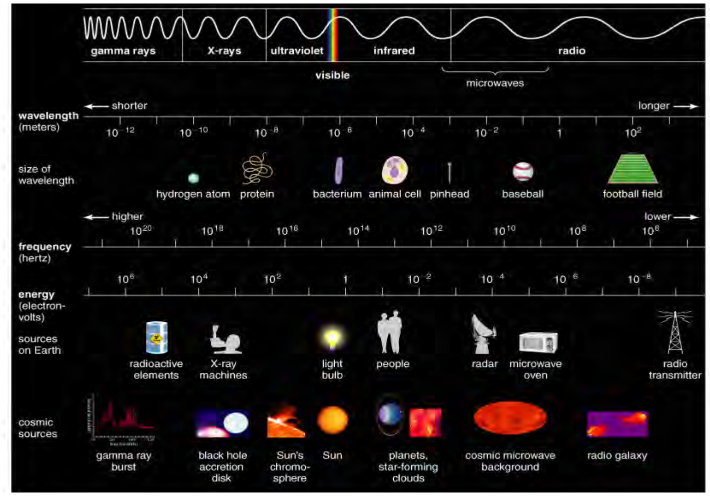
Agenda for Ast 309N, Sep. 18

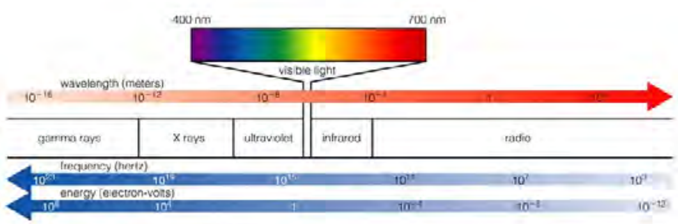
- Feedback on Quiz 1 and 9/13 card
- Kinds of spectra: Kirchhoff's Laws
- Spectral lines; animations
- The Doppler Effect
- Card activity on interpreting images of the Sun
- Quiz 2 on Thursday; on properties of light
- Reading for Thurs. and next Tues.:
  - – Wheeler, pp. 2 – 11 & Fig. on p. 18
  - – Kaler, pp. 12 – 23 (stellar properties)

The Electromagnetic Spectrum



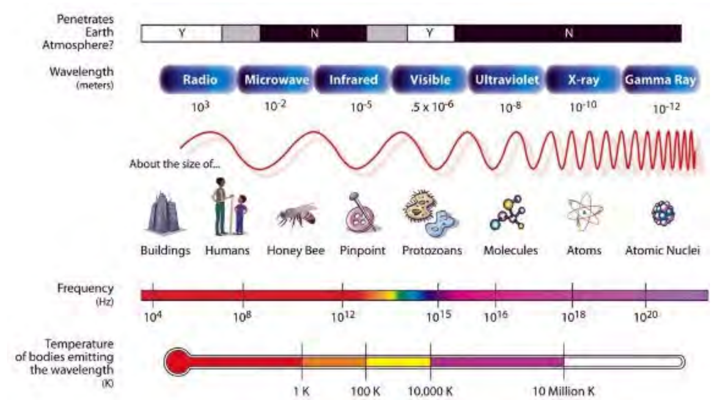
The Electromagnetic Spectrum

Remember: as λ increases, ν decreases, & vice versa (They go in ***opposite*** directions, as show by the arrows.)

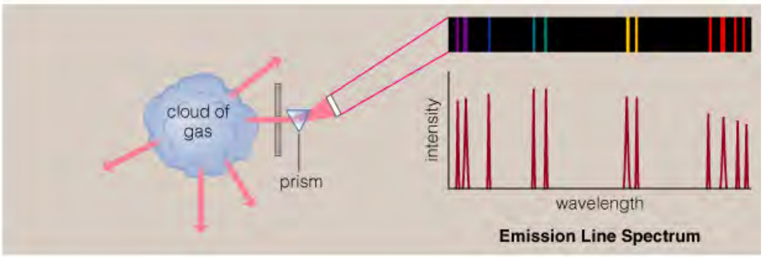


And: as ν increases, e increases; same for decreases. (They go in ***the same*** direction; see arrows.)

The Electromagnetic Spectrum

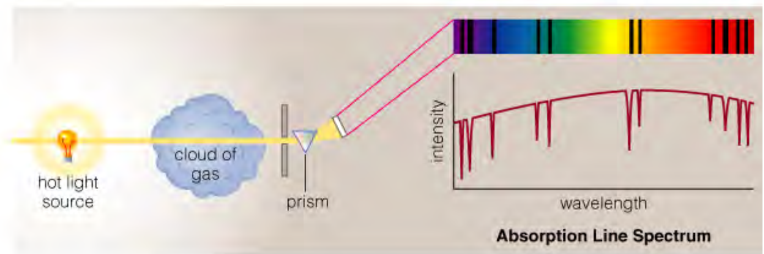


Emission Line Spectrum



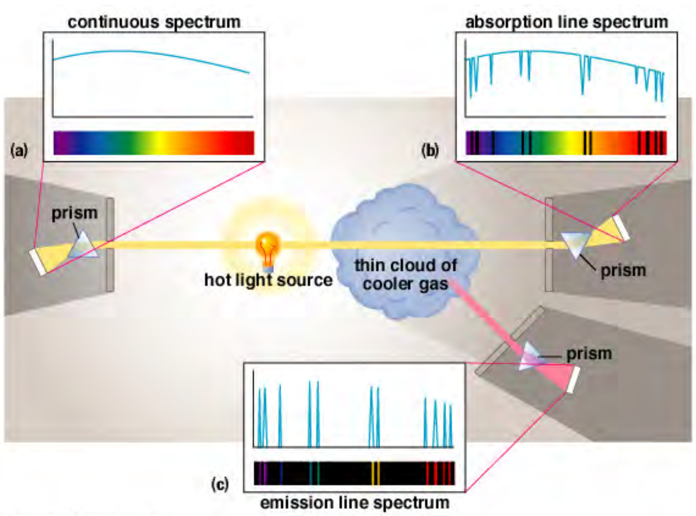
A low-density cloud of hot gas emits only at a few specific wavelengths that depend on what elements are present, producing a spectrum with bright, narrow emission lines.

Absorption Line Spectrum



A low-density gas cloud between us and a source producing a continuous spectrum absorbs only specific wavelengths of light, leaving dark, narrow gaps called absorption lines in the spectrum.

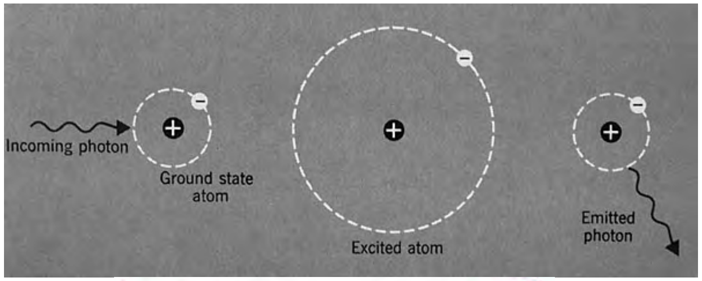
Kirchhoff's Laws

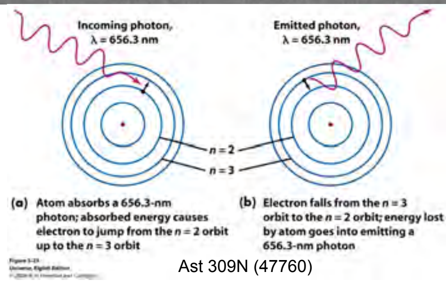


Kirchhoff's Laws in Words

1. A hot, dense glowing object - a "blackbody" - emits a continuous (thermal) spectrum.
2. A hot, low density gas emits light at only certain discrete wavelengths -- an emission line spectrum.
3. Light with a continuous spectrum passing through a cool gas produces dark (absorption) lines.

How Atoms Absorb and Emit Light

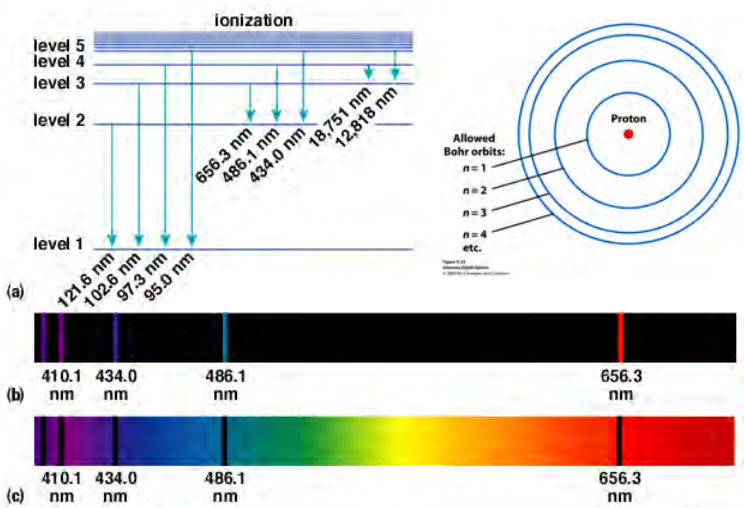




Electron Orbits or "Energy Levels"

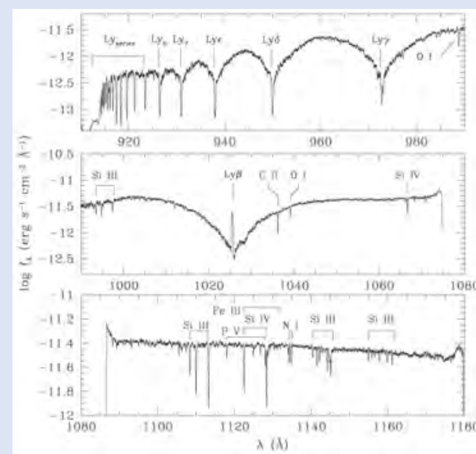
- Each electron exists in an orbit with fixed energy. Kaler (Fig. 1.3) uses the analogy of rungs on a ladder.
- Electrons must ***gain*** energy in order to jump *from a lower orbit or level to one with higher energy*.
- When electrons fall *from a higher to a lower orbit/energy level*, they **lose** energy by releasing a photon.
- The lowest energy level for an atom is the **ground state**. All levels above it are **excited states**.
- When electrons gain enough energy to escape the nucleus, we say the atom is **ionized**.

Electron Transitions in Hydrogen



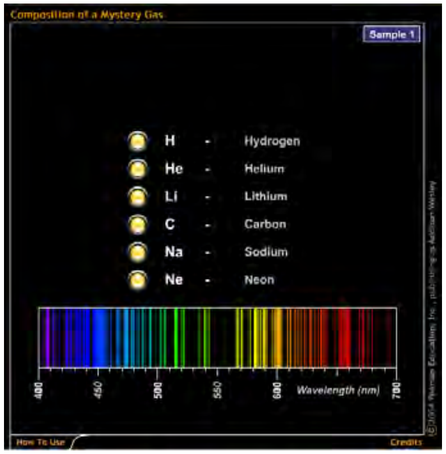
Ultraviolet Spectrum of a hot white dwarf star: H Lyman Lines

The *FUSE* space observatory operated from 1999 – 2007



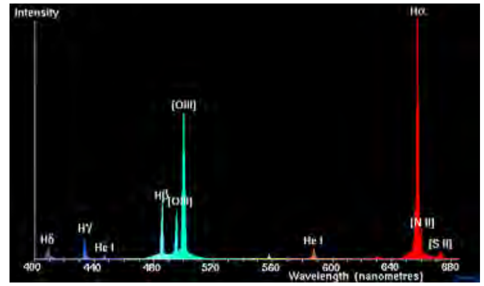
Emission Spectra

The atoms of each element (each ion) element have their own distinctive set of electron energy levels, so they emit a unique pattern of colors, like fingerprints. If it is a hot gas, we see these as an **emission line spectrum**.



The Story of "Nebulium"

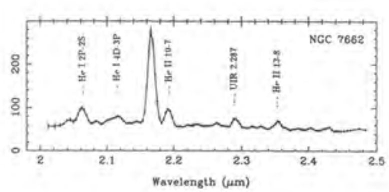
Two bright emission lines in the green, seen in planetary nebulae and the Orion Nebula by William Huggins,1860's



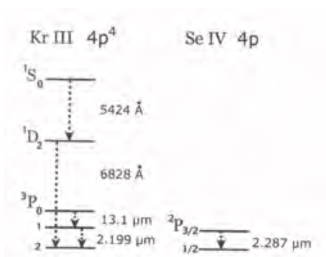
The origin of these lines was not determined for decades: oxygen ions, O++

A Modern Spectroscopic Mystery

Two infrared emission lines, discovered in 1976, not identified with any known atom or molecule.

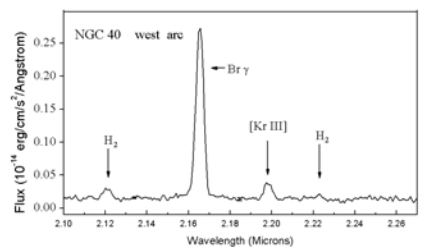


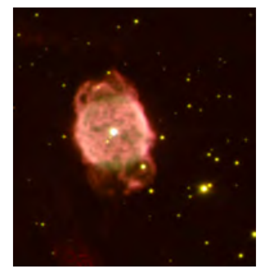
(Note: Same nebula as on the last slide!)



In 2001, I recognized that that these lines come from ions of Selenium and Krypton (Z = 34 and 36).

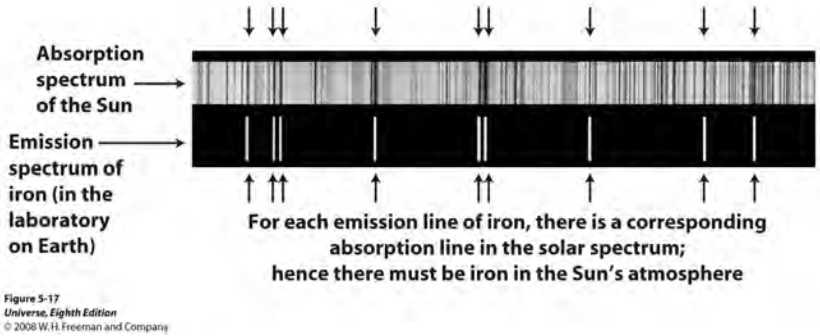
Observations at McDonald Observatory



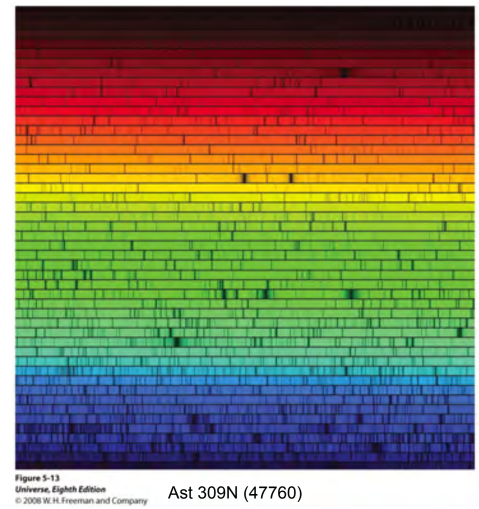


Using a near infrared spectrometer on the Harlan J. Smith 2.7m telescope, my group (including students and collaborators) began observing these lines in planetary nebulae visible from west Texas.

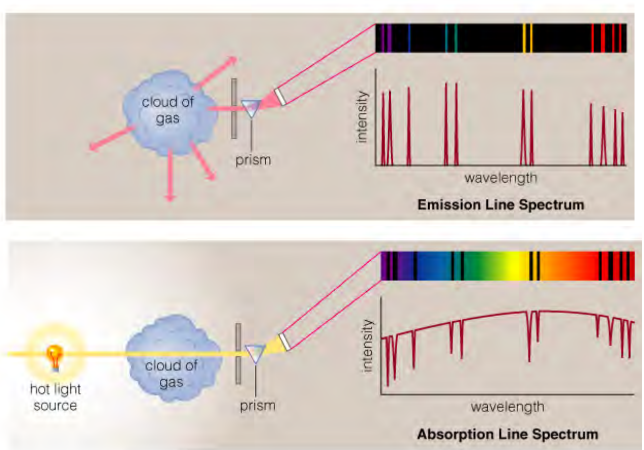
Solar Spectrum: Old-Style Observations



Solar Spectrum: Modern Observations

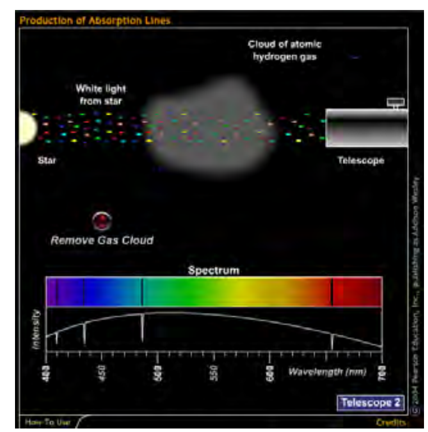


How are Absorption Lines Produced?



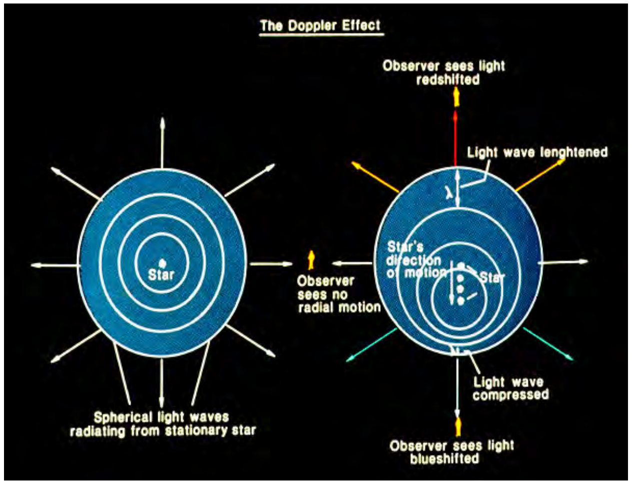
Absorption Spectra

If light shines through a gas, each element will absorb those photons whose colors match their electron energy levels. Then we see an **absorption line spectrum** with all colors *except* those that were absorbed.



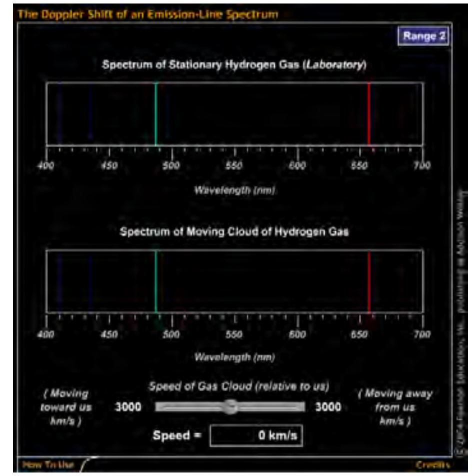
We can determine which elements are present in an object by identifying its emission or absorption lines.

The Doppler Effect



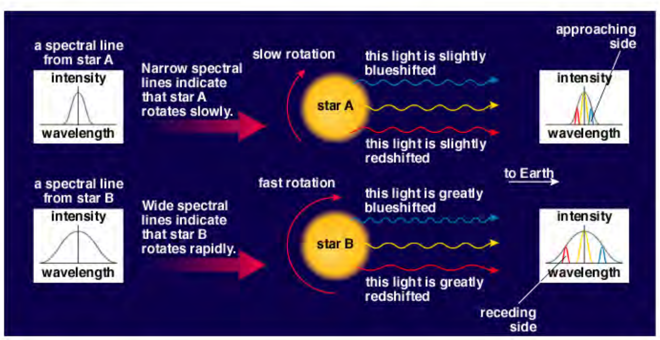
Measuring Radial Velocities

- We can measure the Doppler shift of emission or absorption lines in the spectrum of an object.
- The light will be redshifted if the source is moving away from us, blueshifted if it is moving towards us.
- The amount of the shift tells us how fast the source is moving.



Rotational Velocities

If the object is big enough (in angle) that you can observe the two edges separately, you will see a Doppler shift from one edge to the other; if all the light is blended together, as in a point-like source, the line will be *broadened*.



“Periodic” Doppler Effect