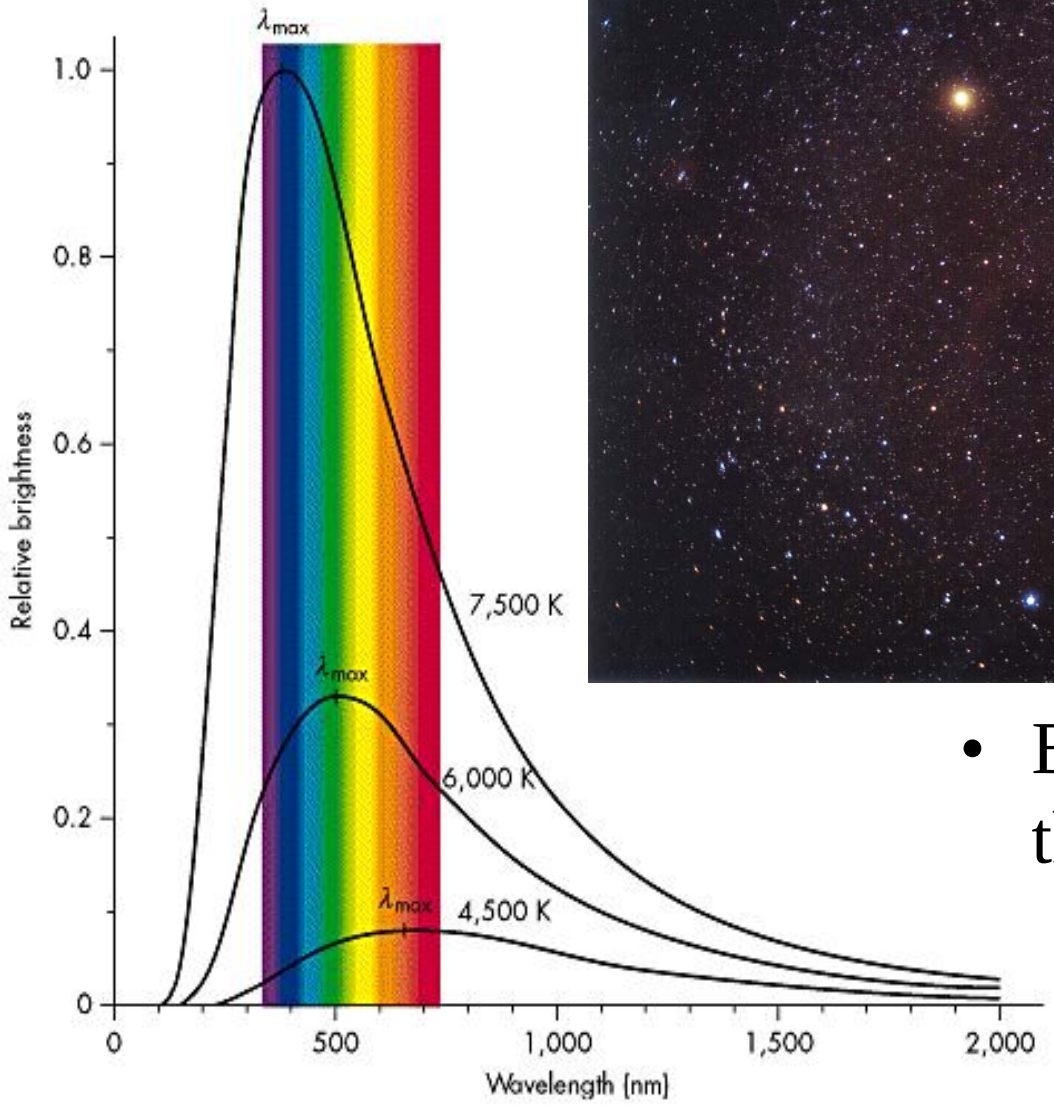
- When light passes through matter, or reflects off of matter, some wavelengths may be absorbed

- Resulting spectrum tells us about the matter!
  - Example: Mars appears red because it's surface absorbs more blue light than red (reflects more red light than blue) ➔ tells us something about what surface is made of



Blackbody Activity

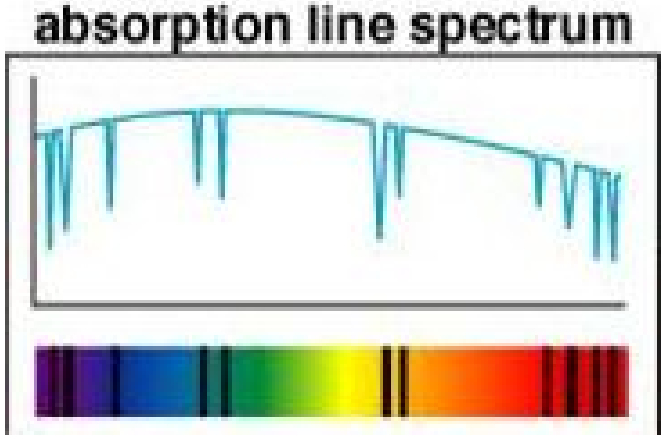
Application to Stars: Thermal Radiation



- Bluer Stars are hotter than redder ones!

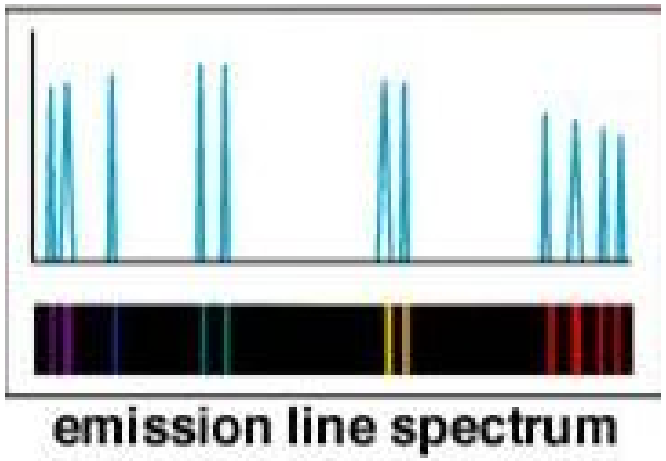
Emission & Absorption

- Photons can be absorbed / emitted by matter:
  - Photon energy matches “jump” in energy levels
    - http://www.astro.uiuc.edu/projects/data/Spectra/orbitals.html

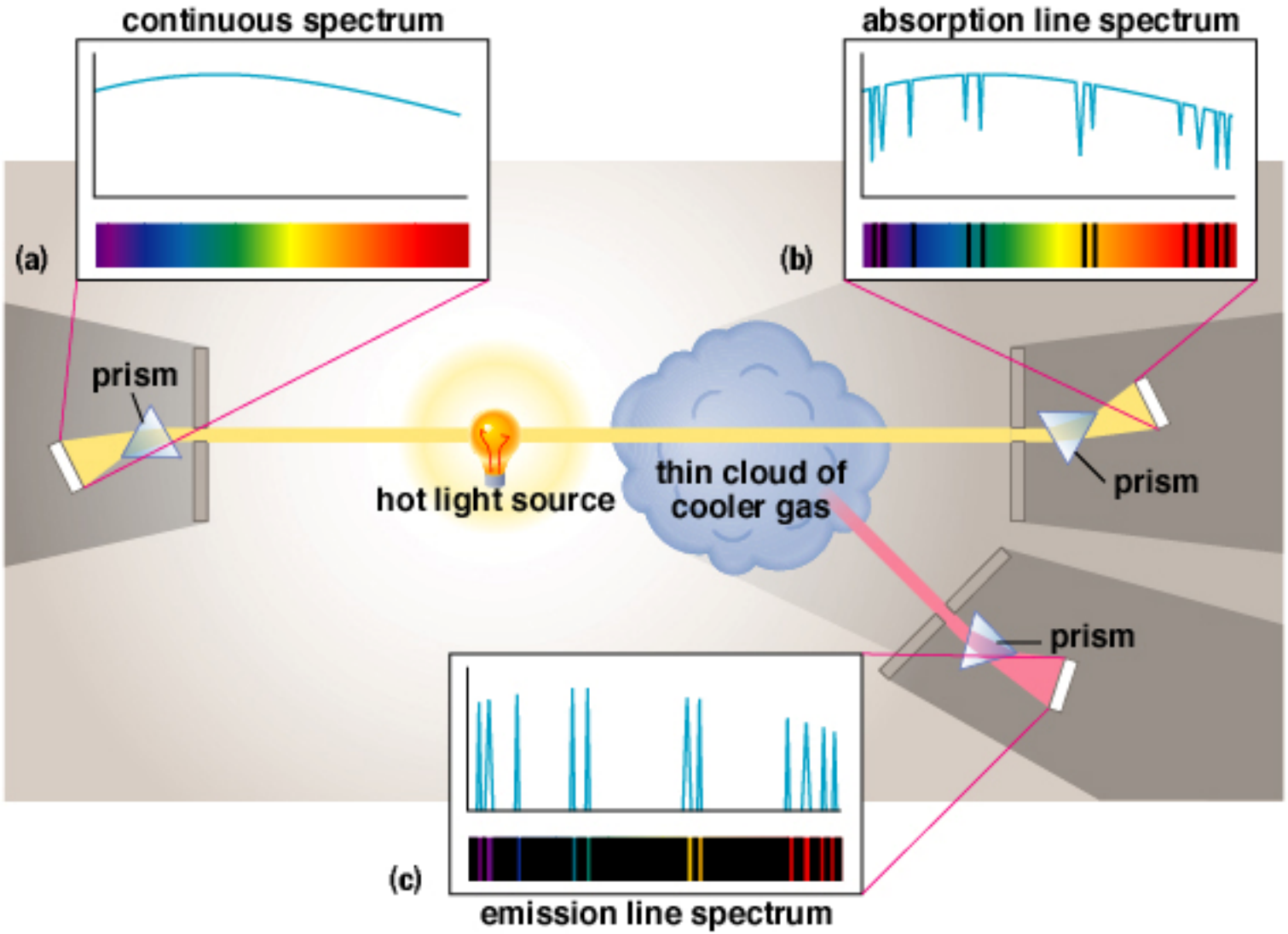


- Atoms absorb photon & gain energy ➔ Absorption-line spectrum

- Atoms emit photon & lose energy ➔ Emission-line spectrum

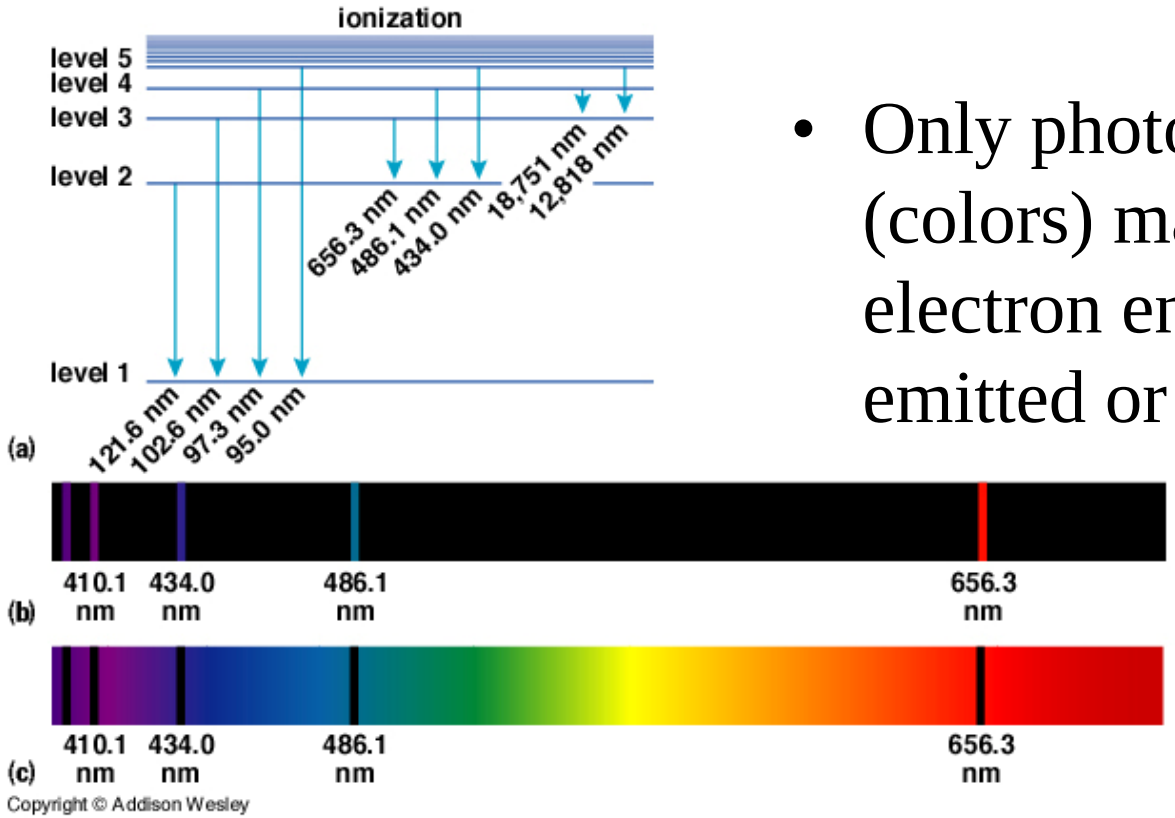


Kirchhoff's Laws: Kinds of Spectra



Types of Spectra Activity

Element Identification



- Only photons whose energies (colors) match the "jump" in electron energy levels can be emitted or absorbed.

- Each element has a ***unique signature*** because of its energy level structure

Application : Chemical Composition

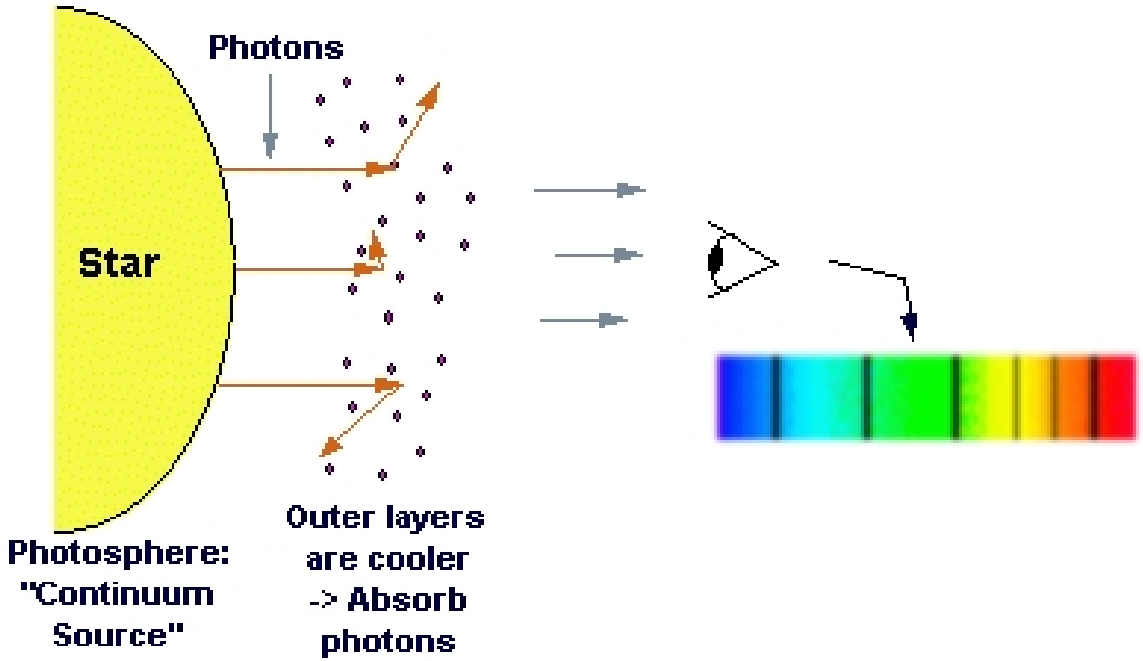
- Presence of absorption lines of a particular element indicates the presence of that element in the absorbing material
  - e.g. atmosphere of a star!

Artificial (Absorption-line) Solar Spectrum:

Laboratory (Emission-line) Spectrum of Iron:

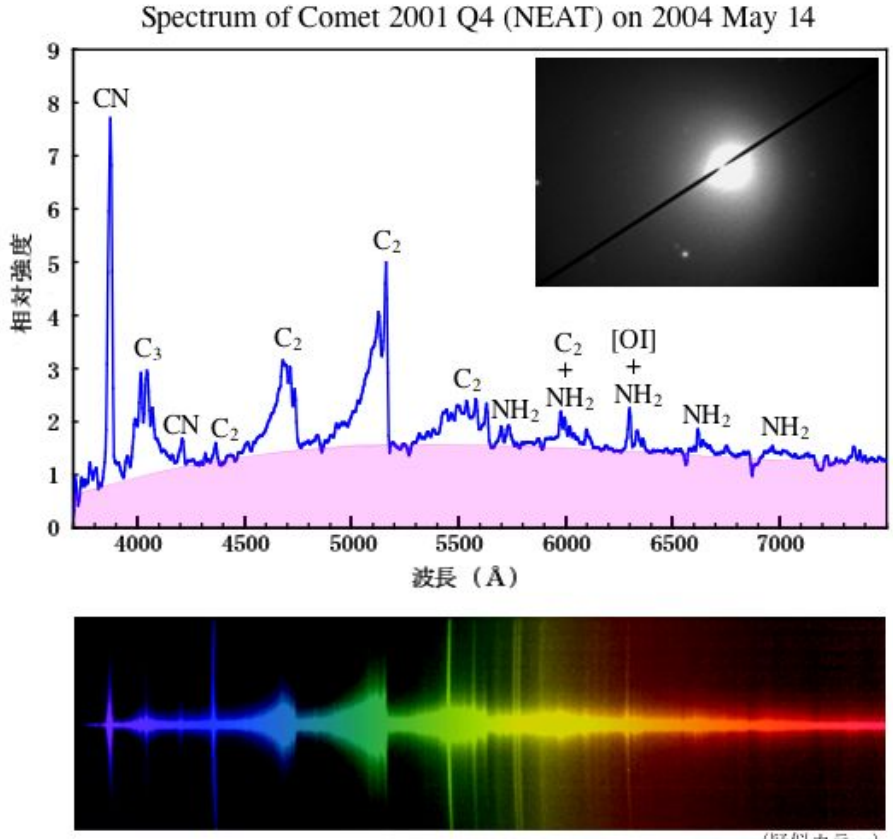
Application to Stars: Absorption spectra

- **Outer layers** of a star are cooler than the dense inner part (i.e. they are the “cool cloud”)



Application: Emission Spectra

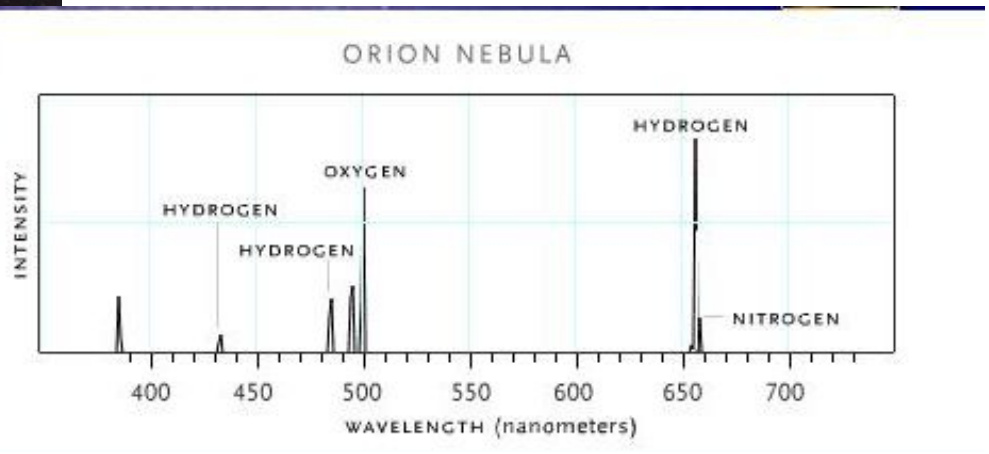
- **Tails of Comets** consist of dust which reflects sunlight, and excited gas which produces an emission-line spectrum.



From http://www.astron.pref.gunma.jp/gallery/comet_2001Q4.html

Application : Chemical Composition

- Presence of emission lines of a particular element indicates the presence of that element in the excited gas

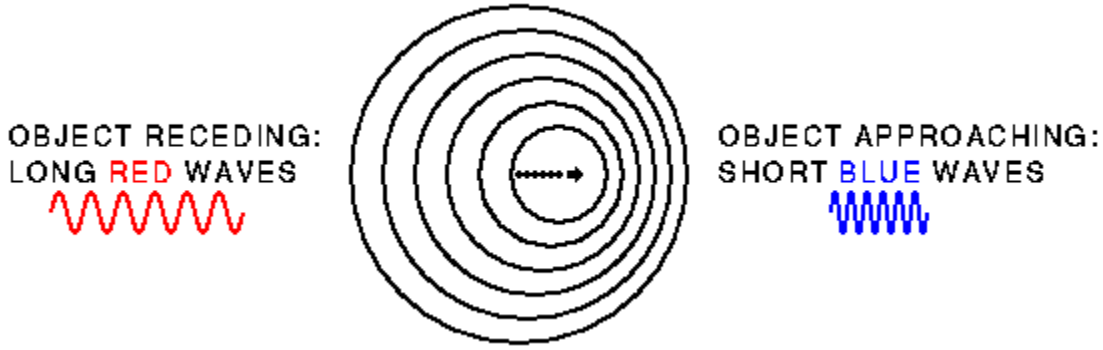


From: http://www.pbs.org/wgbh/nova/origins/spectra.html

The Doppler Effect

How is light affected by the velocity of a source?
(Alternate views:
http://www.fearofphysics.com/Sound/dopwhy2.html
and
http://lectureonline.cl.msu.edu/~mmp/applist/doppler/d.htm)

The Doppler Effect



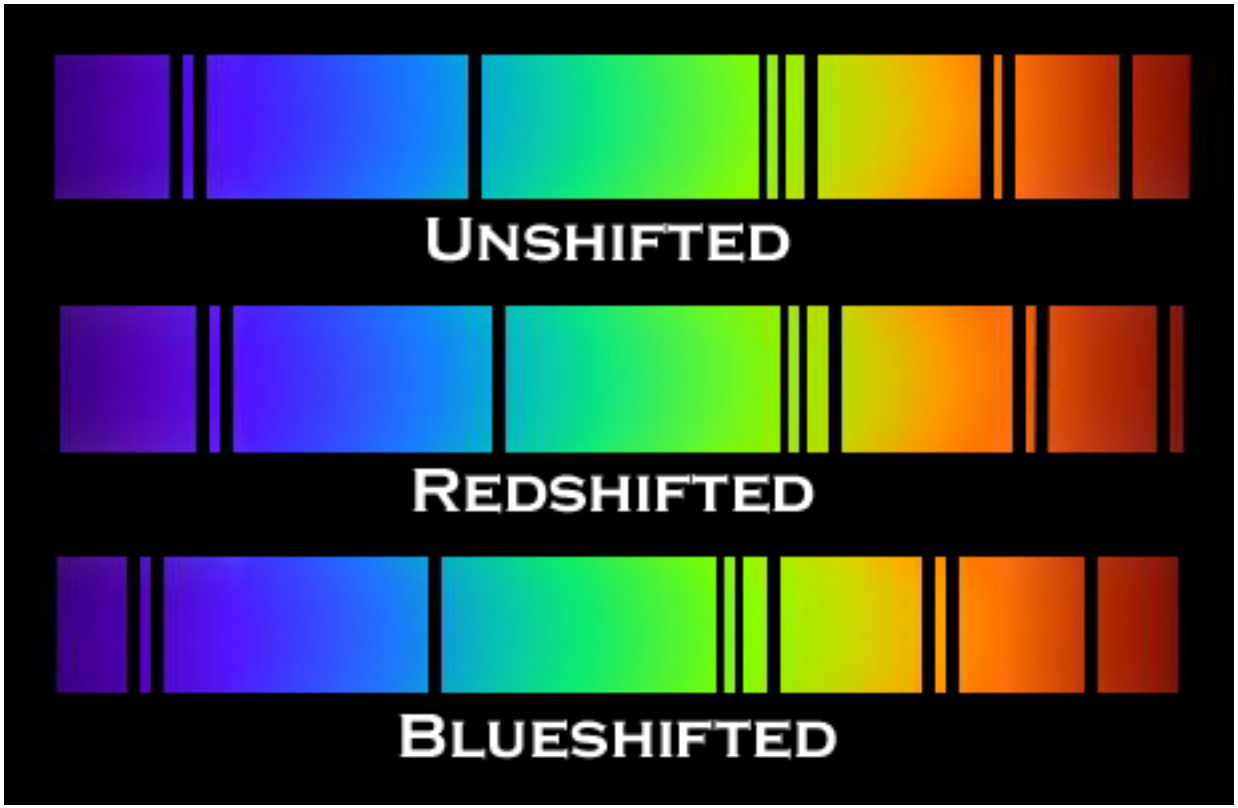
Motion toward observer shortens wavelength (Blue Shift)

Motion away from observer lengthens it (Red Shift)

Faster speed ➔ bigger change in λ

Measuring Radial Velocity

- Measure Doppler shift of emission or absorption lines in a spectrum ➔ *radial velocity* of object

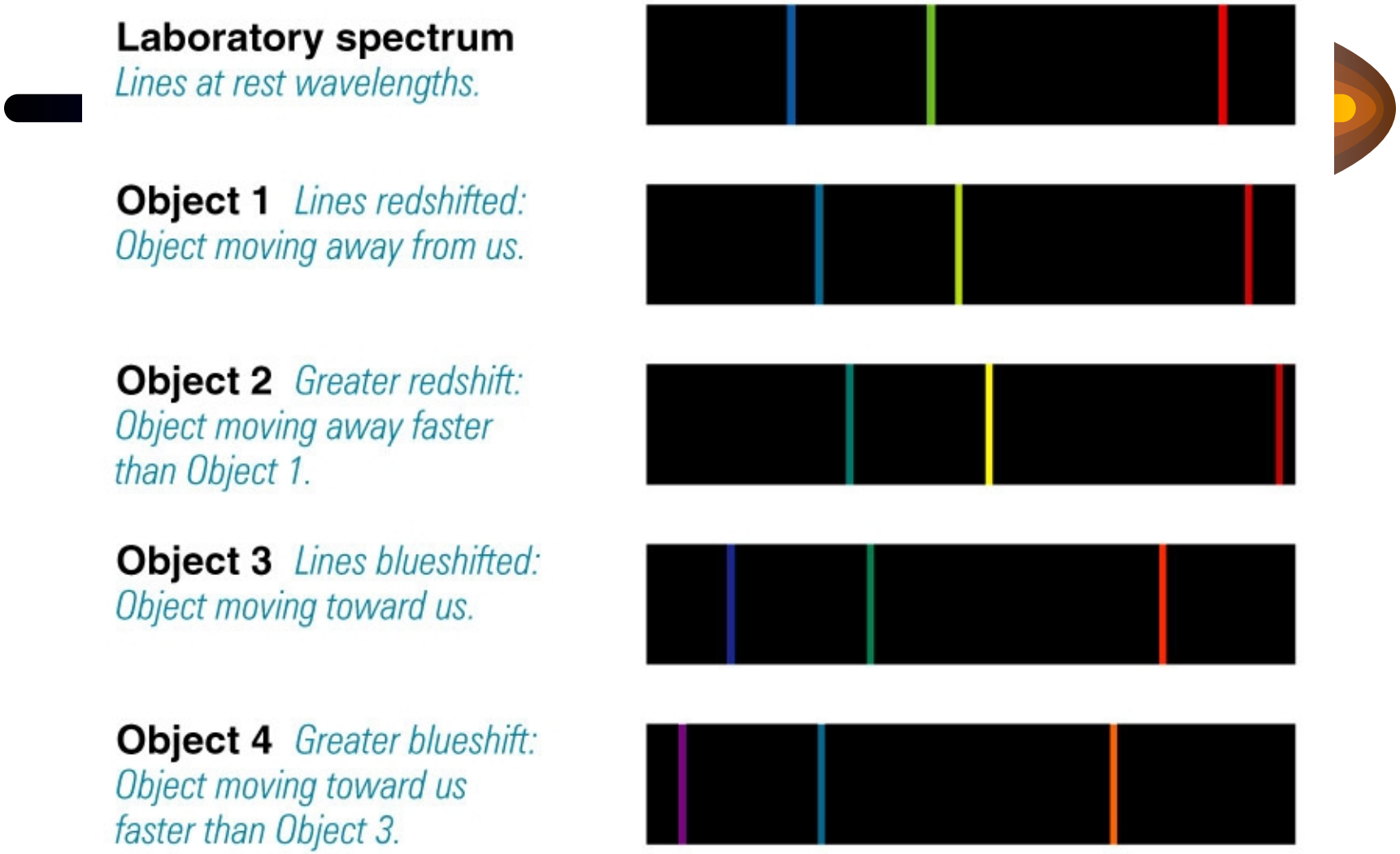


- No Motion
- Motion away
- Motion towards

From: http://www.psi.edu/esp/method.html

Doppler Effect Activity

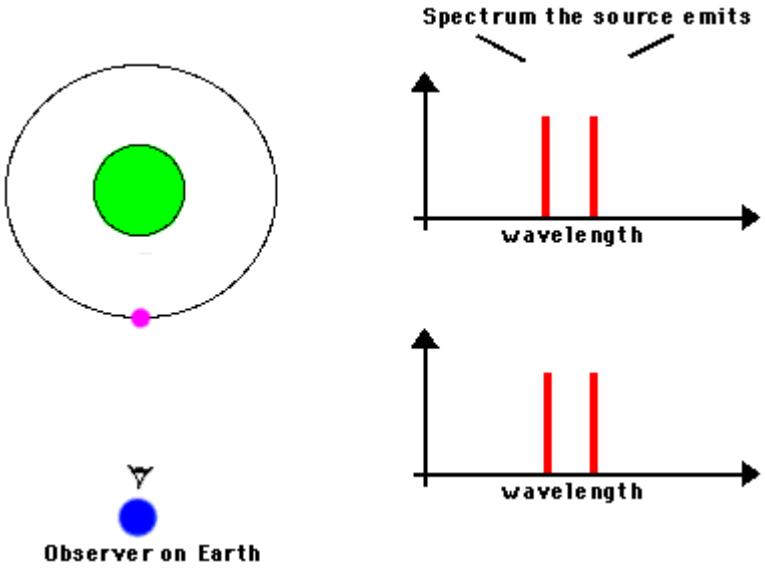
Measuring Radial Velocity

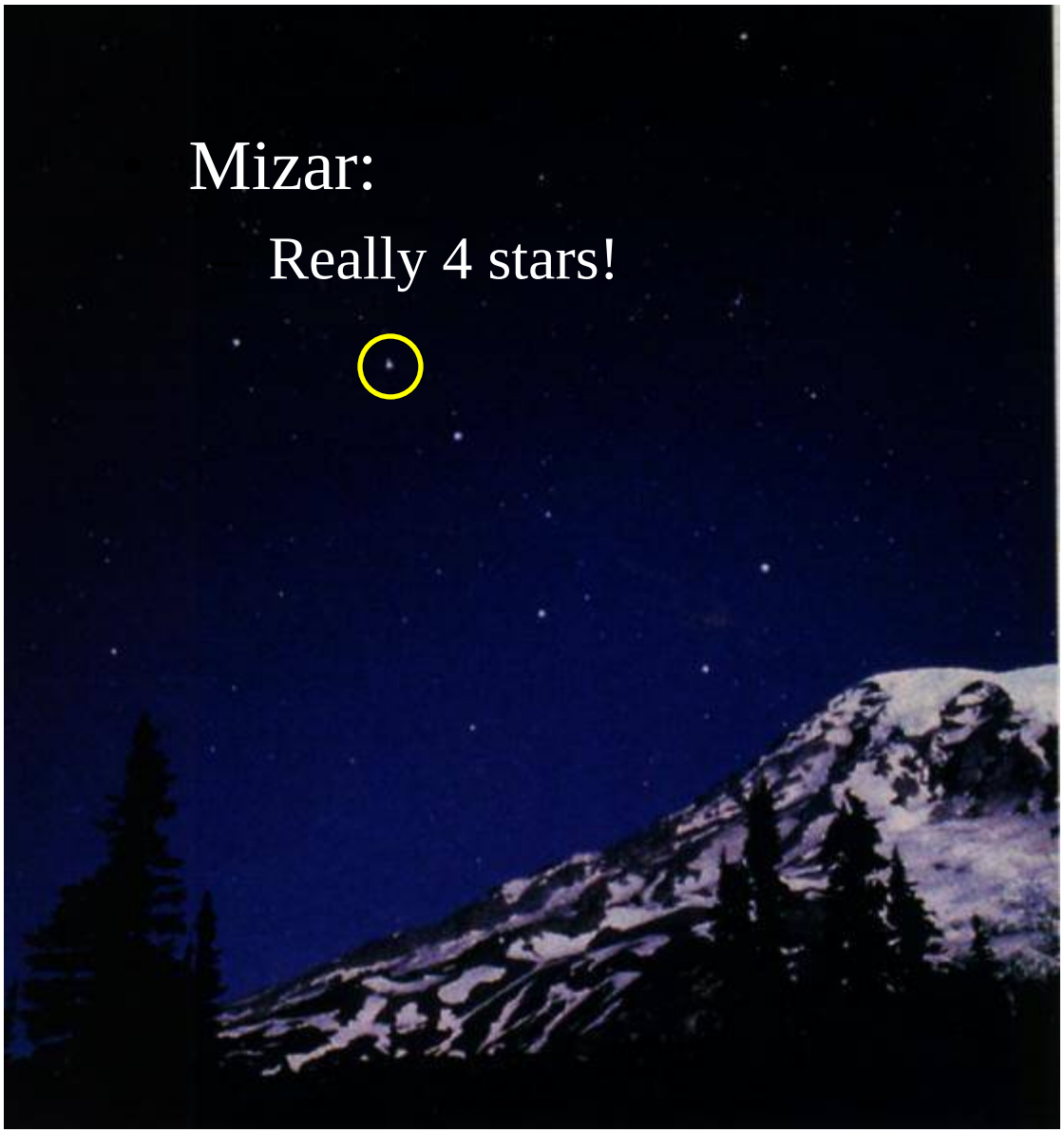


From: http://woodahl.physics.iupui.edu/05-22_anno.jpg

Application: Orbiting Stars

- Motions of stars moving towards & away from us
  - Binary Stars
  - Extrasolar planets

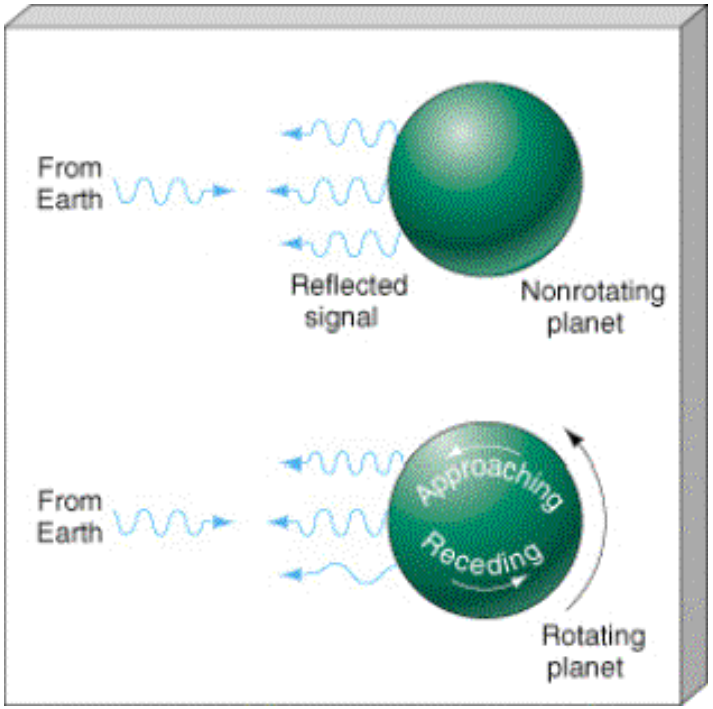


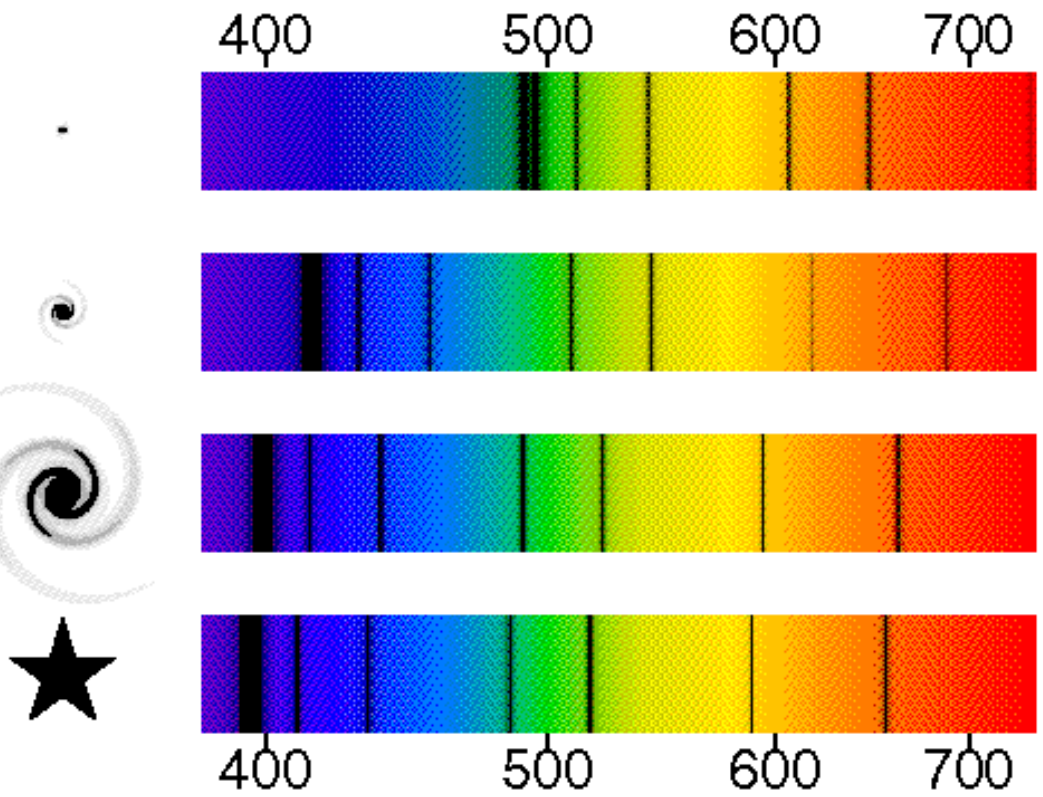


(http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/spectroscopy.htm)

More Applications

- Spin of Venus and/or asteroids:
  - Radar measurements





- Expansion of Universe:
  - Distant galaxies moving away from us

Why is Light so Useful?

- Thermal / continuous spectrum ➔ *temperature*
- Reflected light ➔ *properties of reflecting object*
- Absorption features ➔ *composition* of absorbing material (e.g. star, planet atmosphere)
- Emission lines ➔ *composition* of thin gas (e.g. nebula, tail of comet)
- Doppler effect on lines ➔ *radial velocity*, *spin*!