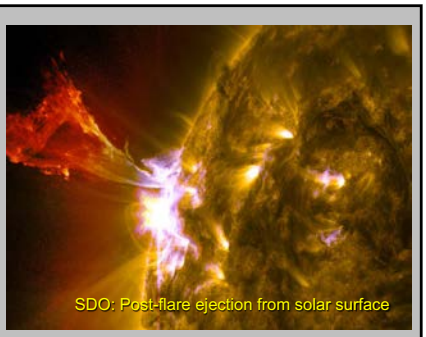
ASTR 1040 Stars & Galaxies



Prof. Juri Toomre TAs: Ryan Horton, Loren Matilsky

Lecture 3 Tues 4 Sept 2018

zeus.colorado.edu/astr1040-toomre

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*

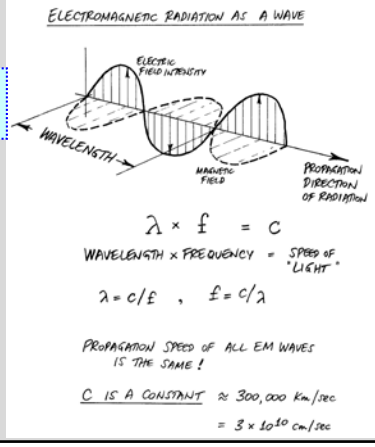
Continuing Topics for Today

- 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* (tonight Tues 4 Sept) by signup (8:30pm; 9:00pm; 9:30pm)
- Hope you completed *HW #0* on MA, now well underway with *HW #1* (due Thur classtime)
- Recitations / AHR office hours can help

Light: The Cosmic Messenger

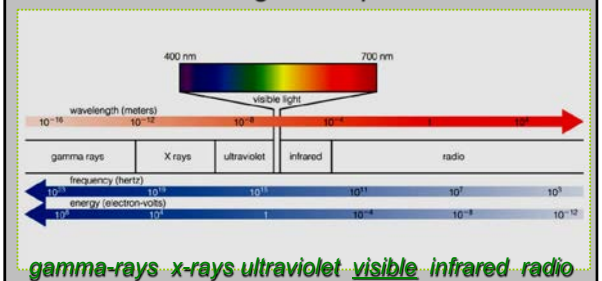
CONTINUING TOPIC

E-M (LIGHT) AS WAVES



Speed of light SAME for all wavelengths

Electromagnetic Spectrum



gamma-rays x-rays ultraviolet visible infrared radio

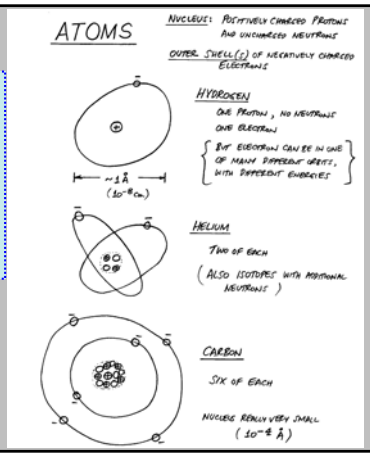
$$c = \lambda \cdot f$$

ATOMS

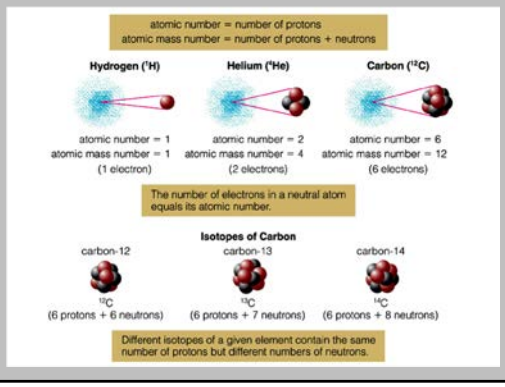
protons, neutrons, electrons

(and quarks ..)

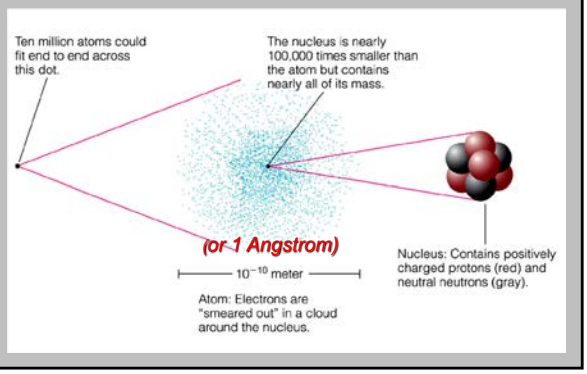
Building blocks for everything



Nucleus and its electron cloud ....



Atoms Involve Big Empty Spaces



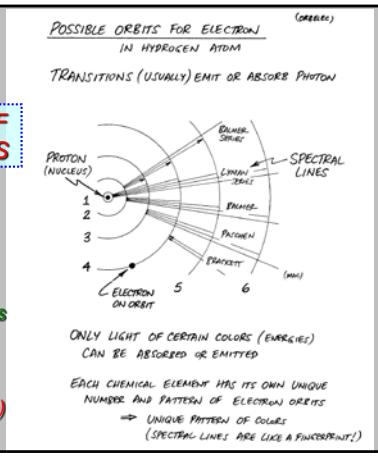
Clicker: *How much time does it take light to travel one Astronomical Unit (1 AU)?*

- A. Speed of light x 1 AU
- B. Speed of light / 1 AU
- C. 1 AU / speed of light
- D. 1 light-year

"ORBITS" OF ELECTRONS

Popping from one orbit to another involves particular PHOTONS

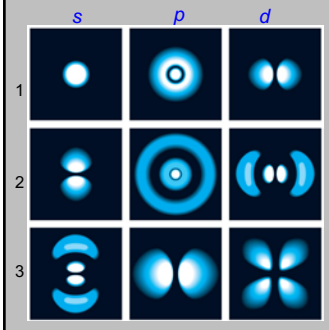
(like DNA prints)



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!**

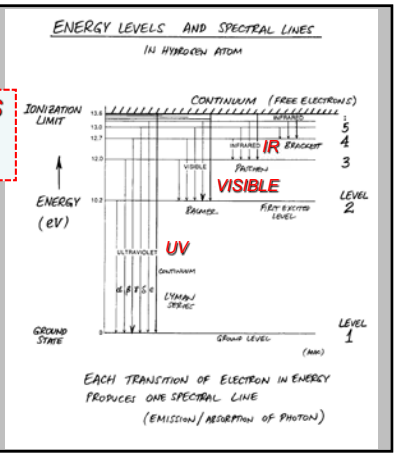
Electron in Hydrogen Atom (S4.3)



- 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)

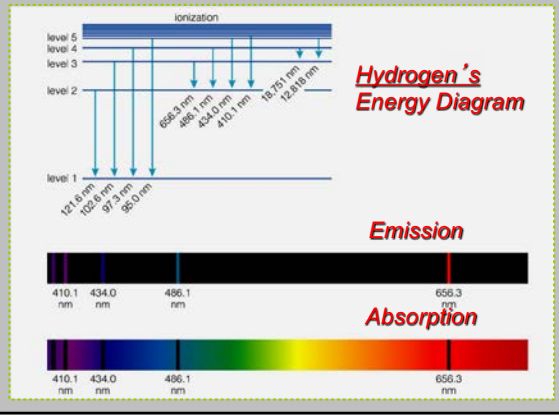
Orbital solutions from Schroedinger wave equation

ENERGY LEVELS (of electrons) IN HYDROGEN



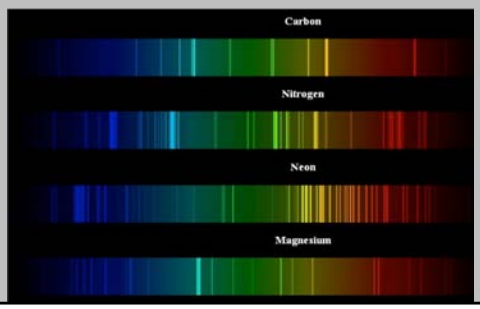
Each transition involves photons of specific color

(like fingerprints)

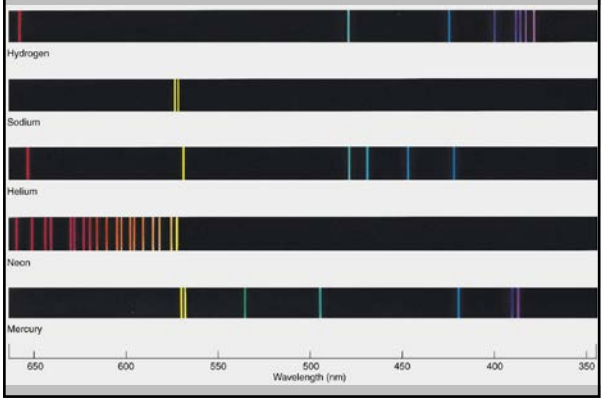


Each atom has a different set of energy levels

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



As in our emission tube demo last 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

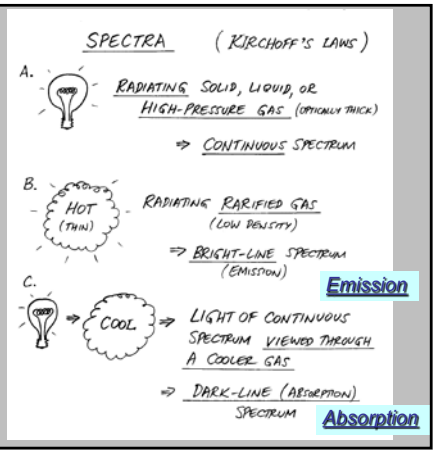
Infrared light can have a wavelength of 3 microns ($3x10^{-6}$ m) and a frequency of $1.0x10^{14}$ Hz. What is the wavelength of light that has a frequency of $0.5\ x10^{14}$ Hz?

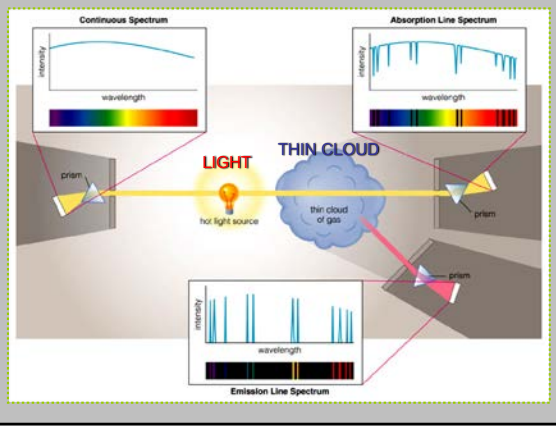
(Hint: What is the relationship between wavelength and frequency?)

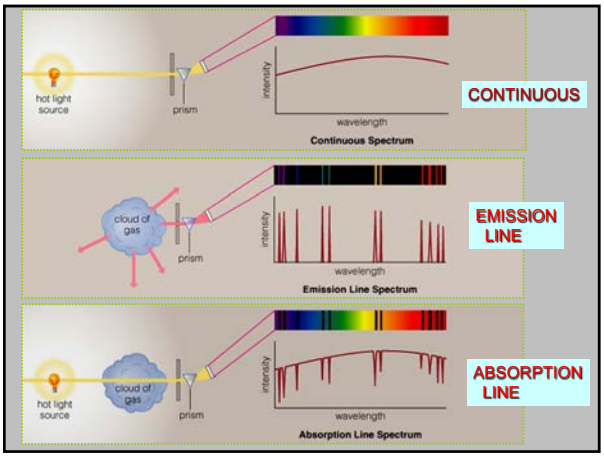
A. *1.5 microns*
B. *2.0 microns*
C. *2.5 microns*
D. *3.5 microns*
E. *6.0 microns*

NATURE OF SPECTRA

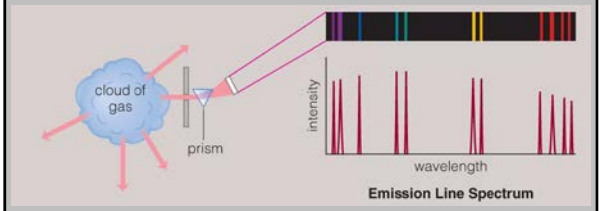
Kirchoff's laws





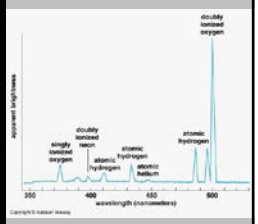


Emission Spectra



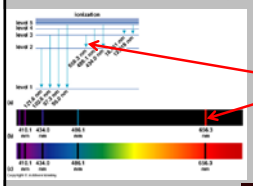
- *Emission for thin, hot gas: Gas glows in specific colors.*

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



Spectrum shows bright emission lines from various elements

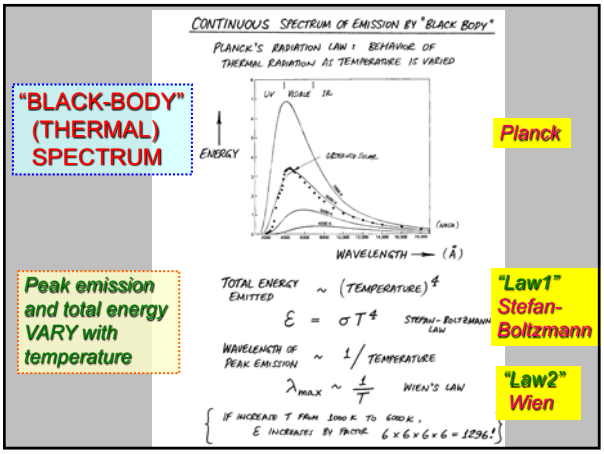
Most common visible light emission line: Hydrogen Alpha



- 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



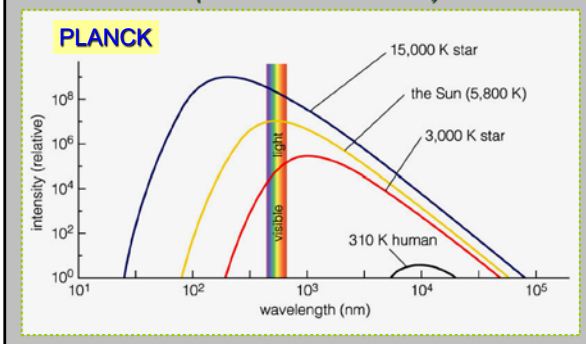
Planck

"Law1" Stefan-Boltzmann

"Law2" Wien

Peak emission and total energy VARY with temperature

Spectra of Continuous Emission (from us and stars)



Thermal radiation spectrum

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

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

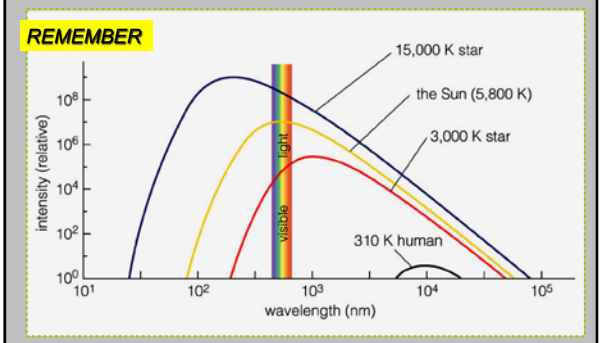
"Luminosity" = "Law 1" x Surface Area of star

Law 2: Wavelength of peak emission

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

Thermal Radiation Emission

REMEMBER



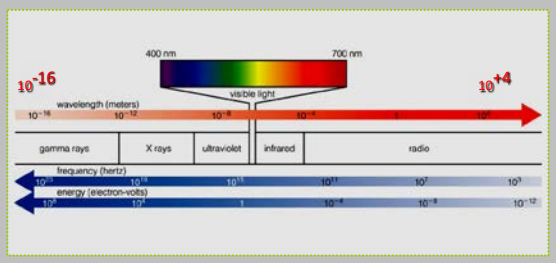
UP the temperature: FAR MORE emission peak at SHORTER wavelengths

Clicker Q – EM Waves

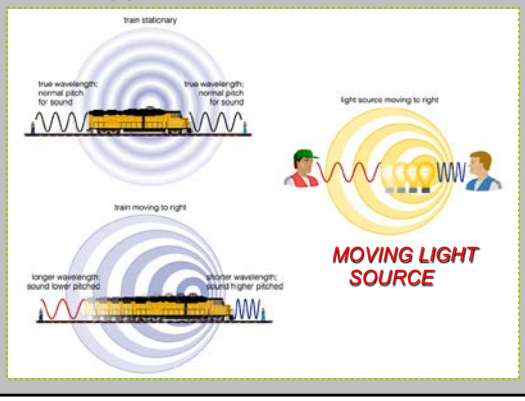
- From ***shortest to longest wavelength***, what is the correct sequence of EM radiation?

- *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