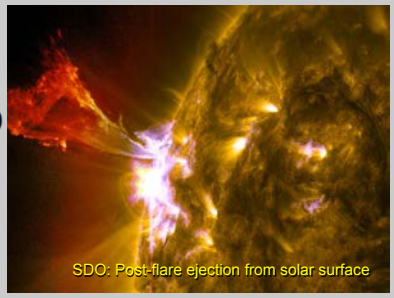
ASTR 1040 Stars & Galaxies



Prof. Juri Toomre TAs: Piyush Agrawal, Connor Bice

Lecture 3 Tues 24 Jan 2017

zeus.colorado.edu/astr1040-toomre

REMINDER

Your account on "Mastering Astronomy"

- Some confusion at CU Bookstore on the use of 8th edition of *Cosmic Perspectives*
- It is essential to have ***your account*** established on Mastering Astronomy (MA) tied into our course "ASTR1040TOOMRE2017"
- We will help replace any incorrect book versions, and get MA access codes corrected
- Be sure to work through MA Homework #0, and Homework #1, due Thur Jan 26

Reading for today's and Thur class:

- Read Chap 5, carefully *(Light and Matter)*
- *This chapter covers a lot – read it at least twice!*
- Start reading Chap 6, *telescopes*

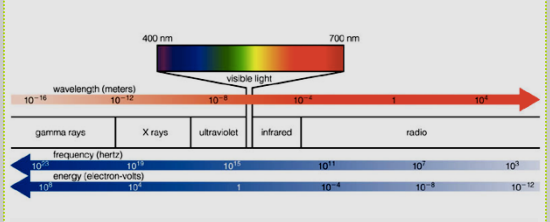
Continuing Topics for Today

- Electromagnetism: Light as waves and photons
- Coupling of atoms and light
- Yields "spectral lines" that are fingerprints unique to each atom
- How gas can emit or absorb light
- *Observatory Night # 1* (this Thur 26 Jan) by signup (7:00pm; 7:45pm; 8:30pm)
- Hope you completed *HW #0* on MA, now well underway with *HW #1* (due Thur classtime)

Light: The Cosmic Messenger

CONTINUING TOPIC

Electromagnetic Spectrum



gamma-rays x-rays ultraviolet visible infrared radio

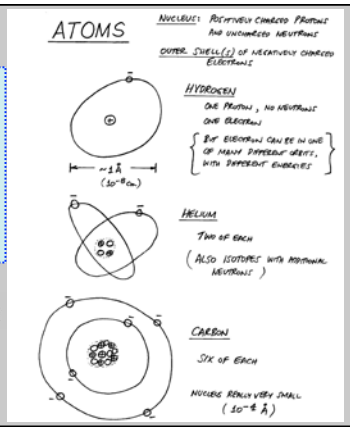
$$c = \lambda \cdot f$$

ATOMS

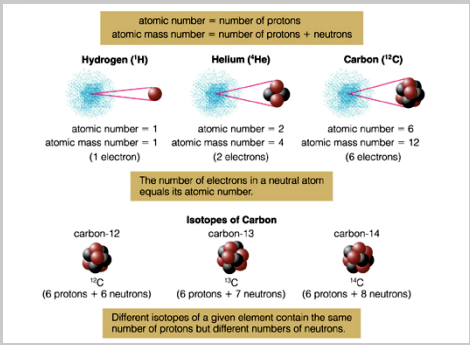
protons, neutrons, electrons

(and quarks ..)

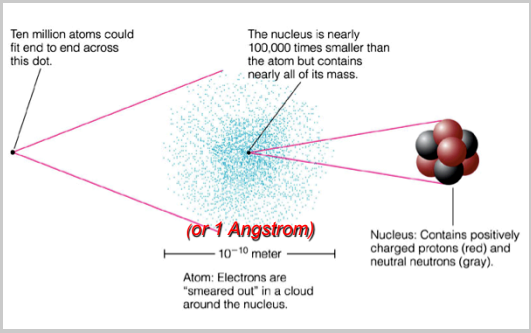
Building blocks for everything



Nucleus and its electron cloud ....



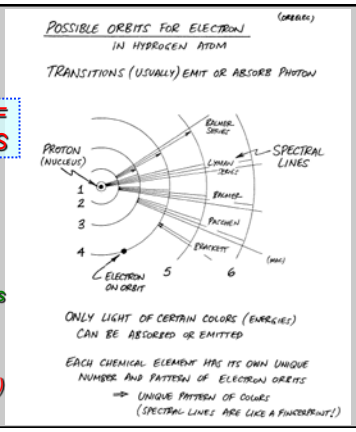
Atoms Involve Big Empty Spaces



"ORBITS" OF ELECTRONS

Popping from one orbit to another involves particular PHOTONS

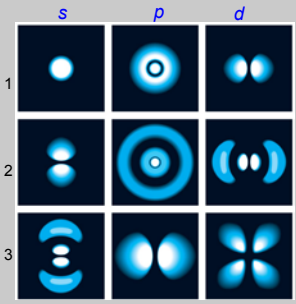
(like DNA prints)



Revolution of "Quantum Mechanics"

- Discrete spectral lines and electron energy levels go hand in hand, but WHY?
- **Classical physics had no real explanations, even if Bohr's model of electron orbits for H looked good**
- A new mathematics/physics had to be invented in the 1920s, with solutions of the "Schroedinger wave equation" giving *probabilities* (orbitals) of where electrons could be located
- **Such "quantum mechanics" also explained why light (photons) act both like waves and particles, and so too electrons!**

Electron in Hydrogen Atom (S4.3)



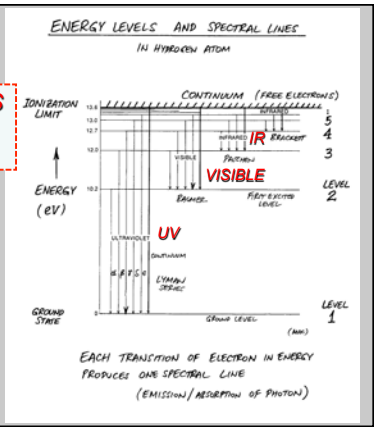
- In ***quantum mechanics***, an electron in an atom does not orbit in the usual sense
- We can know only the *probability* of finding an electron at a particular spot (orbital)

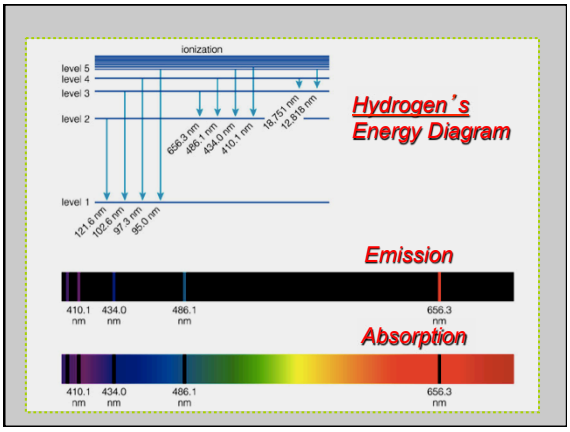
Orbital solutions from Schroedinger wave equation

ENERGY LEVELS (of electrons) IN HYDROGEN

Each transition involves photons of specific color

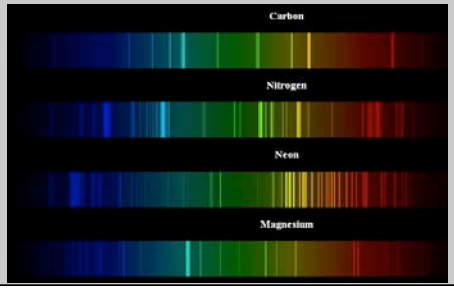
(like fingerprints)



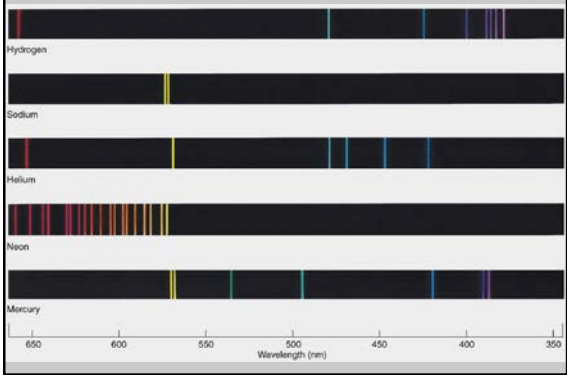


Each atom has a different set of energy levels

- *Just like no two people have the same fingerprints, no two elements have the same emission spectrum*



As in our emission tube demo on Thur



Very important Idea #2

$$E = h \times f$$

Photon's **Energy** = Planck's constant x Photon's **Frequency**

Idea #1 $c = \lambda \cdot f$

Colors of Light

- *Newton showed: White light is made up of many different colors*

Clicker Question

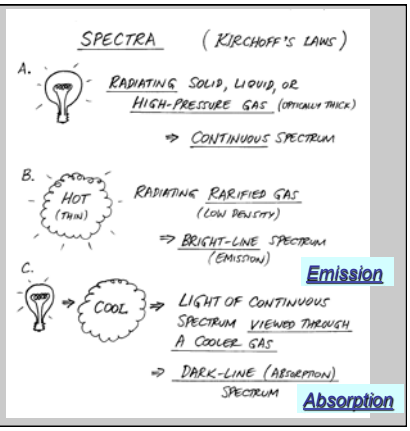
Infrared light can have a wavelength of 3 microns ($3x10^{-6}$ m) and a frequency of $1.0x10^{14}$ Hz. What is the wavelength of light that has a frequency of $0.5 x10^{14}$ Hz?

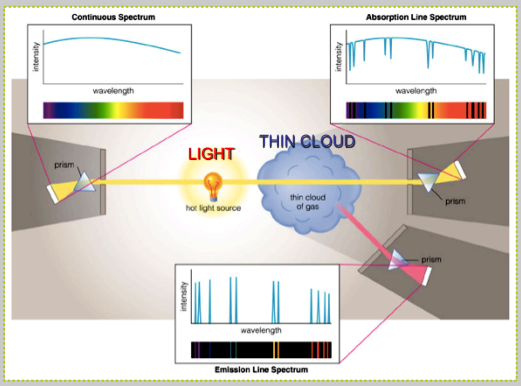
(Hint: What is the relationship between wavelength and frequency?)

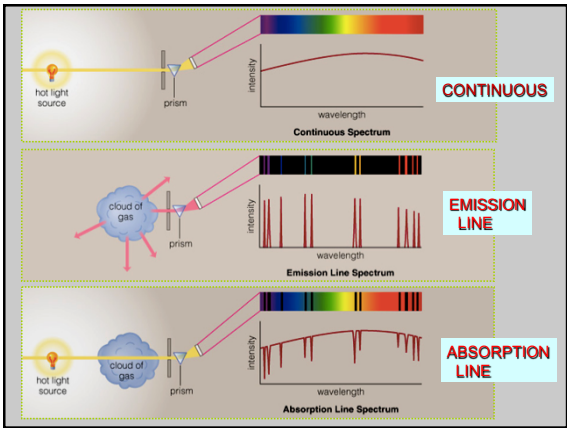
A. 1.5 microns
B. 2.0 microns
C. 2.5 microns
D. 3.5 microns
E. 6.0 microns

NATURE OF SPECTRA

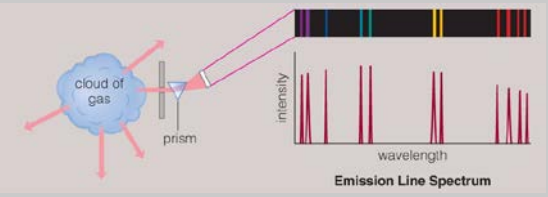
Kirchoff's laws





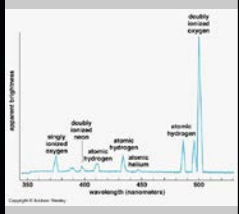


Emission Spectra



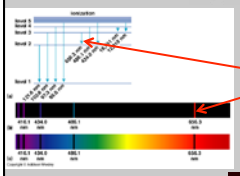
- *Emission for thin, hot gas: Gas glows in specific colors.*

The Crab nebula: remains of an exploded star (supernova, 1054 AD)

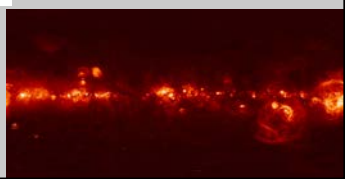


Spectrum shows bright emission lines from various elements

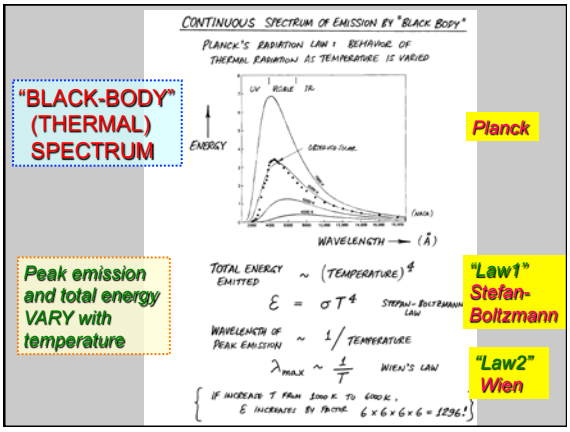
Most common visible light emission line: Hydrogen Alpha



- Hydrogen Alpha
- Level 3 to level 2 energy jump at 656.3 nm
- The universe is mostly red!!



All-sky map of H Alpha emission



"BLACK-BODY" (THERMAL) SPECTRUM

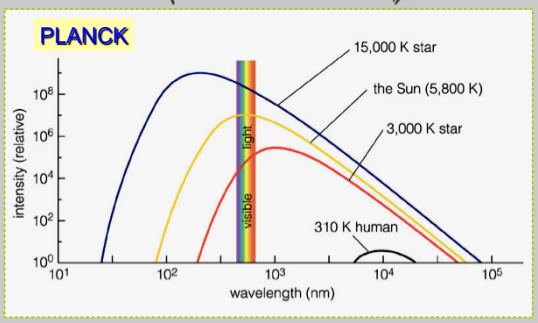
Planck

Peak emission and total energy VARY with temperature

"Law1" Stefan-Boltzmann

"Law2" Wien

Spectra of Continuous Emission (from us and stars)



Thermal radiation spectrum

Law 1: *Power emitted* (per square meter surface area)

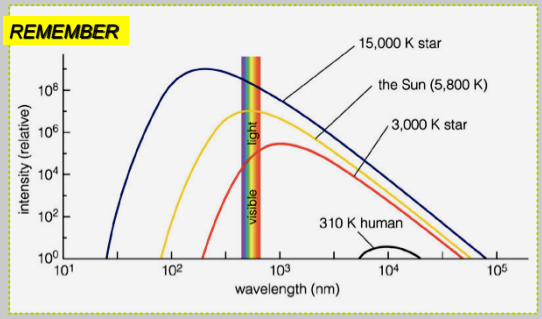
$$\varepsilon = \sigma T^4$$

"Luminosity" = "Law 1" x Surface Area of star

Law 2: *Wavelength* of peak emission

$$\lambda_{max} \sim 1/T$$

Thermal Radiation Emission



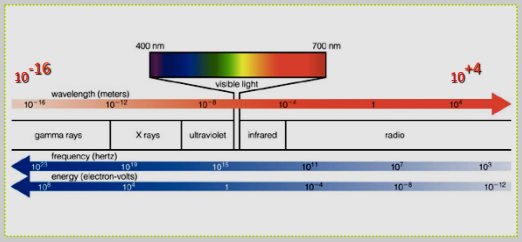
UP the temperature: *FAR MORE emission peak at SHORTER wavelengths*

Clicker Q – EM Waves

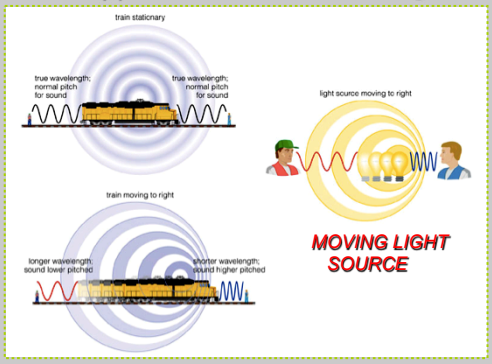
- From *shortest to longest wavelength*, what is the correct sequence of EM radiation?

- *A.* gamma-rays, x-rays, UV, visible, IR, radio
- *B.* gamma-rays, x-rays, visible, UV, IR, radio
- *C.* IR, visible, UV, x-rays, gamma-rays, radio
- *D.* radio, IR, visible, UV, x-rays, gamma-rays

A. gamma-rays,x-rays,UV,visible,IR,radio

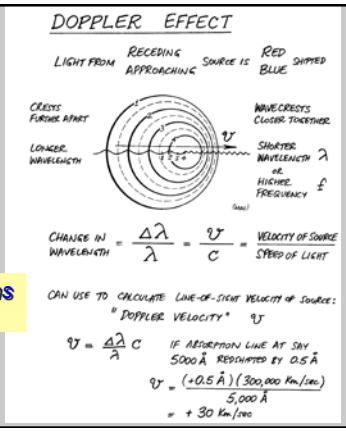


Doppler Effect: Trains and Light



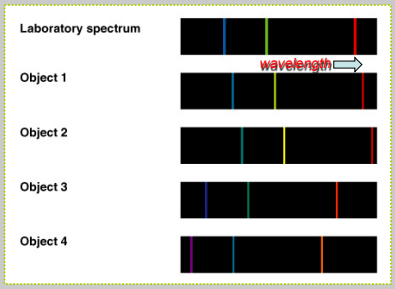
DOPPLER EFFECT

Applied to positions of spectral lines



Doppler Demo

Measuring the Line Shift



Stationary

Moving Away (redshifted)

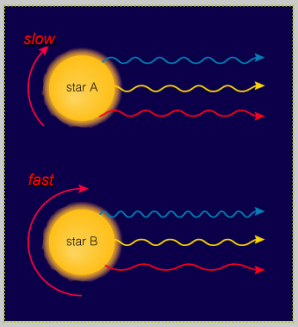
Away Faster

Moving Toward (blueshifted)

Toward Faster

- Measure the Doppler effect from shifts in the wavelengths of spectral lines

How does Doppler shift tell us the ROTATION RATE of a star?



Doppler shifts from different portions of star broaden the spectral line

Black hole in the center of galaxy M84 was detected using Doppler shifts!

- Big blueshift just above center, big redshift just below
  - gas whirling at incredible velocities around the core