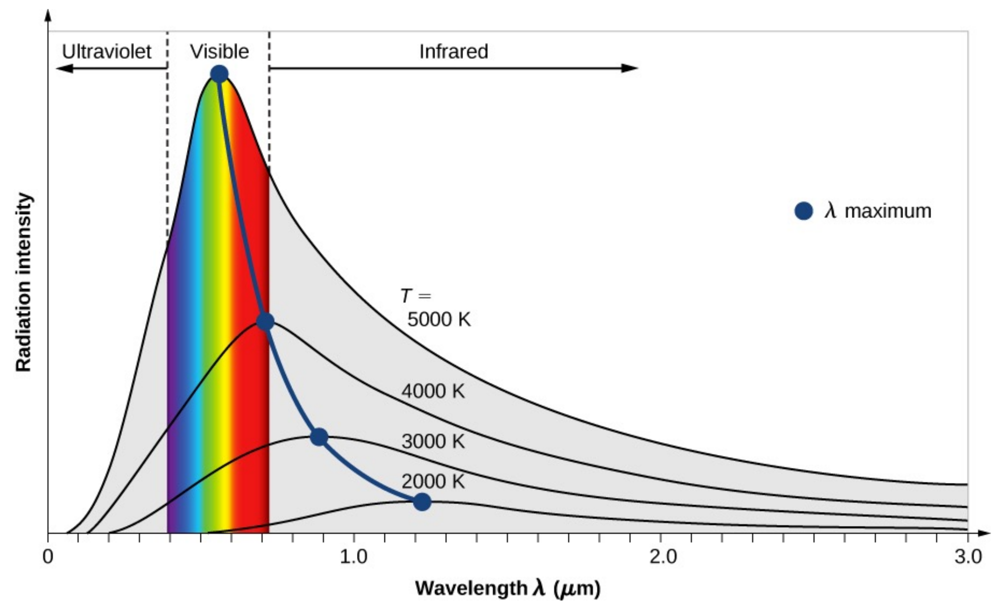
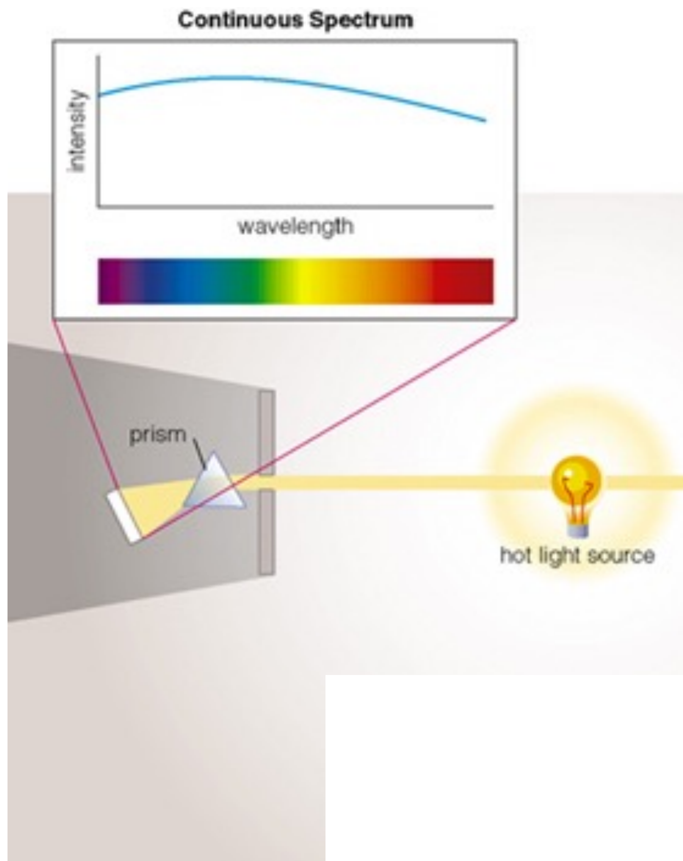
Phys 301 Class 18
Spectroscopy, the Bohr Model

3 Types of Spectra

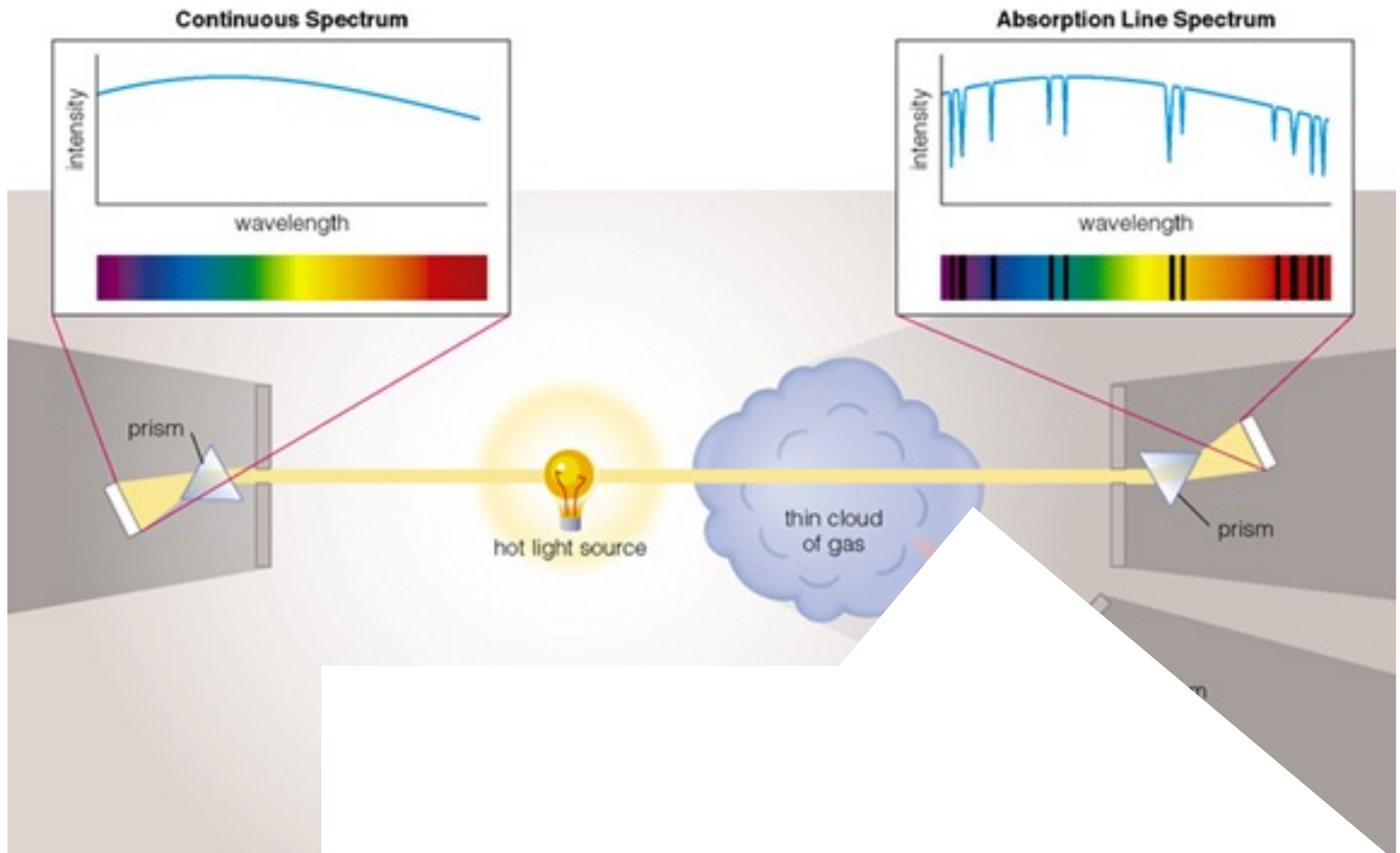
- First: Blackbody or Continuous Radiation
- Objects that are very hot and dense.



Types of Spectra

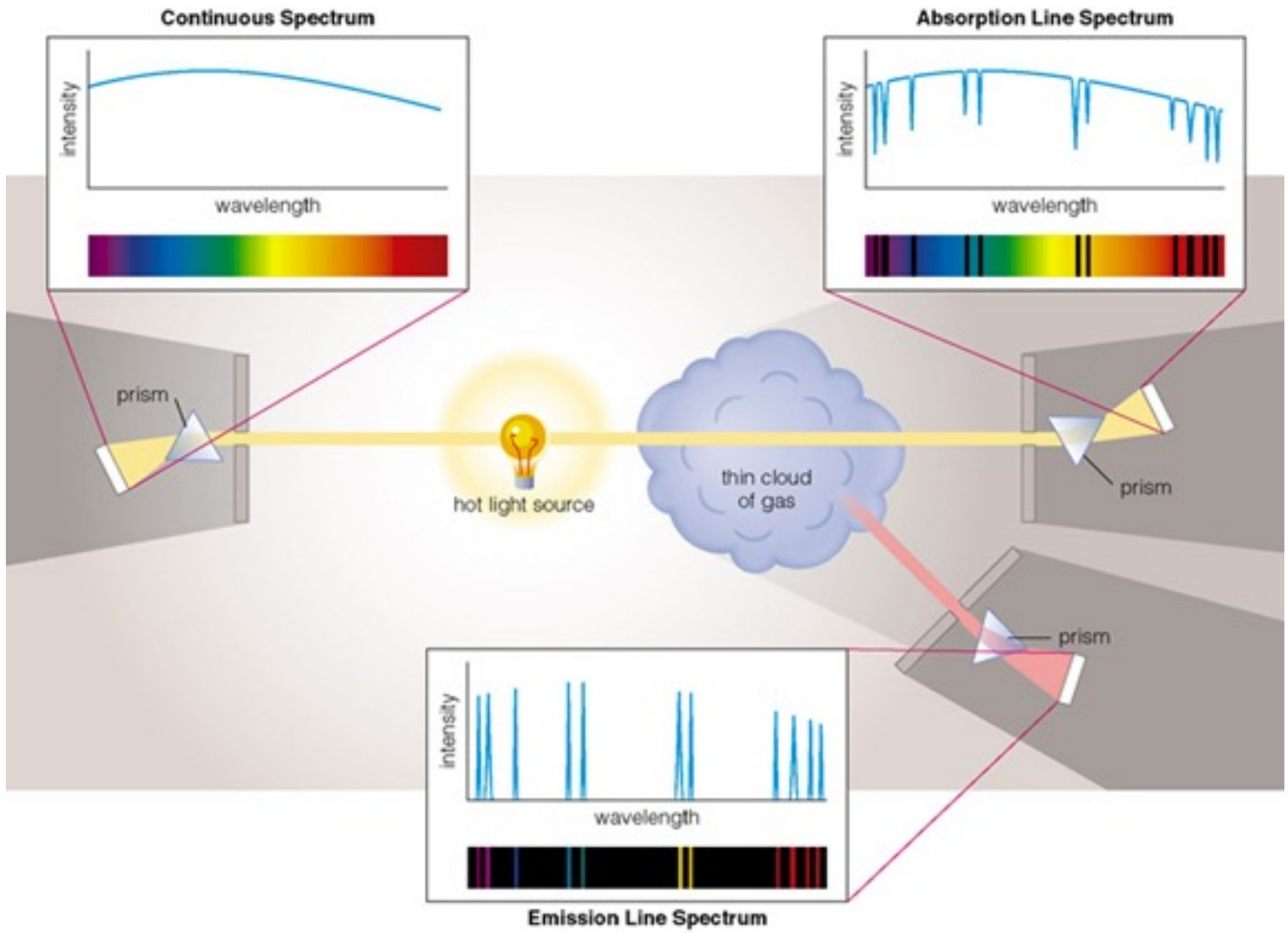


Types of Spectra



Types of Spectra

- Which type do we see when observing the Sun?



Atomic "Fingerprints"

Figure 6.15 The emission spectrum of atomic hydrogen: The spectral positions of emission lines are characteristic for hydrogen atoms. (credit: "Merikanto"/Wikimedia Commons)

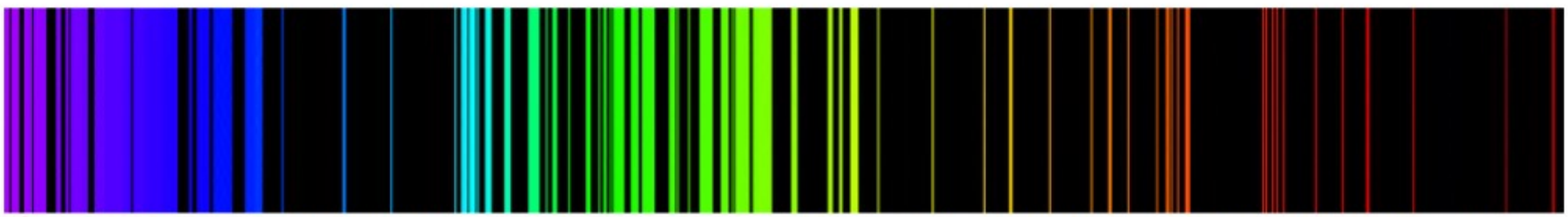
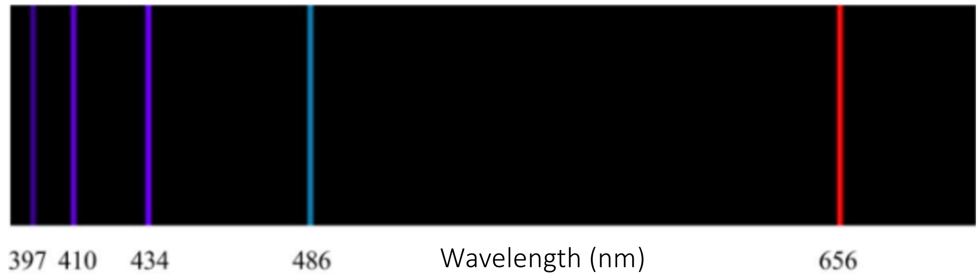


Figure 6.16 The emission spectrum of atomic iron: The spectral positions of emission lines are characteristic for iron atoms.

Balmer Formula

(1885)



- The wavelengths of hydrogen emission lines were measured in the laboratory.
- 4 (or 5) lines in the visible.
- This equation works: but why?

$$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2} \right) \quad for\ n = 3,4,5,6(,7)$$

What are the units of R_H?

Rydberg Formula (1888)

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \quad for\ n_i = n_f + 1, n_f + 2, n_f + 3 \cdots$$

$$R_H = 1.09737 \times 10^7 \mathrm{m}^{-1} \text{(Rydberg Constant for Hydrogen)}$$

- Other emission lines discovered.
- Special names given to some values of n_f– generally person who first experimentally observed that "series" of lines.

Spectral Series of Hydrogen

n_f	Name	Approx. Region of EM	Discovery
1	Lyman	Ultraviolet	1906-1914
2	Balmer	Visible, UV	1885 (equation)
3	Paschen	Infrared; all subsequent series overlap	1908
4	Brackett		1922
5	Pfund		1924
6	Humphreys		1953

Practice Problem: Pfund

- What is the longest wavelength possible in the Pfund series? ($n_f = 5$)
- What is the shortest wavelength possible?
- How many lines are in the Pfund series?

$$R_H = 1.09737 \times 10^7 \, \mathrm{m}^{-1} = 0.0109737 \ \mathrm{nm}^{-1}$$

- What is the longest wavelength possible in the Pfund series? ($n_f = 5$)

$$\frac{1}{\lambda} = R_H\left(\frac{1}{5^2} - \frac{1}{6^2}\right), \lambda = 7456 \text{ nm}$$

- What is the shortest wavelength possible?

$$\frac{1}{\lambda} = \lim_{n_i \to \infty} R_H\left(\frac{1}{5^2} - \frac{1}{n_i^2}\right), \lambda = 2278 \text{ nm}$$

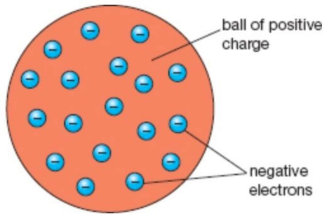
- How many lines are in the Pfund series?

There are an infinite number of lines in each series.

BUT WHY??? Niels Bohr, 1913

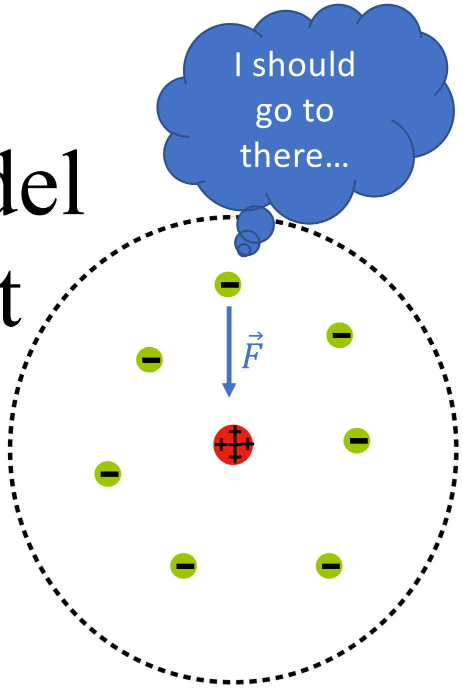
- Notice Rydberg Formula depends not on λ, but $1/\lambda$. (Which *we* know is proportional to energy…)
- First, what was the state of knowledge of atoms?

Atomic Models

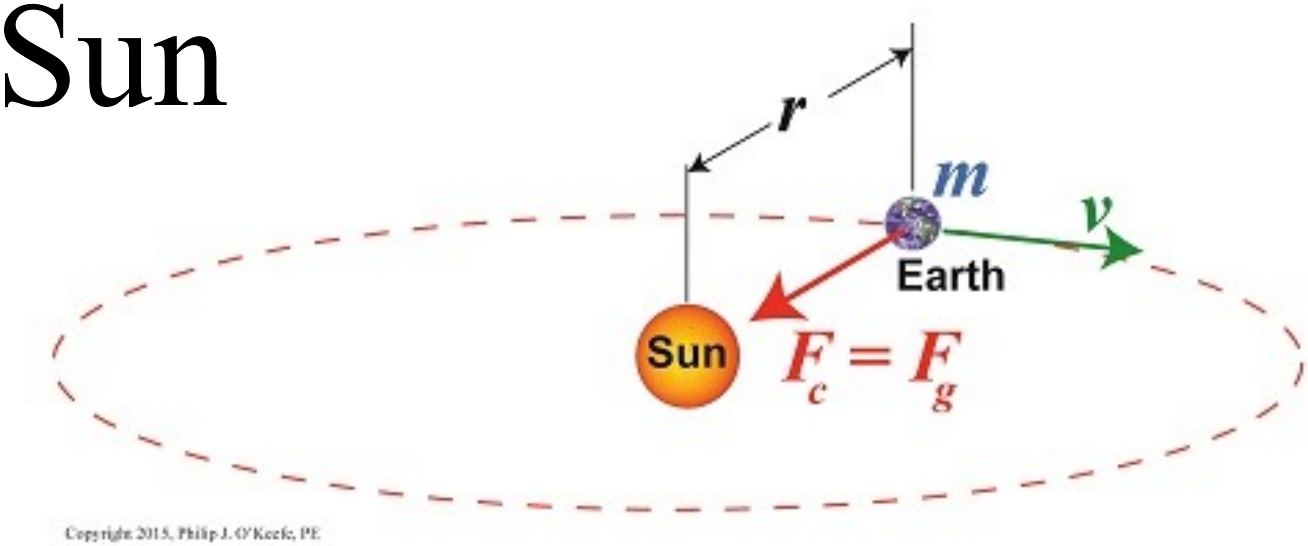


Thomson's 'plum-pudding' model of the atom

- 1904, Thomson, "plum pudding" model
- 1909, Rutherford gold foil experiment
  - Nucleus is positively charged.
  - Nucleus contains almost all the mass,
  - But only exists in one small point.
  - Negatively charged electrons are far away.
- *Why* these spectra? *Why* does electron, if attracted to nucleus, stay far away?



An Analogy – Planets are Gravitationally Attracted to the Sun



Note: orbits are *not* circular because the Earth and Sun orbit their mutual center of mass.

Classical Derivation of Bohr Radius, Energy Levels

- Handout Parts I and II

Derivation Results

$$r_n = a_0 \frac{n^2}{Z} \qquad E_n = Z^2 \frac{E_0}{n^2}$$

n = Quantum Number

Z = atomic number (charge of nucleus)

$$a_0 = 5.29 \times 10^{-11}\text{m} = 0.529 \text{ Å}$$

Bohr Radius of Hydrogen (radius of first orbital)

$E_0 = -13.6 \text{ eV}$, ground state energy of hydrogen atom

Energy Level Diagram, Transitions

- Handout

What Have We Learned?

- Young's Double Slit Experiment
  - Light acts like a wave.
- Blackbody Radiation, Planck Function
  - Energy of oscillators is quantized.
- Photoelectric Effect and Compton Scattering
  - Light acts like a particle of energy $E = hf$.
- Spectroscopy and Bohr's Model
  - Energy levels of electrons are quantized.