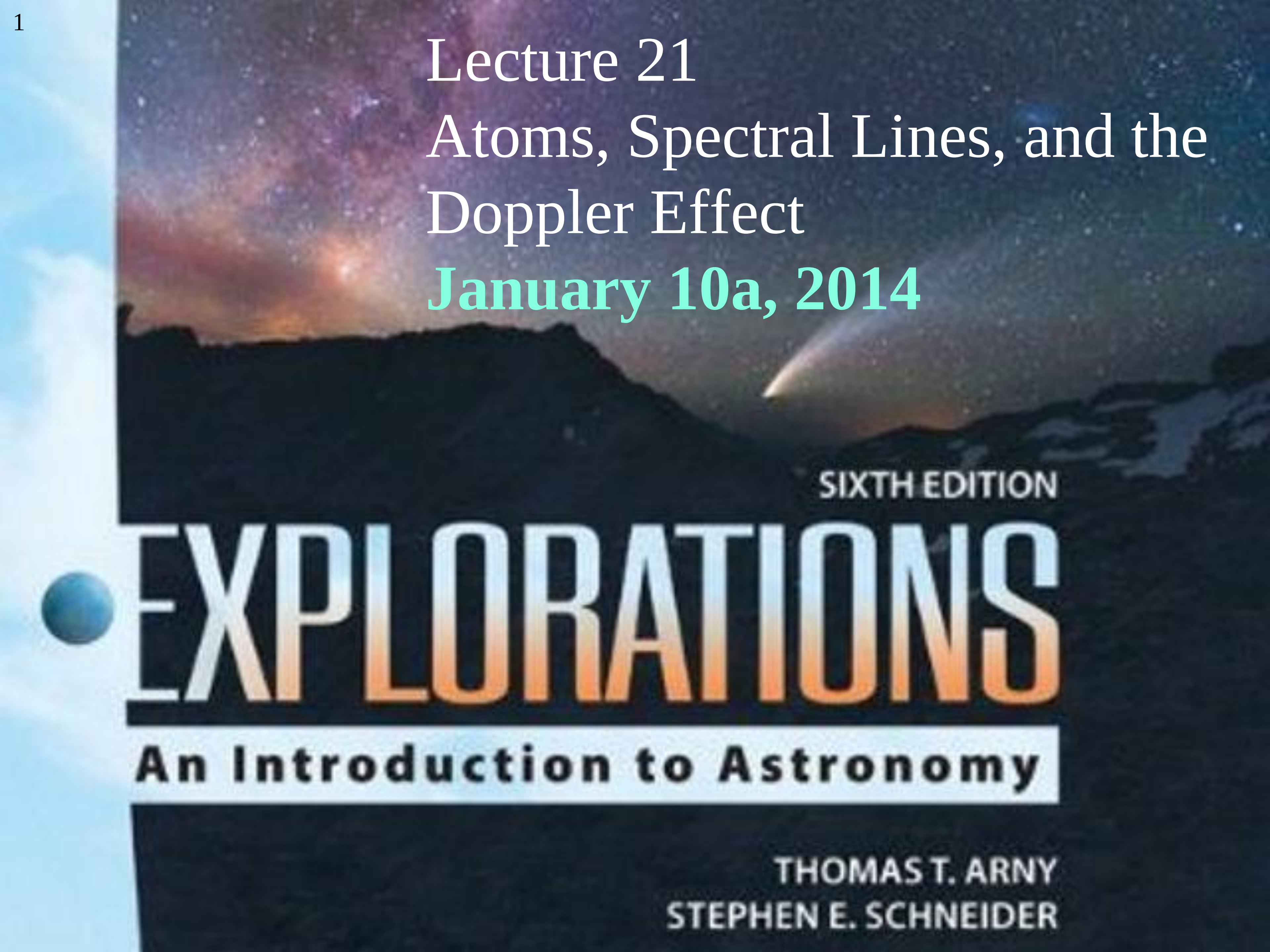
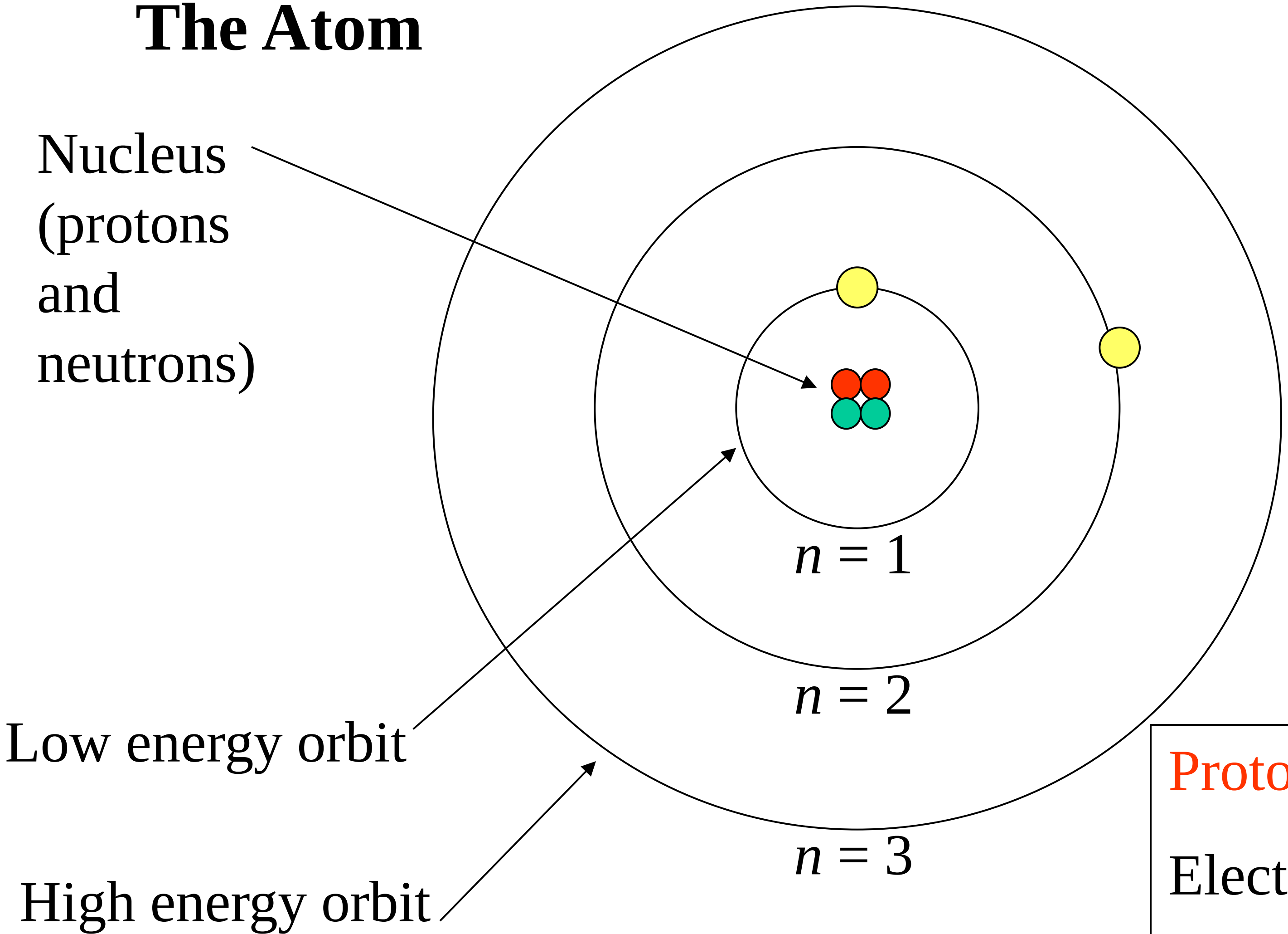
Lecture 21
Atoms, Spectral Lines, and the Doppler Effect

January 10a, 2014



Atoms and Spectral Lines

The Atom



Protons: + charge

Electrons: – charge

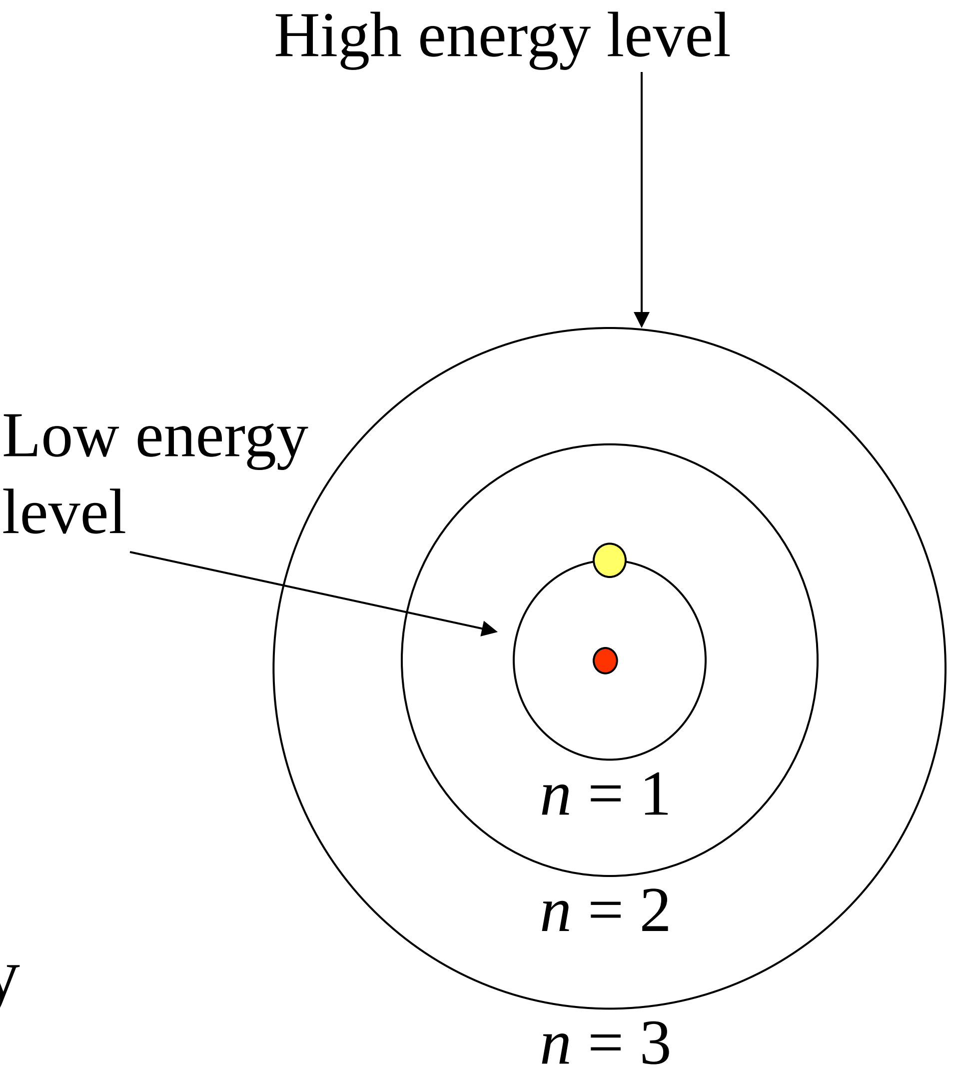
Neutrons: neutral

Atoms

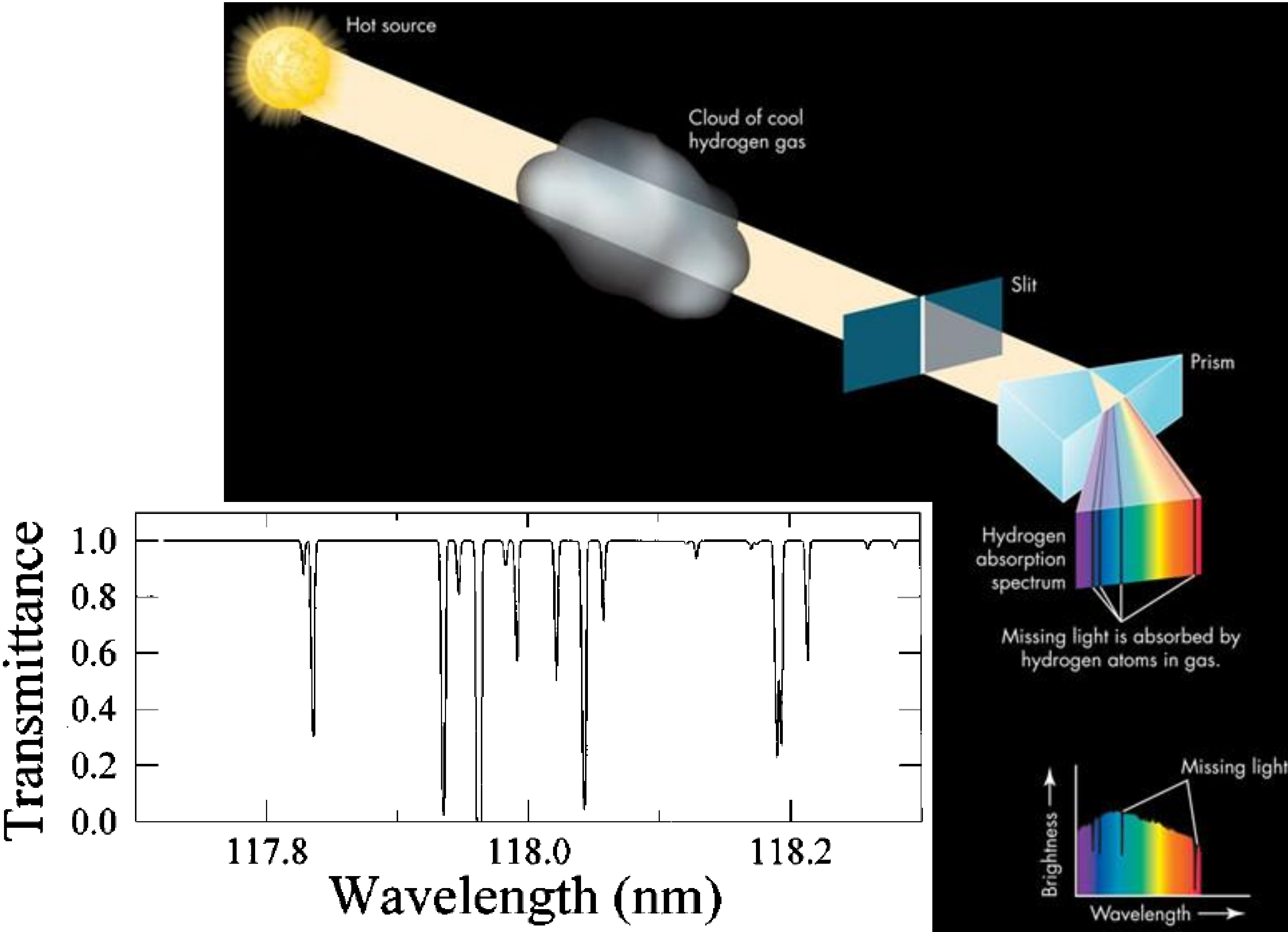
- The type of element depends on the number of protons in the nucleus.
  - Hydrogen = 1 proton
  - Helium = 2 protons
  - Carbon = 6 protons
- # of electrons usually equals number of protons
  - Atom is electrically neutral
  - Ion: atom where number of electrons does not equal number of protons

Electrons

- Electrons can move to different orbits, but they must gain or lose energy to do so.
- Energy difference between levels is unique for each element
- The emitted or absorbed photon energies, and hence wavelengths, correspond to the difference between energy levels.

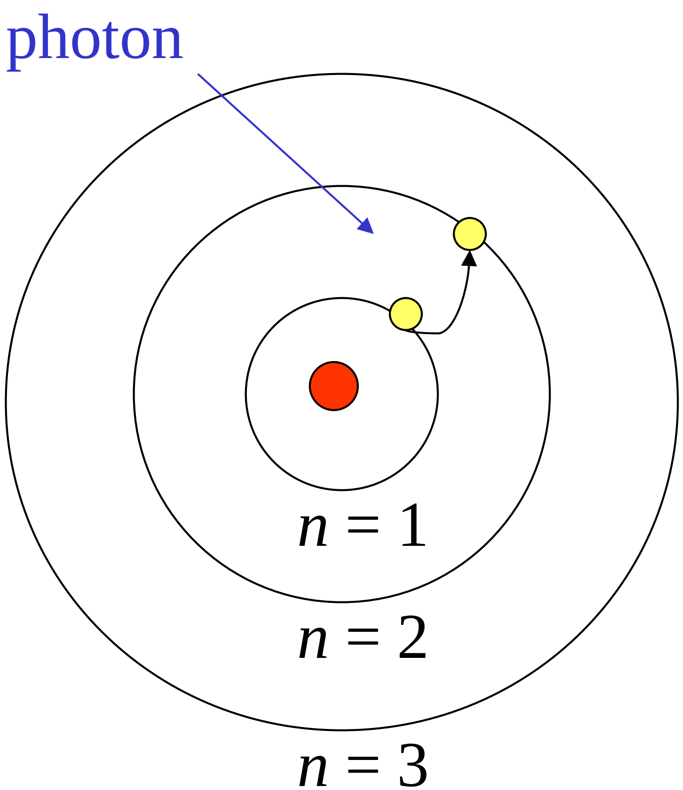


Absorption Lines

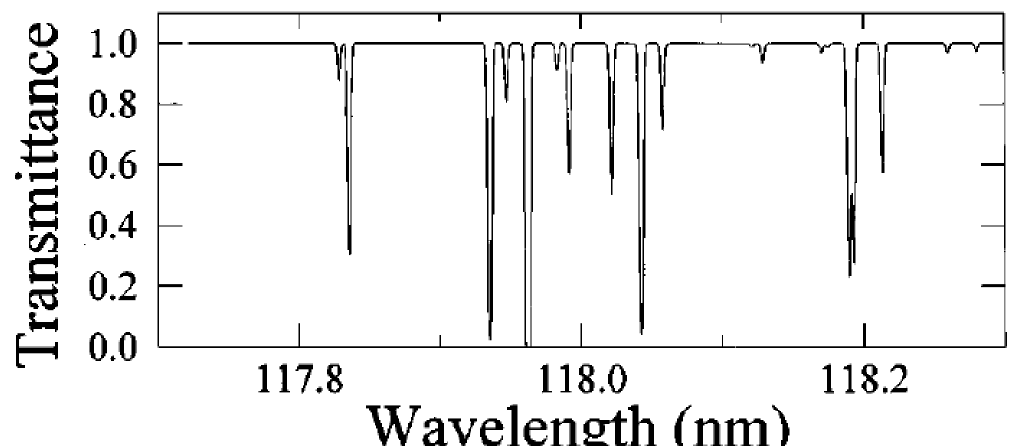


Absorption Spectra

- Continuum radiation observed after passing through a cool gas
- Electron in gas absorbs photon of light to move to a higher energy level



Photon energy must be equal to energy difference between atom’s energy levels



Emission Spectrum

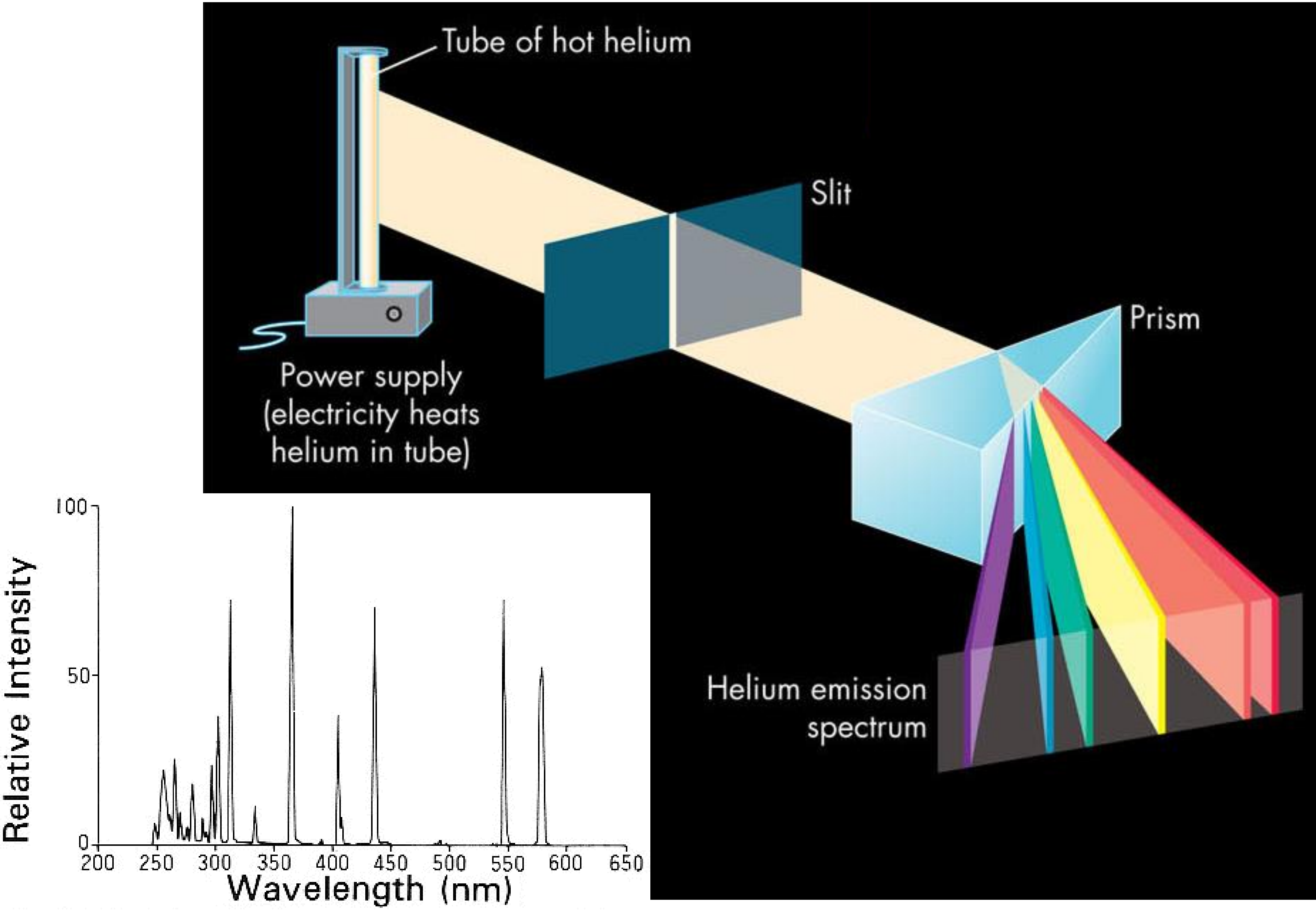
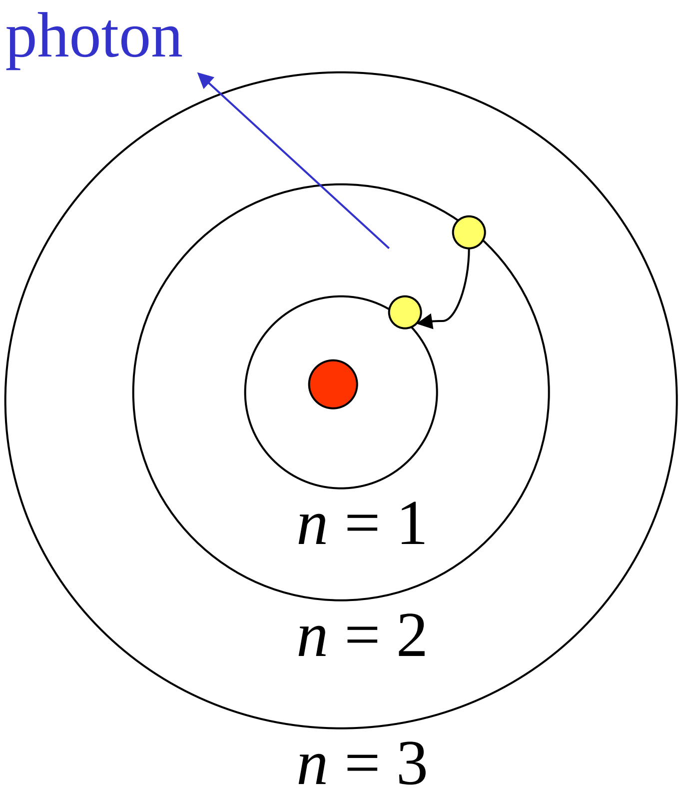


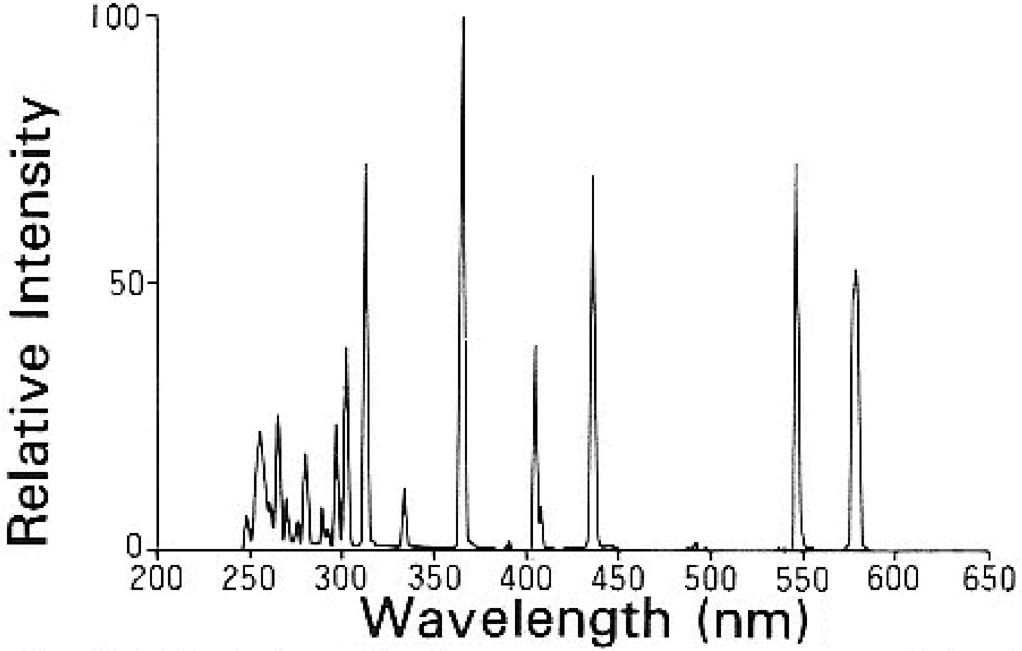
Figure 3.14 Copyright © The McGraw-Hill Companies, Inc.

Emission Spectra

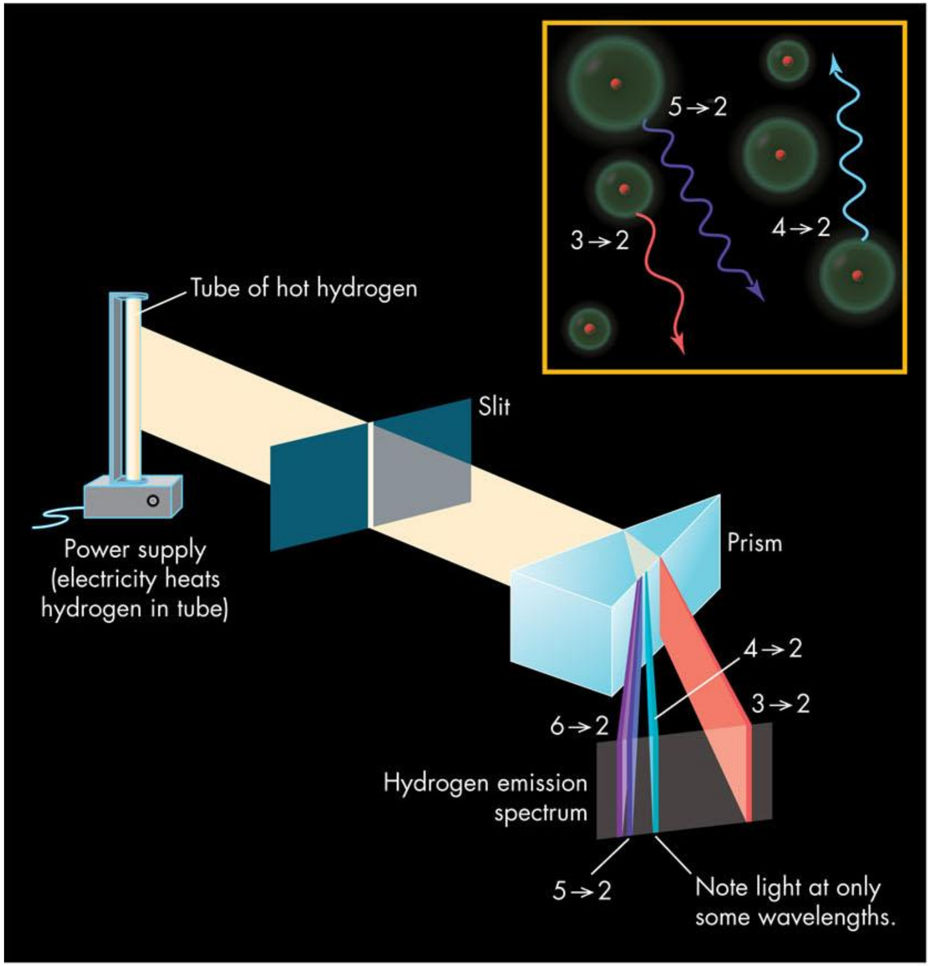
- Observe a hot, thin gas
- Electron gives off a photon of light to move to a lower energy level



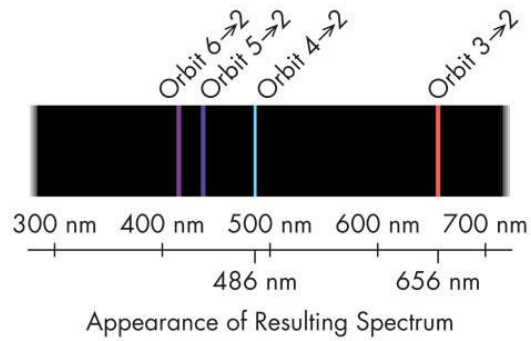
Photon energy must be equal to energy difference in atom

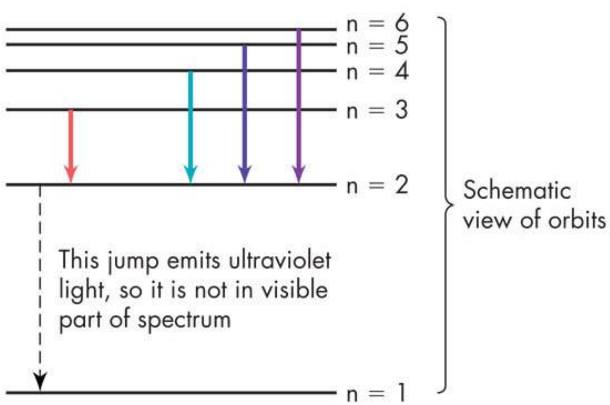


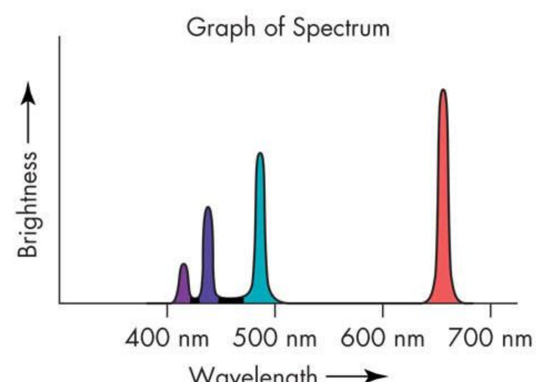
Emission Lines



Hydrogen atoms in tube
Atom emits at wavelength set by the orbit its electron happens to be in. Thus, if electron jumps from orbit 3→2, the atom emits red light. If the electron jumps from 5→2, it emits violet, etc. *No* orbit jump corresponds to yellow or green light so those colors do not appear in the hydrogen spectrum.







The relatively cool, thin, outer atmosphere of a star will produce a ___________.

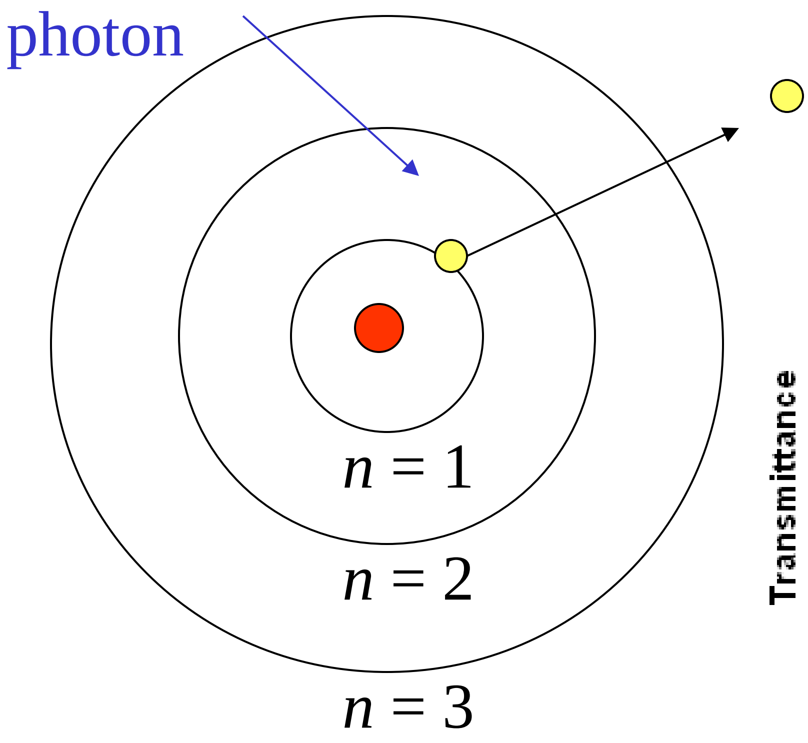
A. continuum spectrum
B. absorption spectrum
C. emission spectrum
D. blackbody spectrum

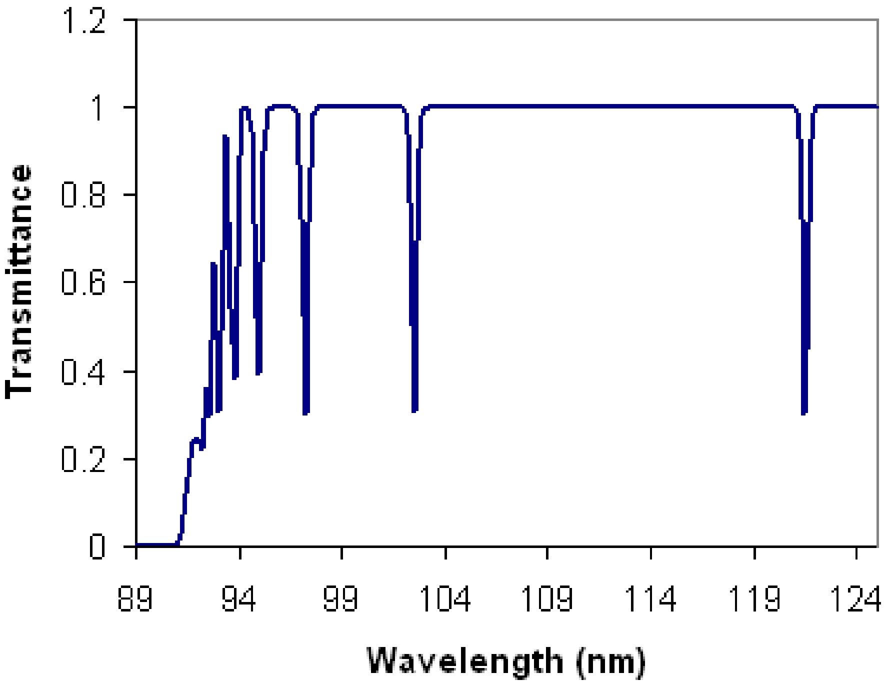
The relatively cool, thin, outer atmosphere of a star will produce a ___________.

A. continuum spectrum
B. absorption spectrum
C. emission spectrum
D. blackbody spectrum

Ionization

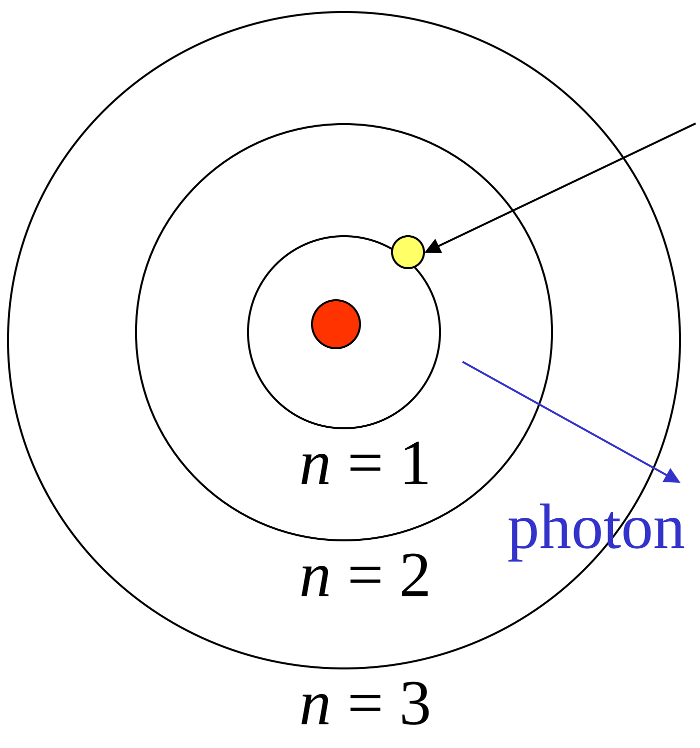
- Electron absorbs enough energy from photon to leave the atom

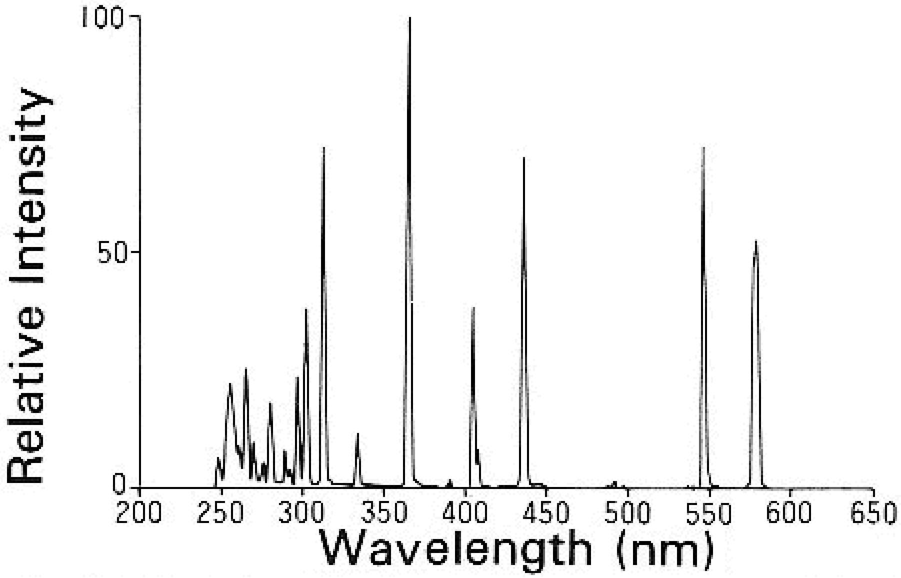




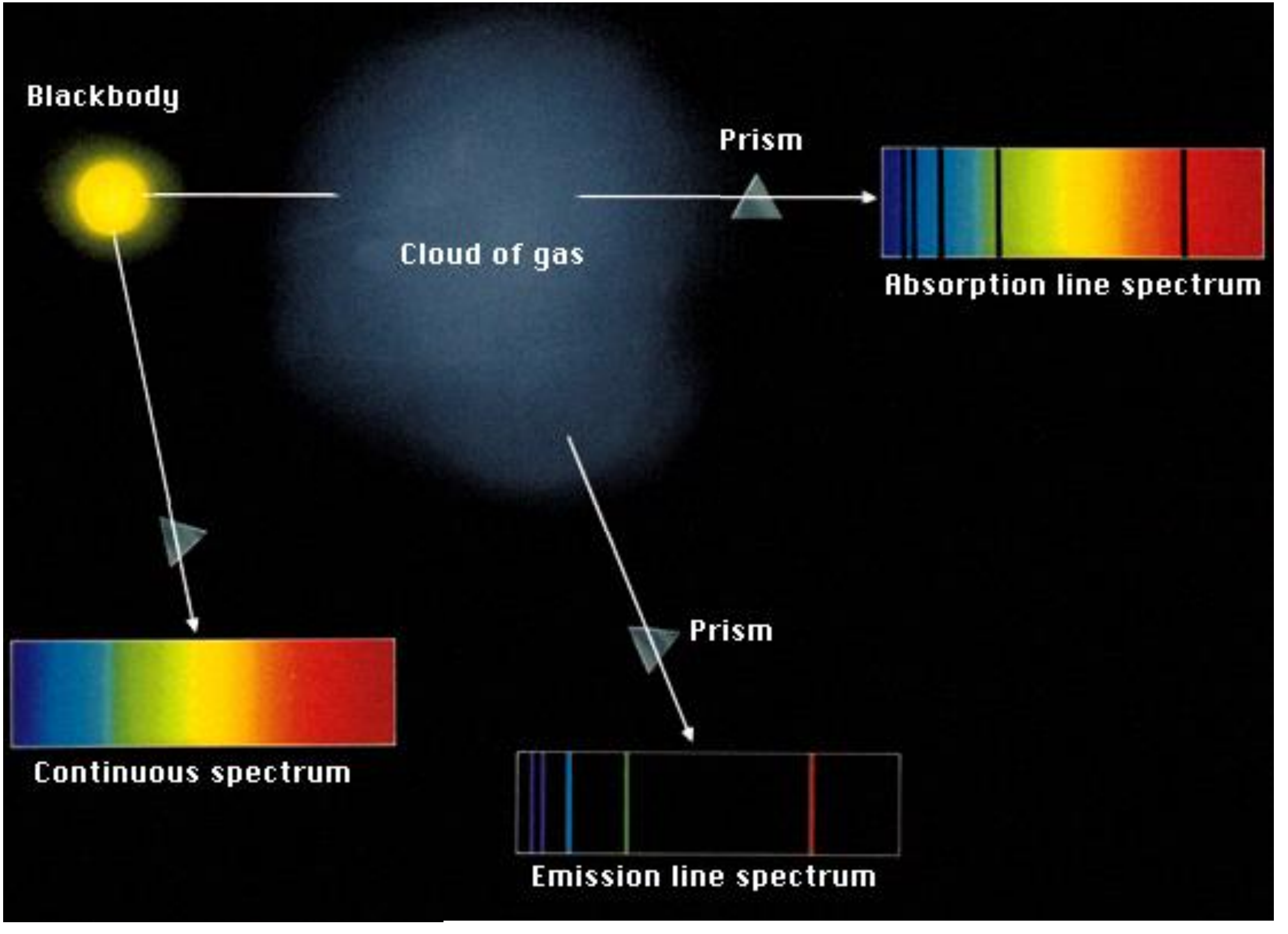
Recombination

- Electron recombines with the atom and the atom emits energy in the form of a photon



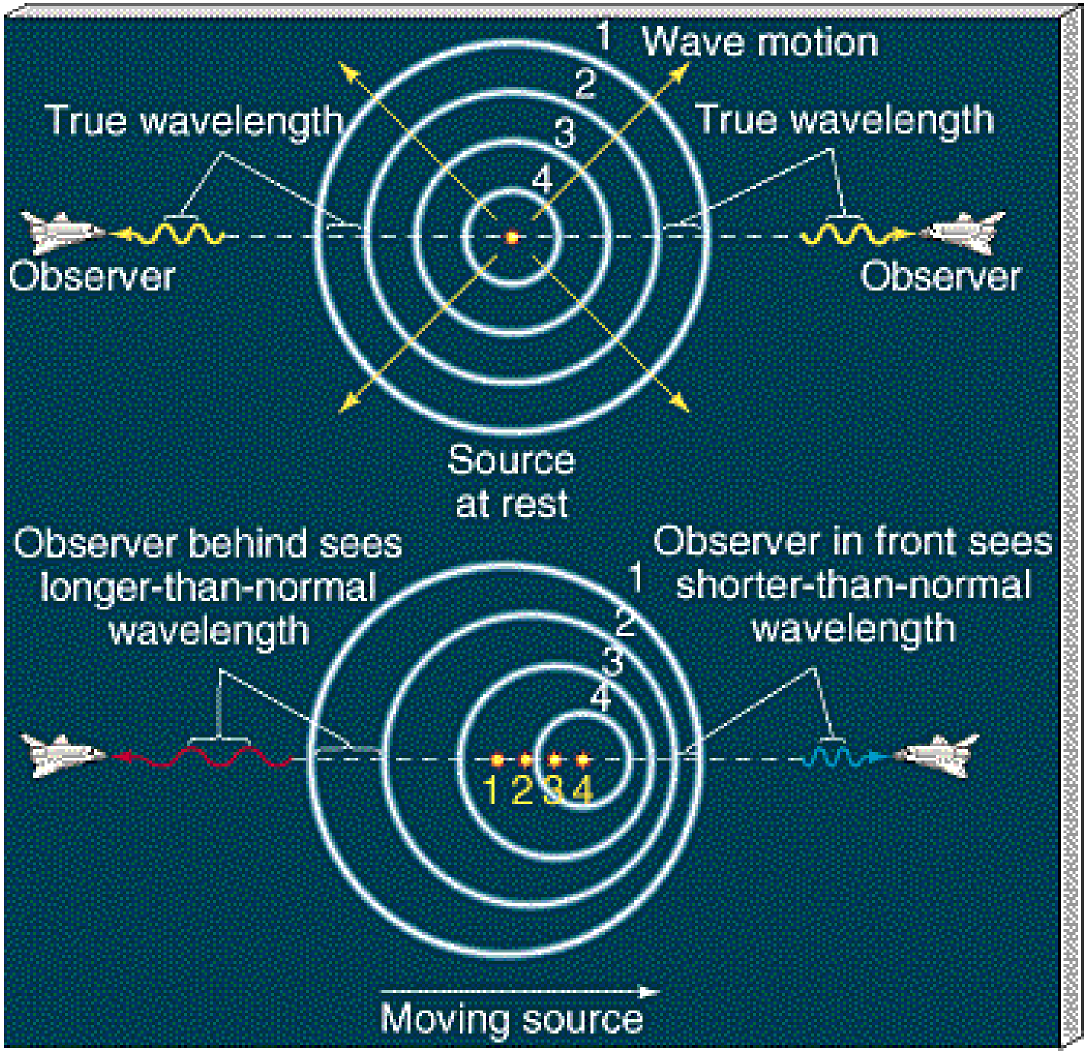


Review of Spectra



Doppler Shift

- The wavelength of light is affected by the motion of the object.



[Applet 1]

[Applet 2]

[Applet 3]

Doppler Shift

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

$\Delta\lambda$ = change in wavelength
λ = rest wavelength
v = line of sight velocity
c = speed of light

- The larger the velocity, the greater the wavelength shift.

Suppose a spectral line with a normal wavelength of 633.000 nm is measured at 633.225 nm by a telescope spectrograph. What is the speed (relative to Earth, along the line of sight) of the object that emitted the spectral line?

A. 355 km/s
B. 633 km/s
C. 107 km/s
D. 225 km/s

Suppose a spectral line with a normal wavelength of 633.000 nm is measured at 633.225 nm by a telescope spectrograph. What is the speed (relative to Earth, along the line of sight) of the object that emitted the spectral line?

A. 355 km/s

B. 633 km/s

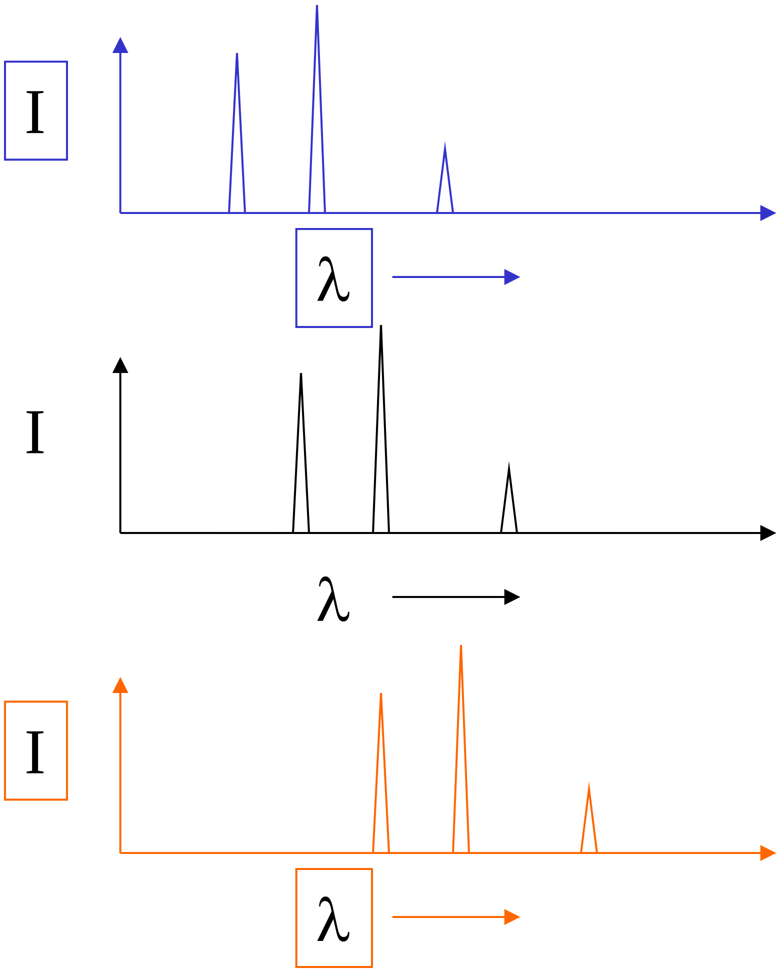
C. 107 km/s

D. 225 km/s

$$v = c\frac{\Delta\lambda}{\lambda} = \left(3.0\times10^{8}\ \text{m/s}\right)\frac{0.225\ \text{nm}}{633.0\ \text{nm}}$$

$$= 1.07\times10^{5}\ \text{m/s} = \boxed{107\ \text{km/s}}$$

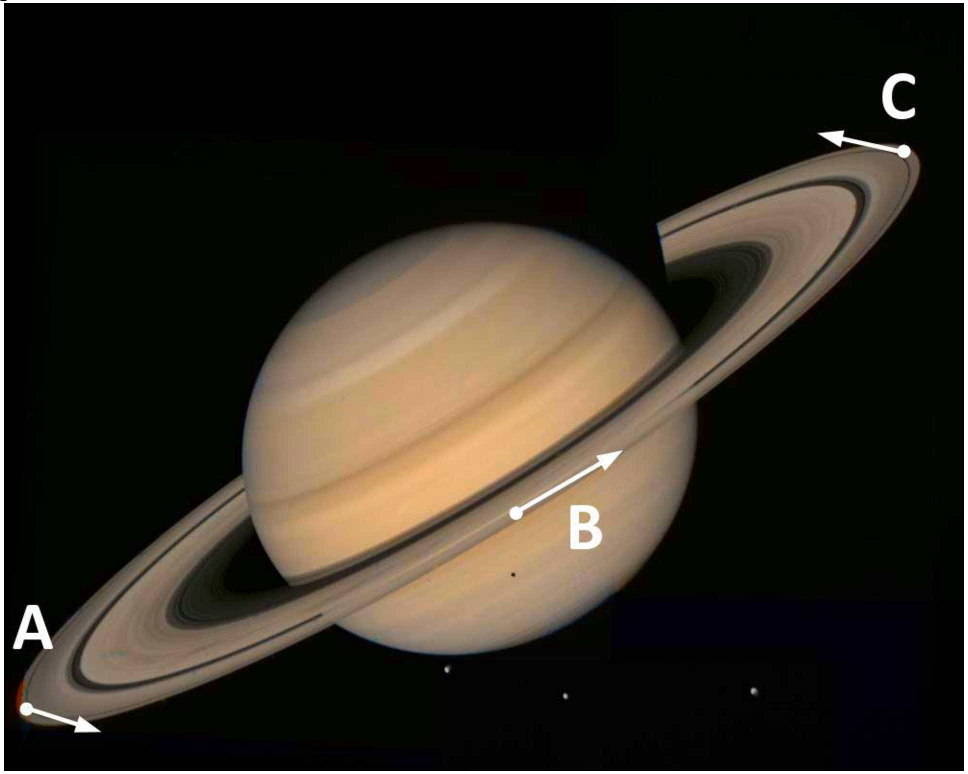
- Object moving toward observer: wavelength gets shorter (blue-shifted)

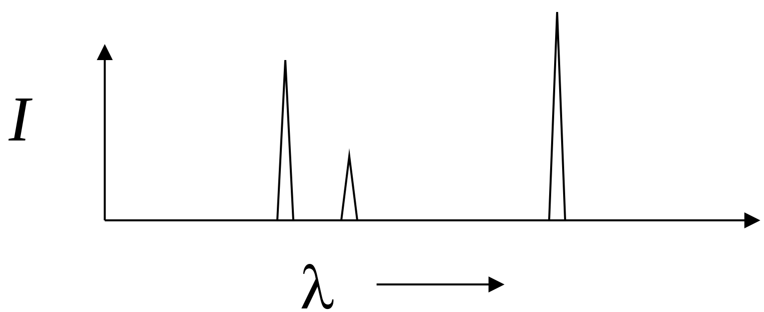


- Object moving away from observer: wavelength gets longer (red-shifted)

- NOTE: Side-to-side motion cannot be measured with the Doppler effect.

Rotation of objects



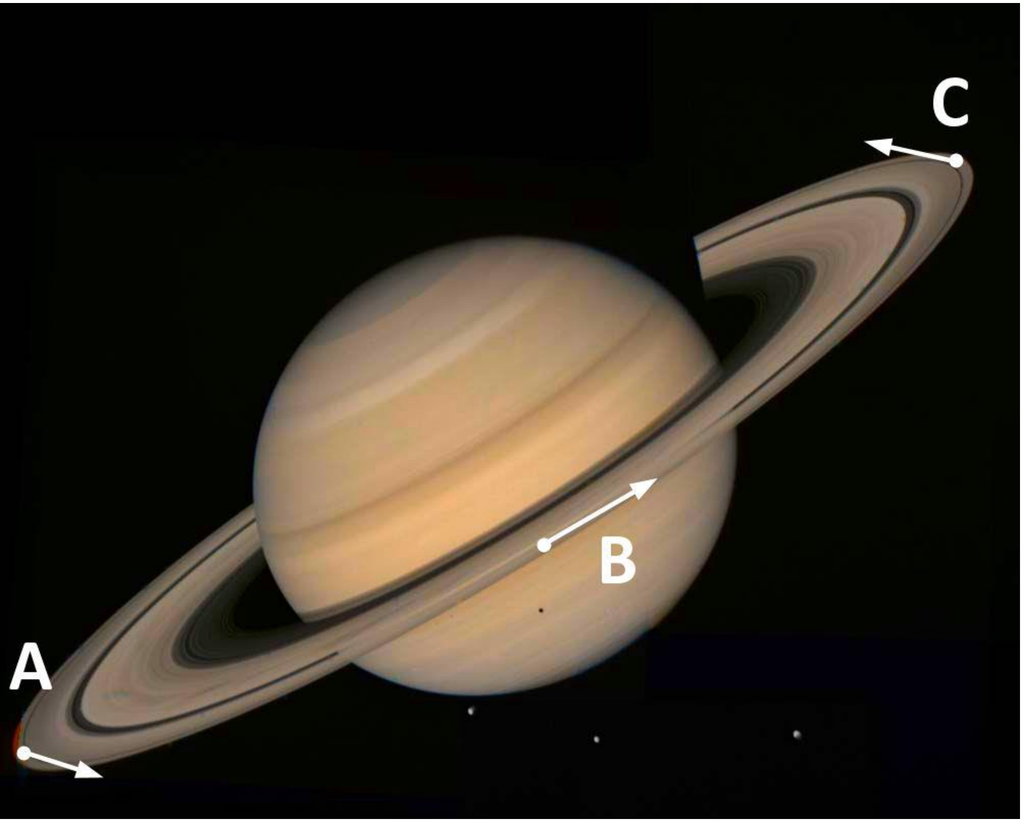


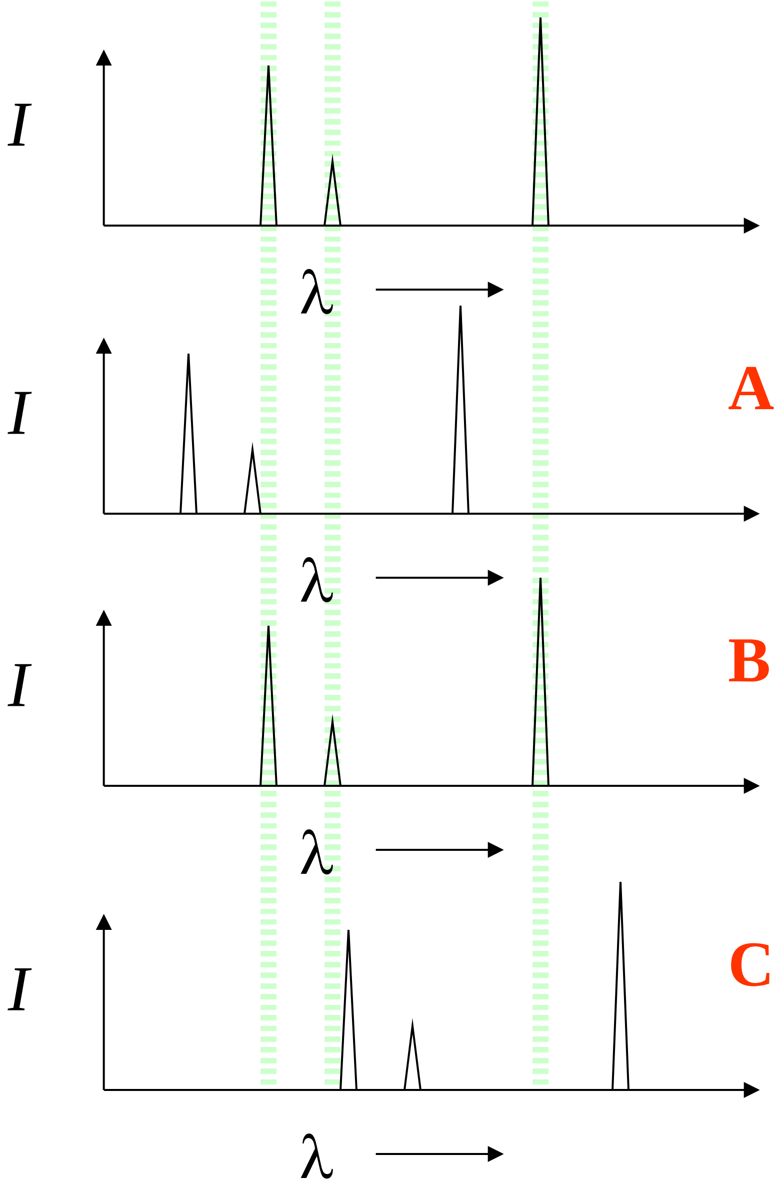
Spectrum of ice when at rest

The spectra of the ice in Saturn’s rings are different when observed from points A, B, and C, as compared with the spectrum collected when the ice particles are at rest.

Spectrum of Saturn's Rings

Spectrum of ice when at rest





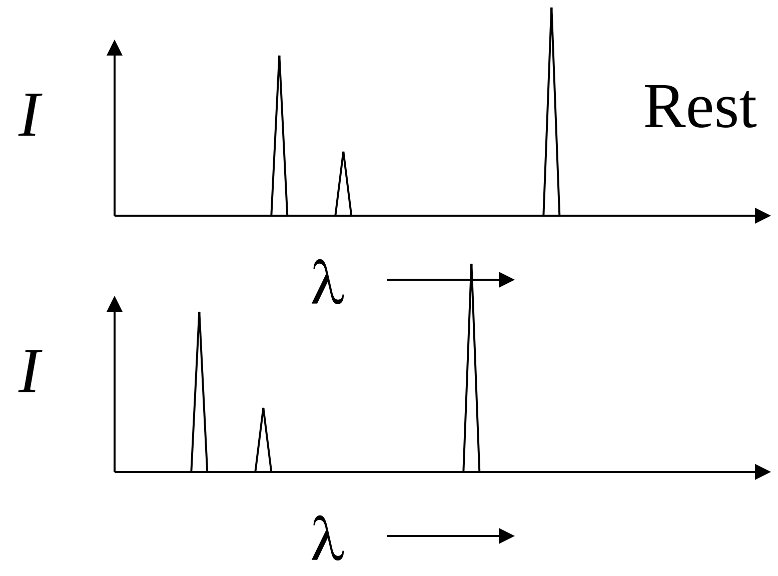
The spectrum at the bottom is emitted by an object

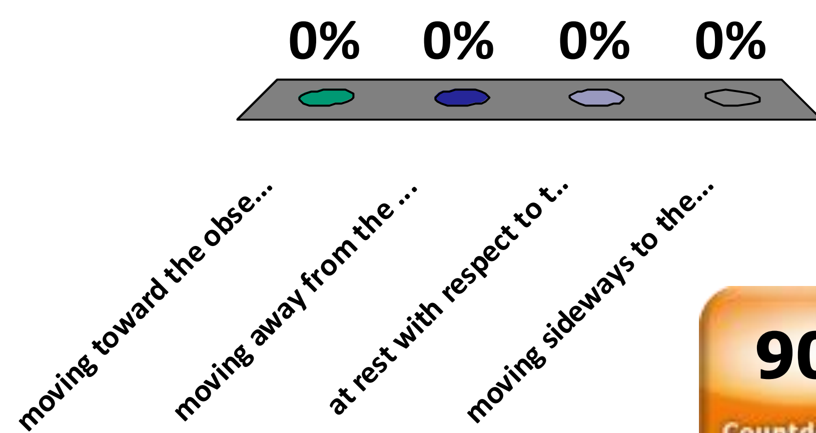
A. moving toward the observer

B. moving away from the observer

C. at rest with respect to the observer

D. moving sideways to the observer





0 of 5