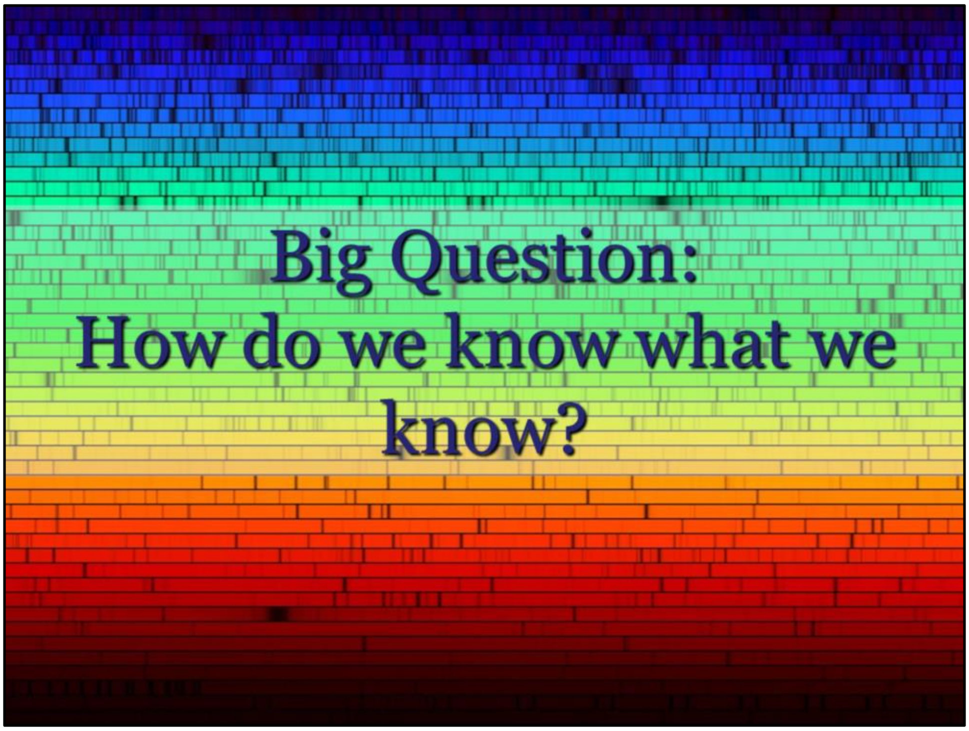
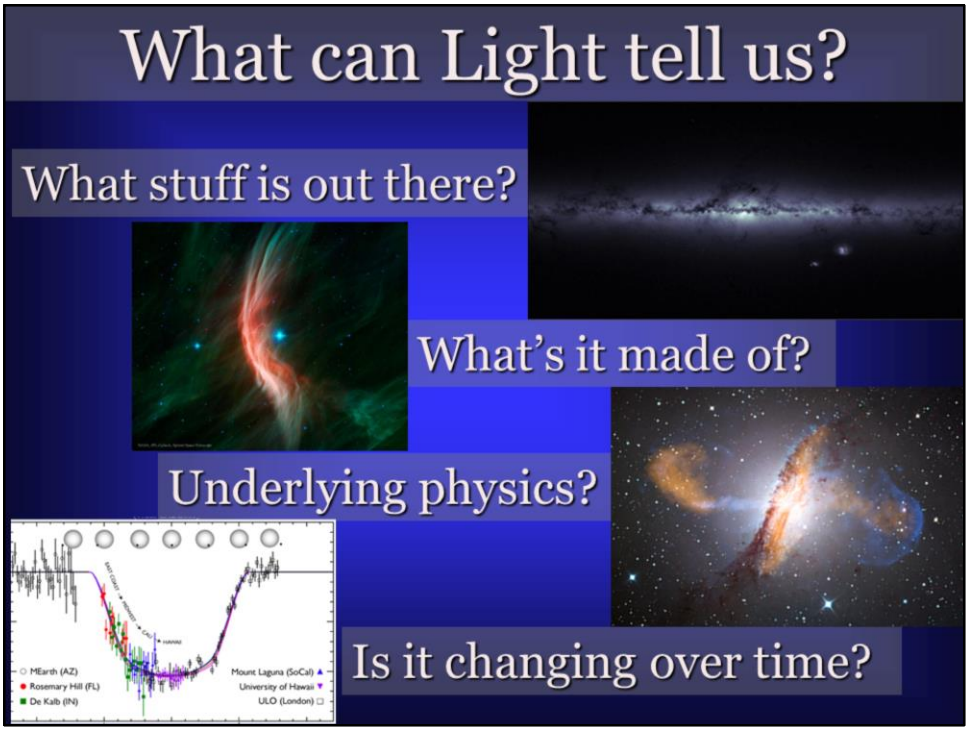
Light

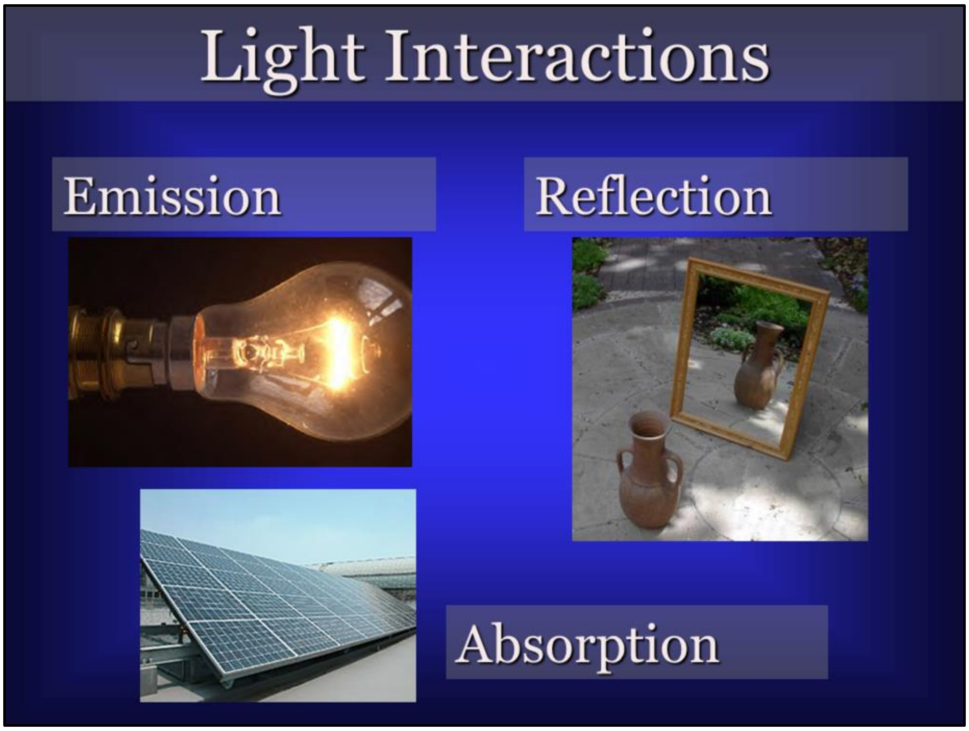

"As I understand it, they want an immediate answer. Only trouble is, the message was sent out three million years ago."


Big Question:
How do we know what we know?

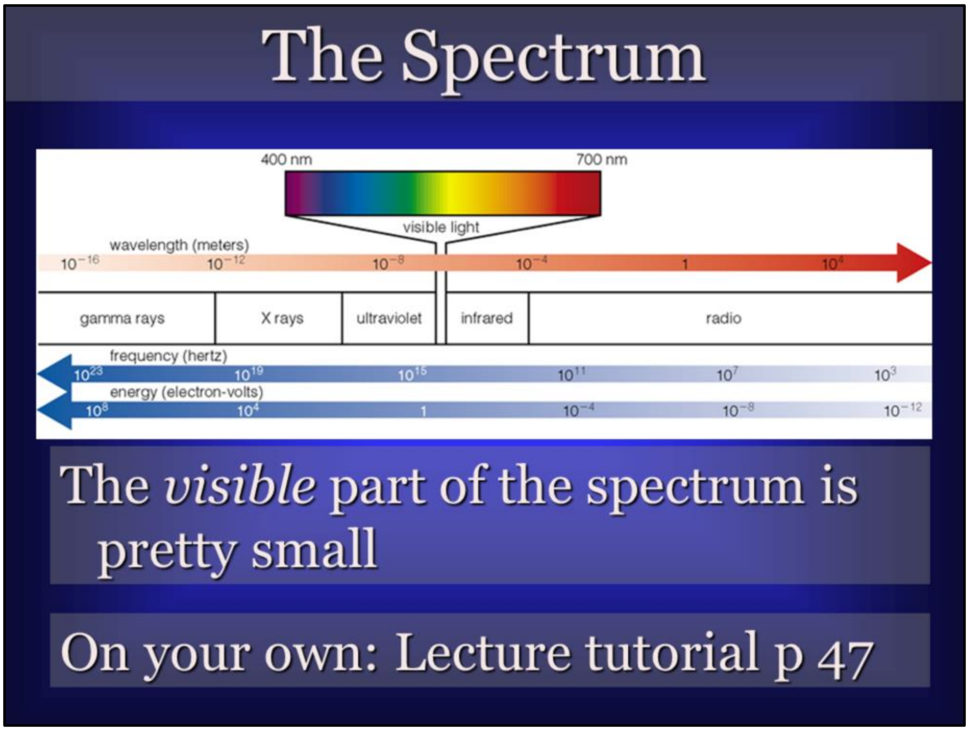


How do we answer these questions?

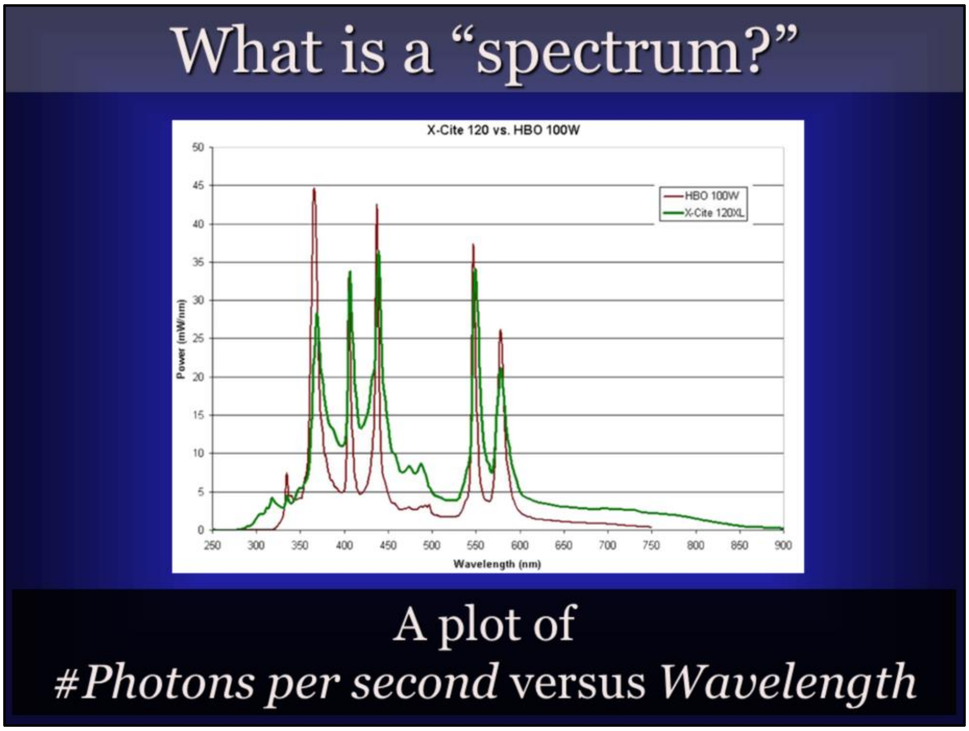
Images:
Milky way: http://www.cosmos.esa.int/web/gaia/iow_20150703 *ESA/Gaia-CC*
Zeta Oph: http://apod.nasa.gov/apod/ap150705.html (NASA/JPL/Spitzer)
Centaurus A: ESO/WFI (Optical); MPIfR/ESO/APEX/A.Weiss et al. (Submillimetre); NASA/CXC/CfA/R.Kraft et al. (X-ray)
https://en.wikipedia.org/wiki/File:ESO_Centaurus_A_LABOCA.jpg
Exoplanet timing: http://www.personal.psu.edu/ebf11/mystuff/press.html (Eric Ford, journal article: http://iopscience.iop.org/0004-637X/703/2/2091/pdf/0004-637X_703_2_2091.pdf)



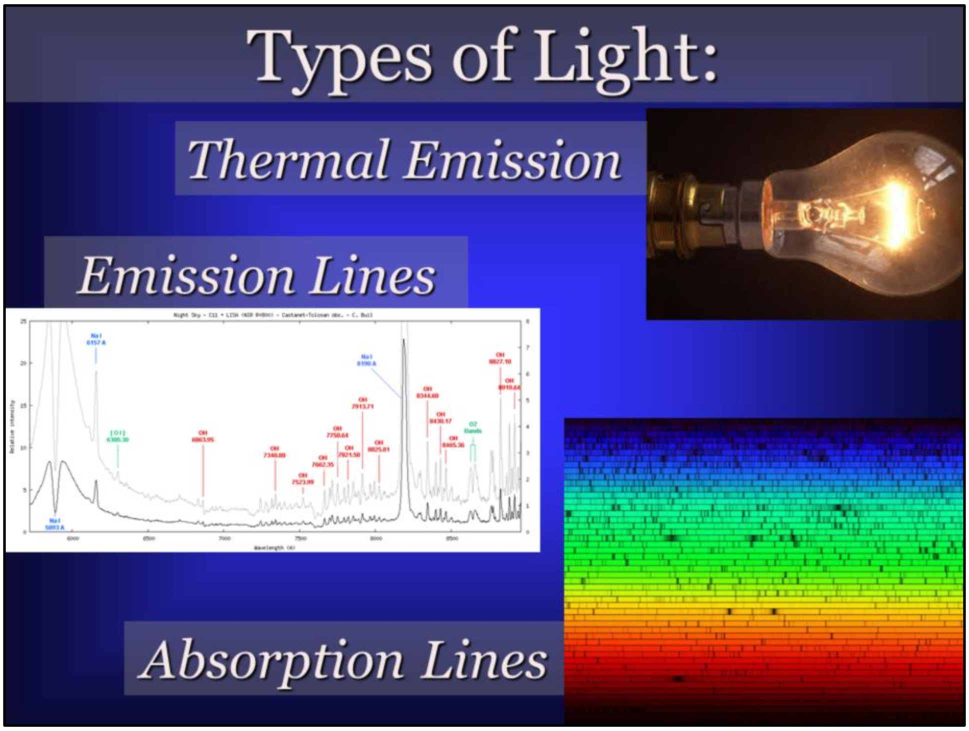
We will talk about each of these things in turn… but first let’s take a look at a tool we can use to examine light. We’ve already seen the word “spectrum” but we didn’t really define it….



Visible meaning your eye can see it
But it’s ALL light
Radio waves are light with a looong wavelength



# of photos = brightness

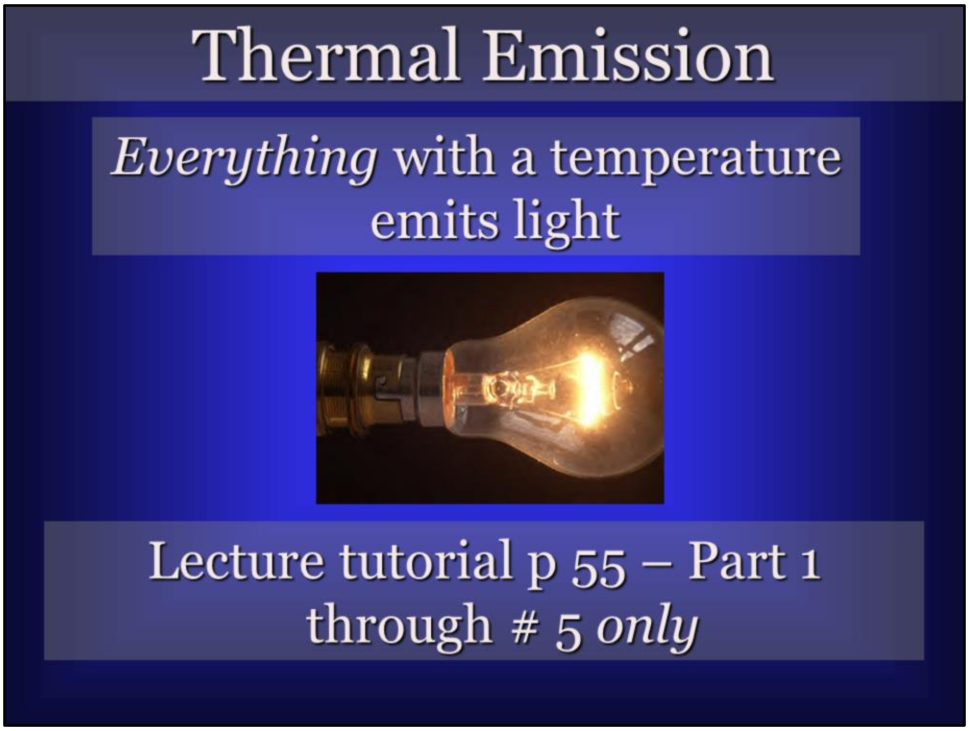


Lecture tutorial: Temperature and Luminosty, part 1 through question 5 only (p 55)
Lecture tutorial: Blackbody Radiation.

Everything with a temperature emits light.
Including all of us! We don't emit at wavelengths that can be seen by our eyes.

But we have special cameras that can see our light…

*** NOTE: **Thermal Emission** is the same thing as **Blackbody Emission** or **Continuous Emission**! ***



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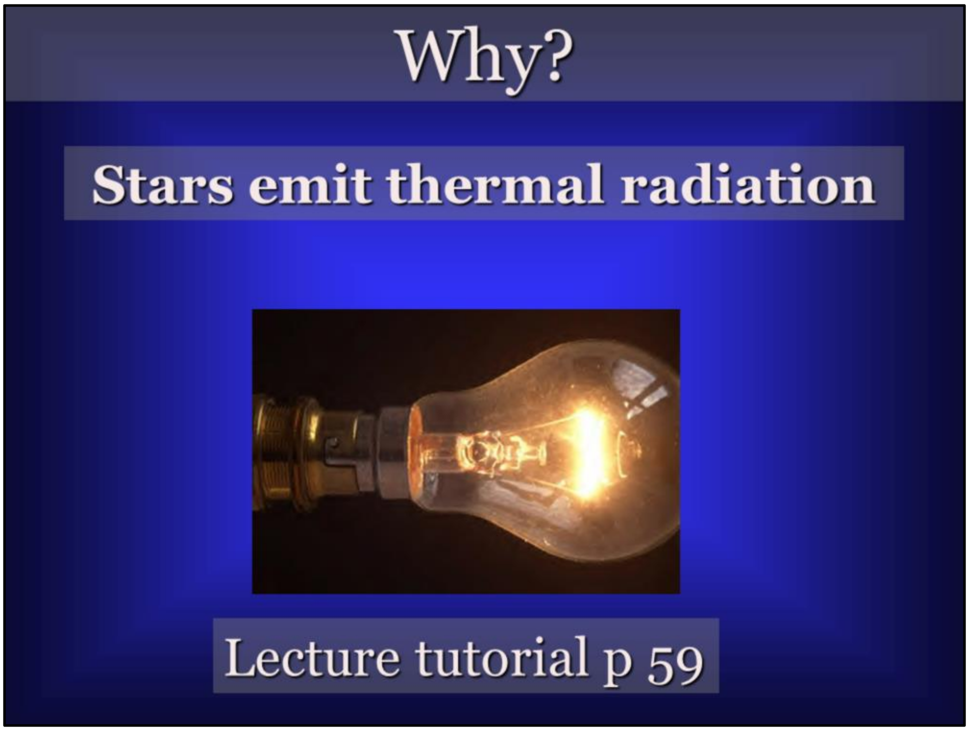
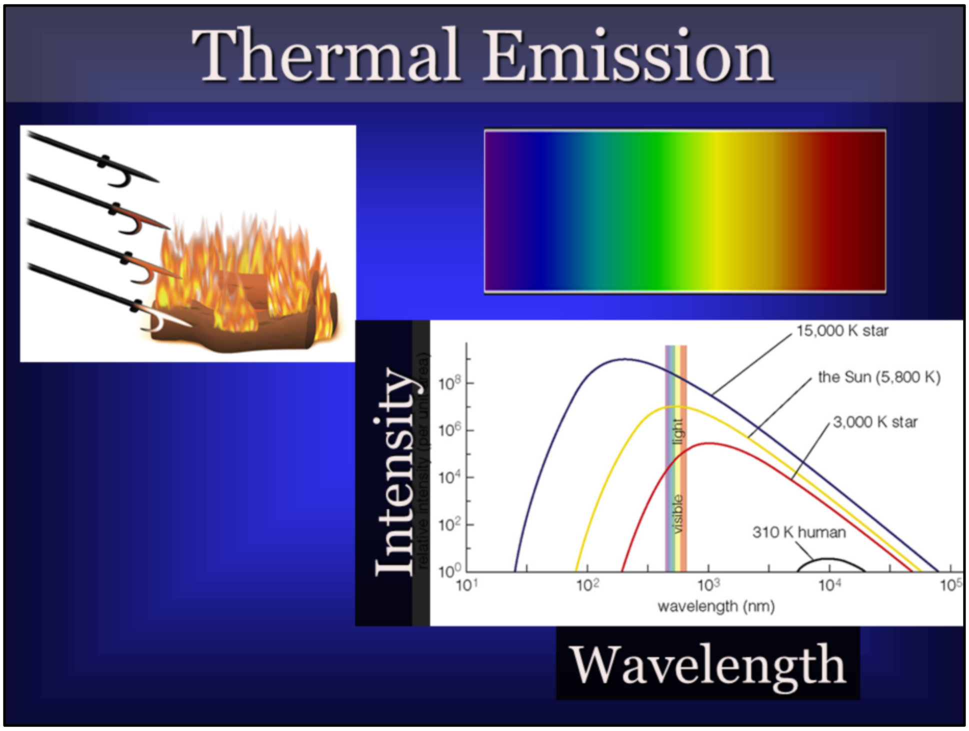


Discussion: What do we need? What conditions?

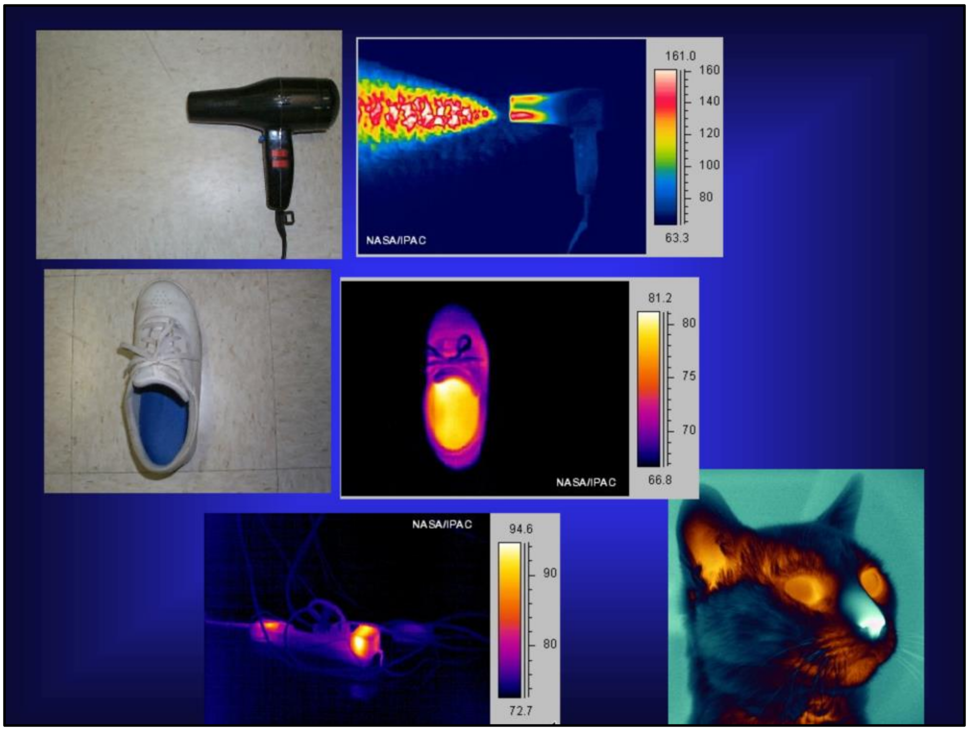
Are there other situations that are not the same? That might emit light? What other things might happen to light? (remember earlier!)

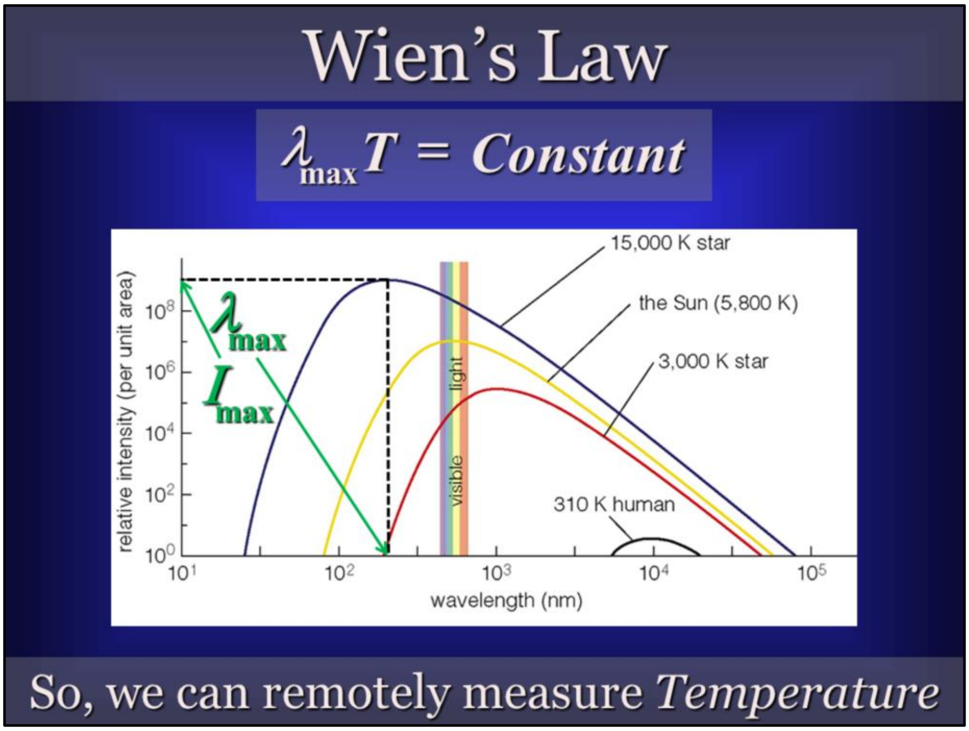


Blackbody emission is emission from DENSE objects.

The spectrum that we see is known as a Black Body curve.
The Black Body curve changes as we change the Temperature of an object.

What color does the 15,000 K star appear to our eyes?
What color does the 3000 K star appear to our eyes?


161.0
160
140
120
100
80
63.3
NASA/IPAC
81.2
80
75
70
66.8
NASA/IPAC
NASA/IPAC
94.6
90
80
72.7

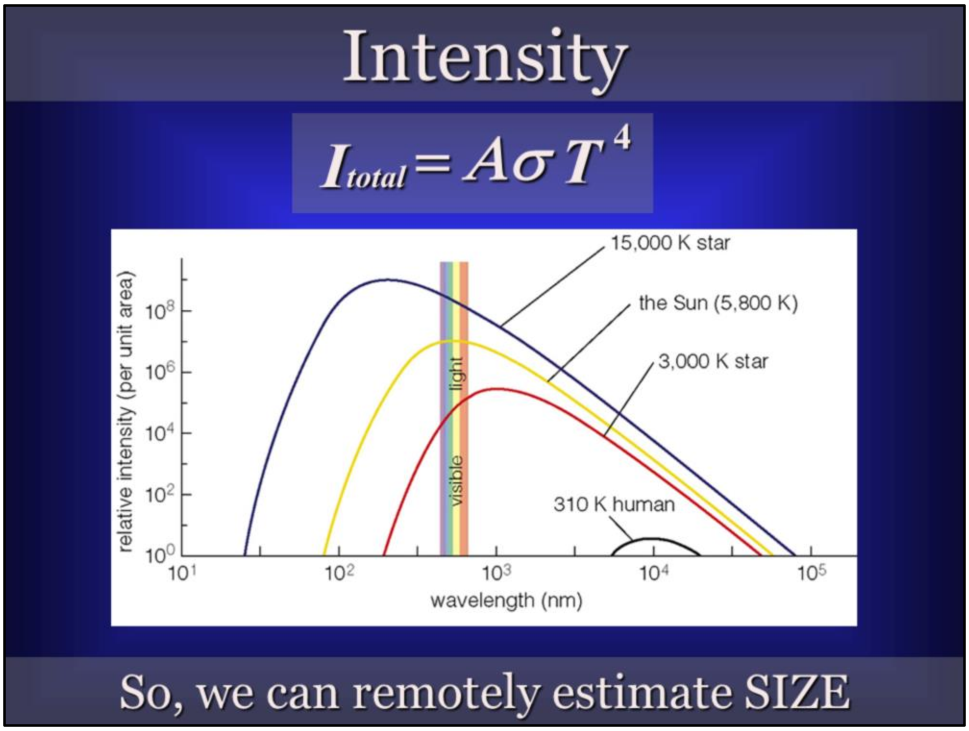


The coordinates of the peak of the blackbody gives us information.

The "x-coordinate" of the blackbody peak is called Lambda Max.
Lambda Max is related to the temperature of the object.

T = Temperature.
The Constant is the same for EVERY blackbody emitter in the Universe.

I can know the Temperature of an object by taking a spectrum and measuring Lambda Max!

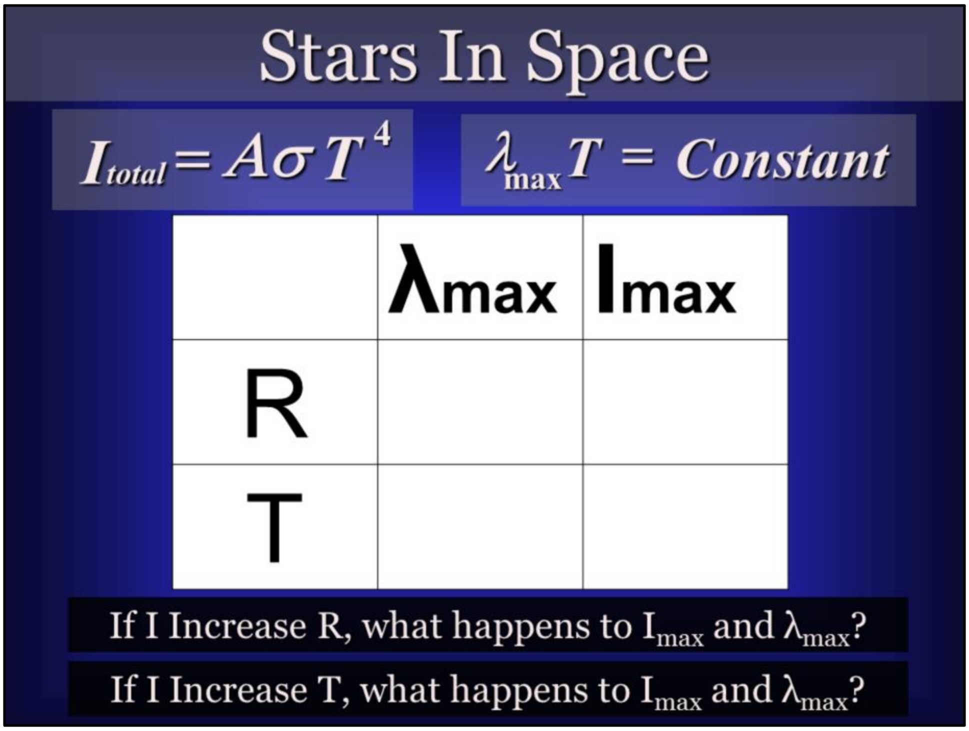


The coordinates of the peak of the blackbody gives us information.

The "y-coordinate" of the blackbody peak is called Maximum Intensity
Maximum Intensity is related to the temperature AND the Surface Area of the object.

A = Surface Area
T = Temperature

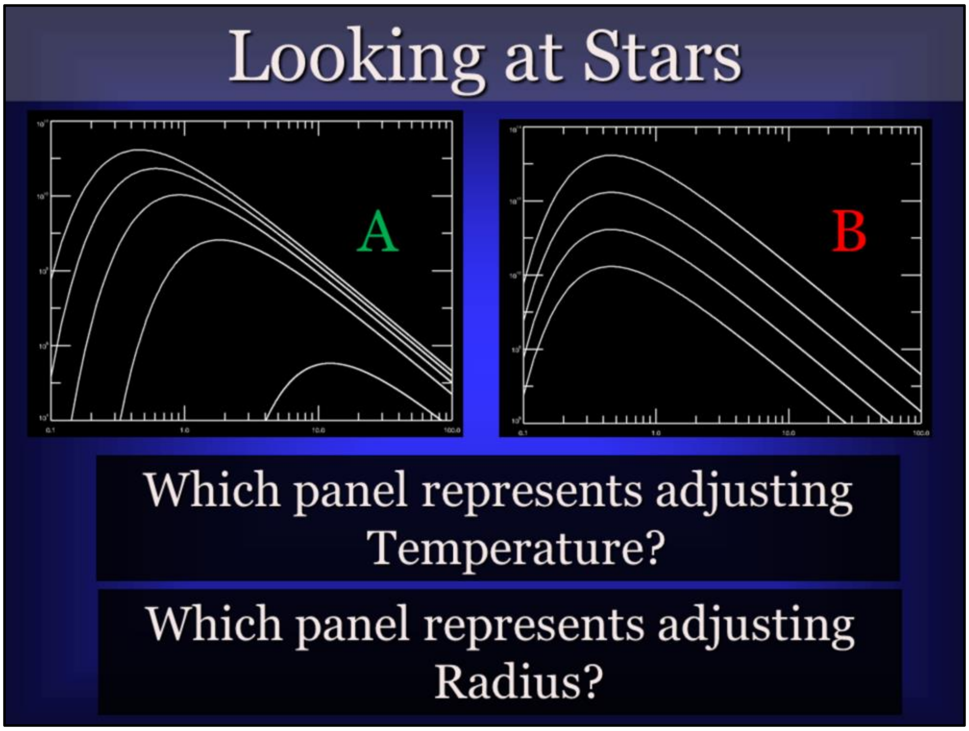
I can know the Size of an object by measuring the Maximum intensity and the Temperature!



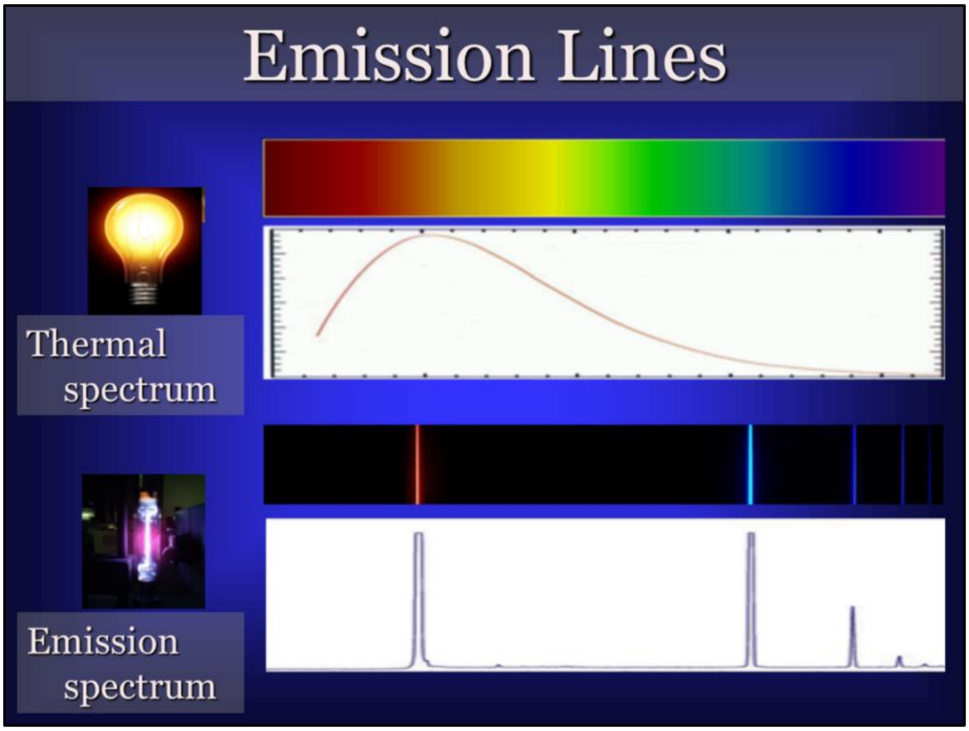
Given our two relationships for Blackbody emitters, let's think about Stars In Space!

Increasing R increases the SIZE of the star. That makes Imax go up, but leaves Lambda max unchanged.
Increasing T increases BOTH lambda max AND Imax.

The blackbody spectrum helps us with temperature (first) and size (second). But to get a real size we need to know something about *distance*, or some other property (e.g. this is a main sequence star: fusing H to He in its core).

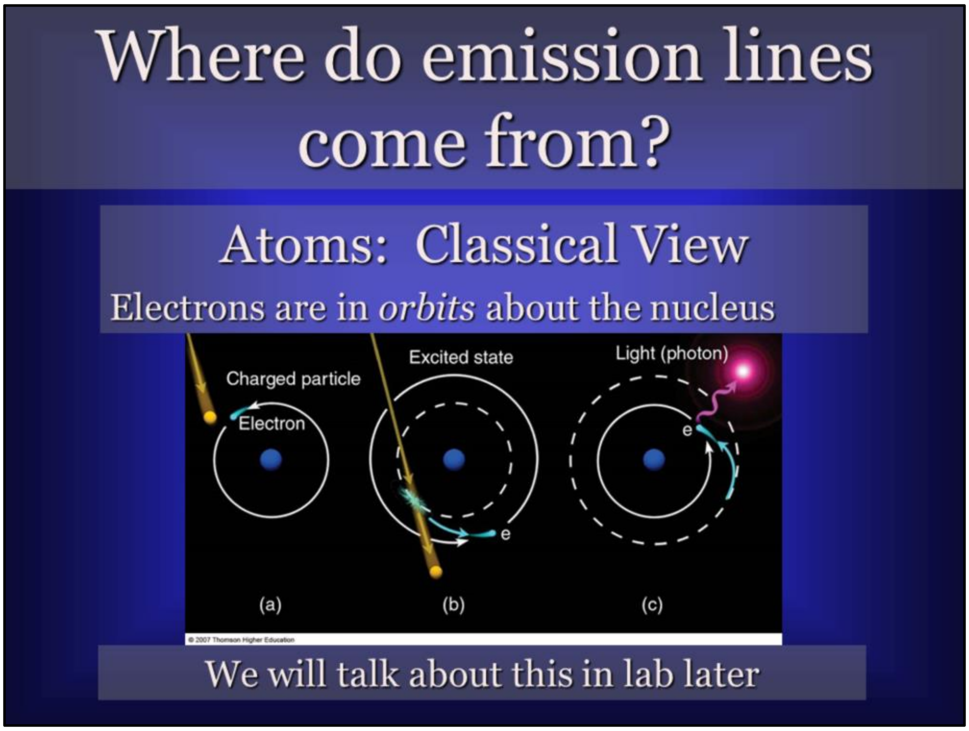


Blackbody spectrum: hot, dense (by dense, I mean **opaque**) objects



Top: continuous, blackbody spectrum
Bottom: Emission lines

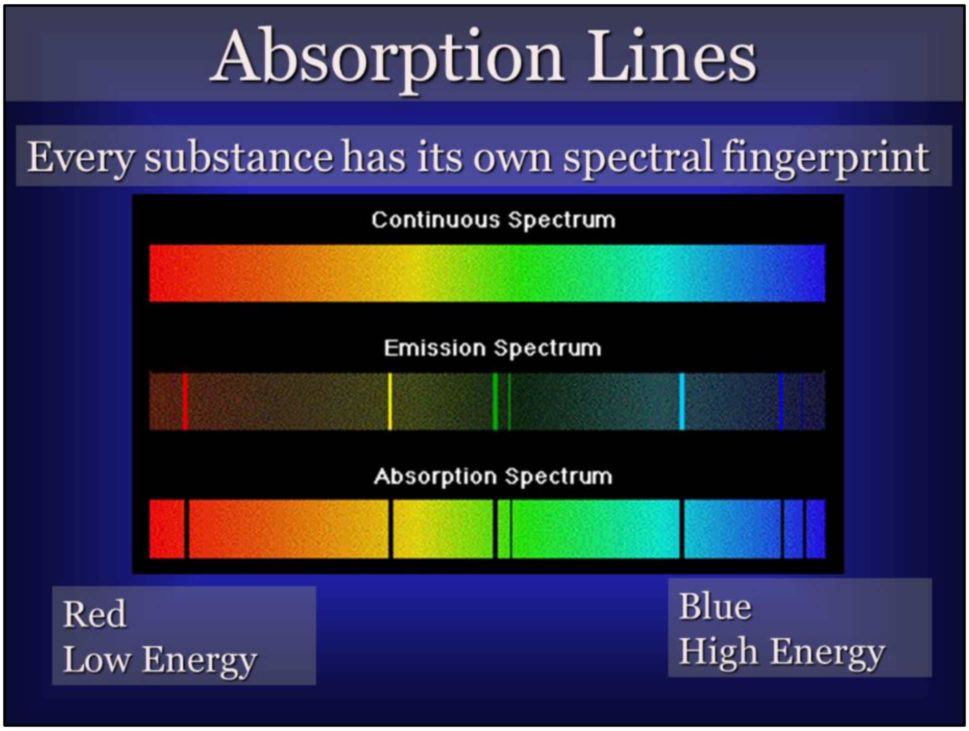
So… if we excite some atoms, we'll see the fingerprint as emission lines.
A line is a very narrow emission feature of a very specific color



Electrons in an atom can gain or lose energy (like the potential energy in a planetary orbit)
When they undergo a collision, the bound electron gains energy and bounces up.
It doesn't LIKE being up, so it drops back down, losing energy and emitting a photon.

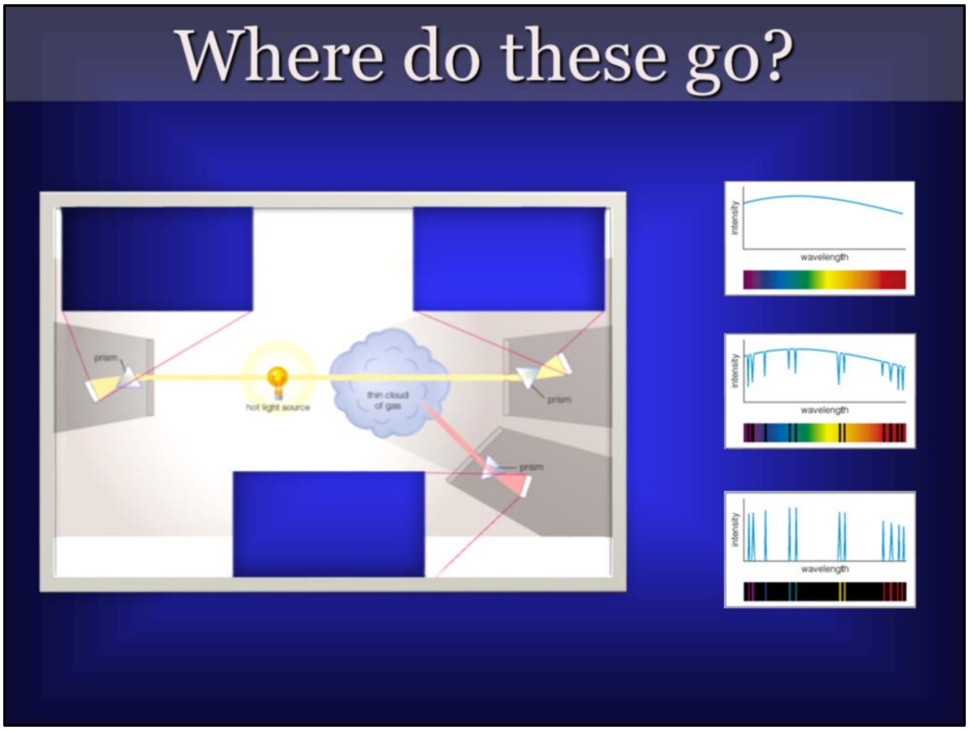
But, they can ONLY occupy discrete orbits, there are no in betweens.
Every element has its own unique set of orbital levels, and thus A fingerprint in light.

(Analogy: Pac-kid atom only likes blue and red m&ms!)

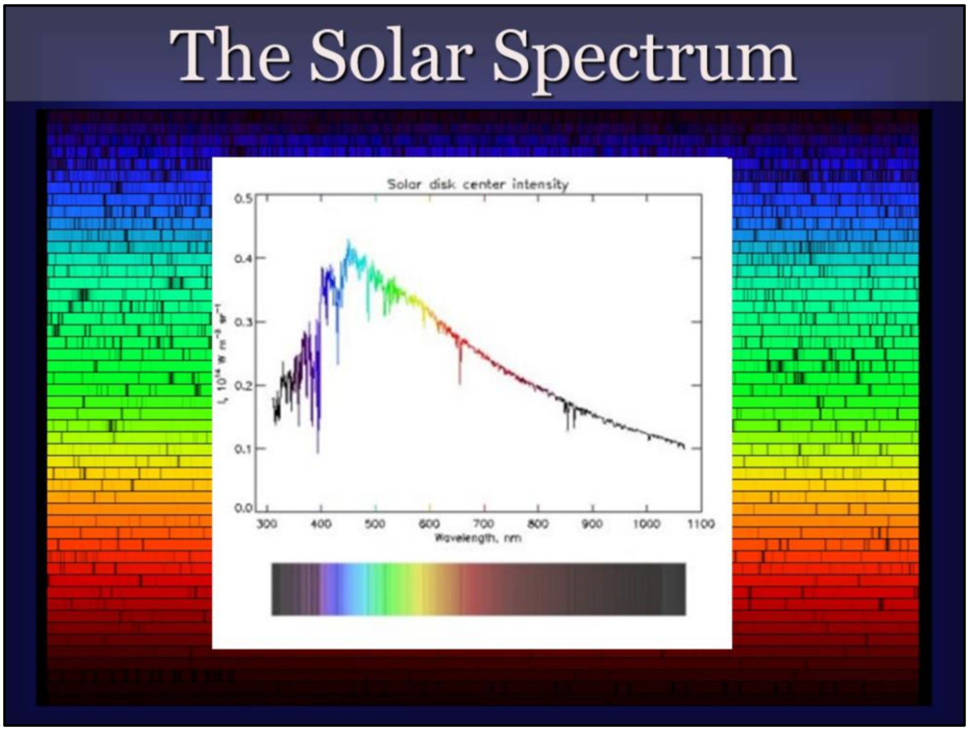


The absorption spectrum is the same as the emission spectrum for a given element. Only instead of emitting light, the atom is taking light out of a background continuum (or rainbow).

Lecture Tutorial: Types of Spectra (p 63)

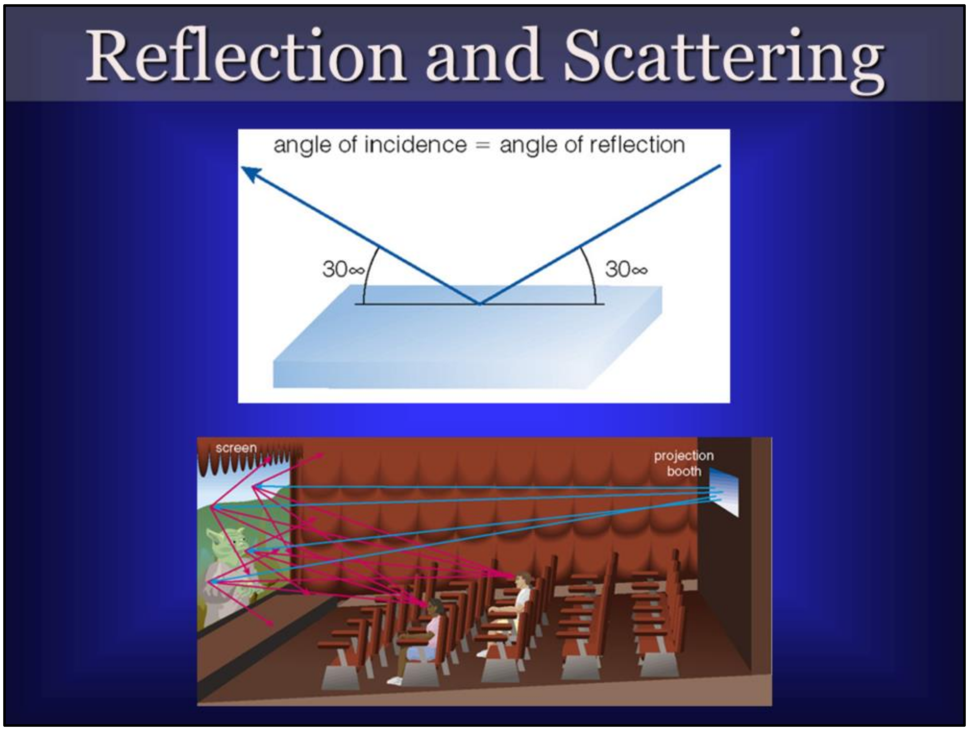


Each blue box is a different observer. What goes where?



What can we tell about the sun based on its spectrum?

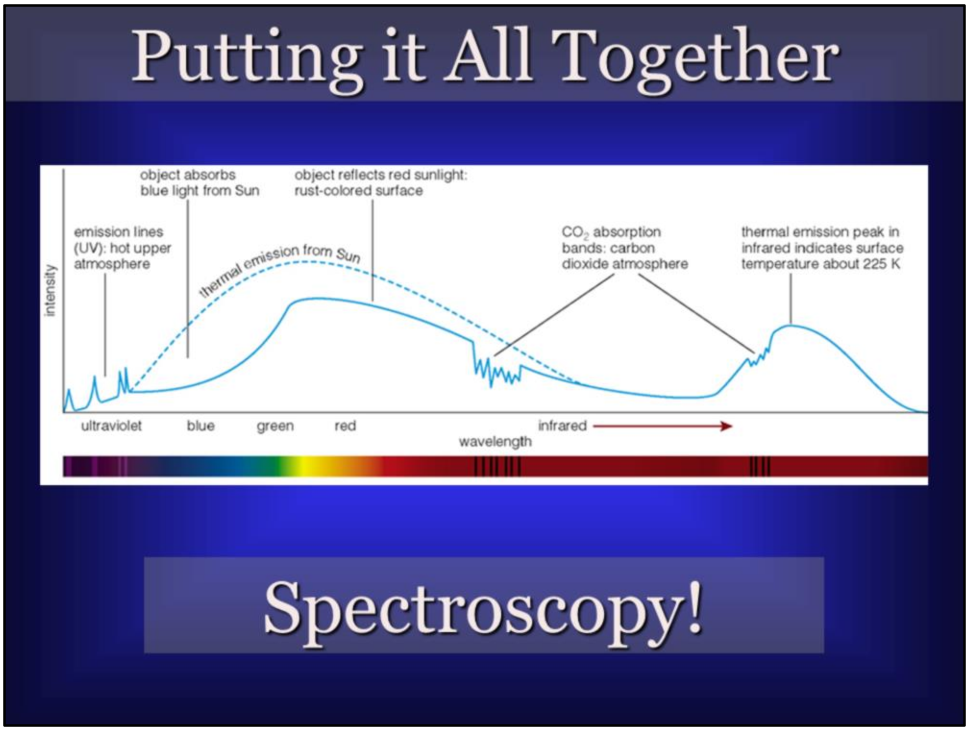
Notice we have: underlying thermal spectrum, absorption lines, and a few emission lines. What do each of these tell us?



We tend to think of reflection in terms of mirrors.
But reflection is how we see most objects.
Already existing photons bounce off of a surface to your eye.

Some surfaces are lumpy and scatter the light

Wavelength dependant scattering.
Blue is scattered more strongly than red.
At sunset, the light must go through a lot of atmosphere so all of the blue is scattered out.



When we look at spectra, we generally look at a plot of intensity versus frequency or wavelength instead of the color bar.
The color bar is like looking down at the earth from a satellite. The plot is like turning the satellite view sideways so that you can see the height of the landscape.

This spectrum contains all of the things that we've talked about… atomic emission and absorption, scattering, reflection, thermal emission…
The job of a spectroscopist is to figure out what sort of physical configuration would give rise to such a spectrum.

Light Equations:

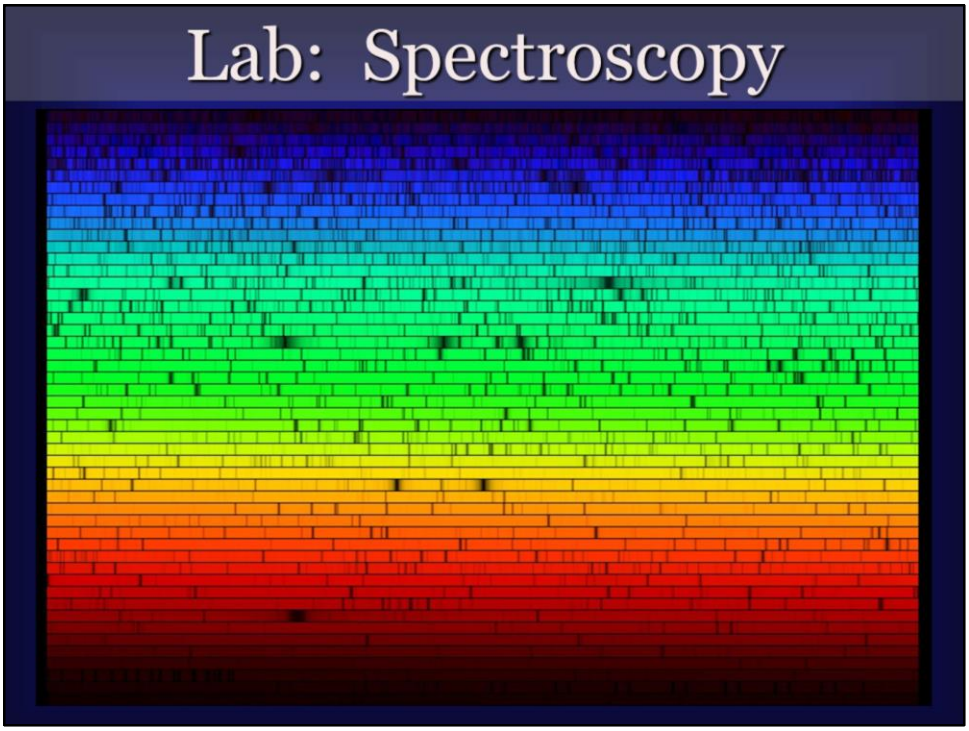
$$c = \lambda f$$

(special case v = c)

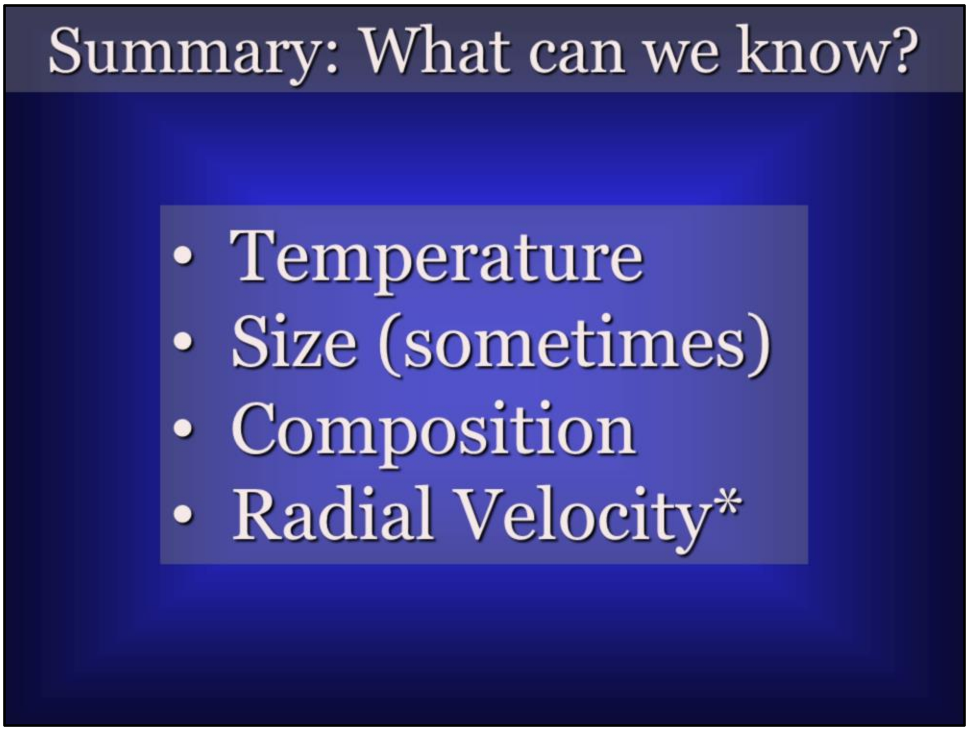
$$E_\lambda = h c / \lambda = h f$$

$$\lambda_{max} T = \textit{constant}$$

$$I_{total} = A \sigma T^4$$



Three categories of spectra: Thermal (blackbody), Emission, Absorption



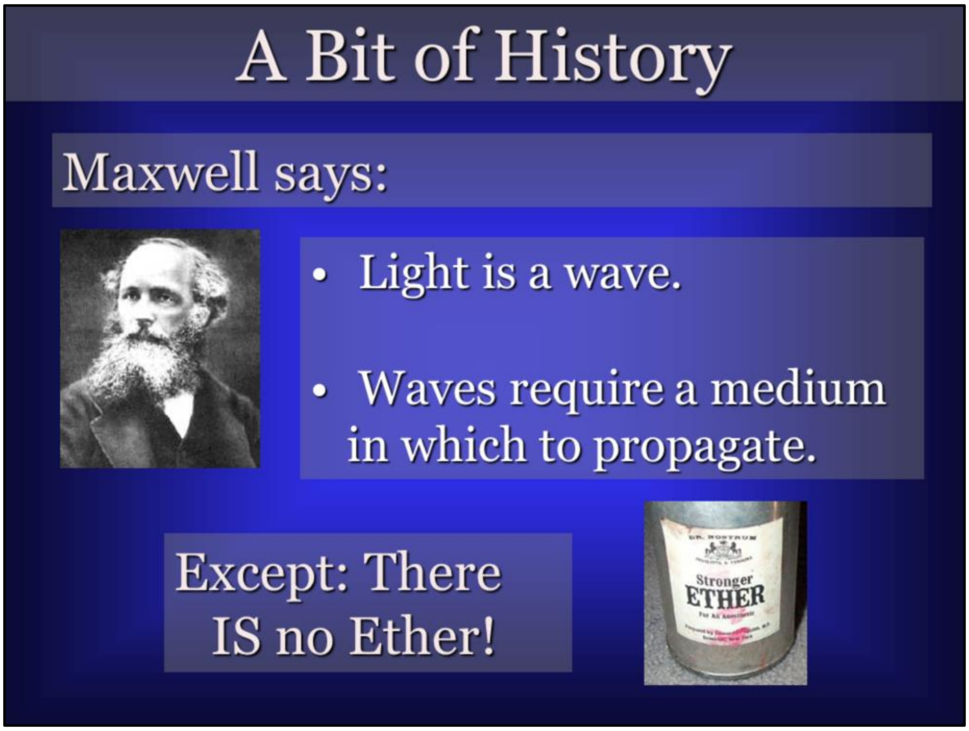
We didn't talk bout how to get radial velocity (moving toward/away from us) but will talk about it later.

What is Light?

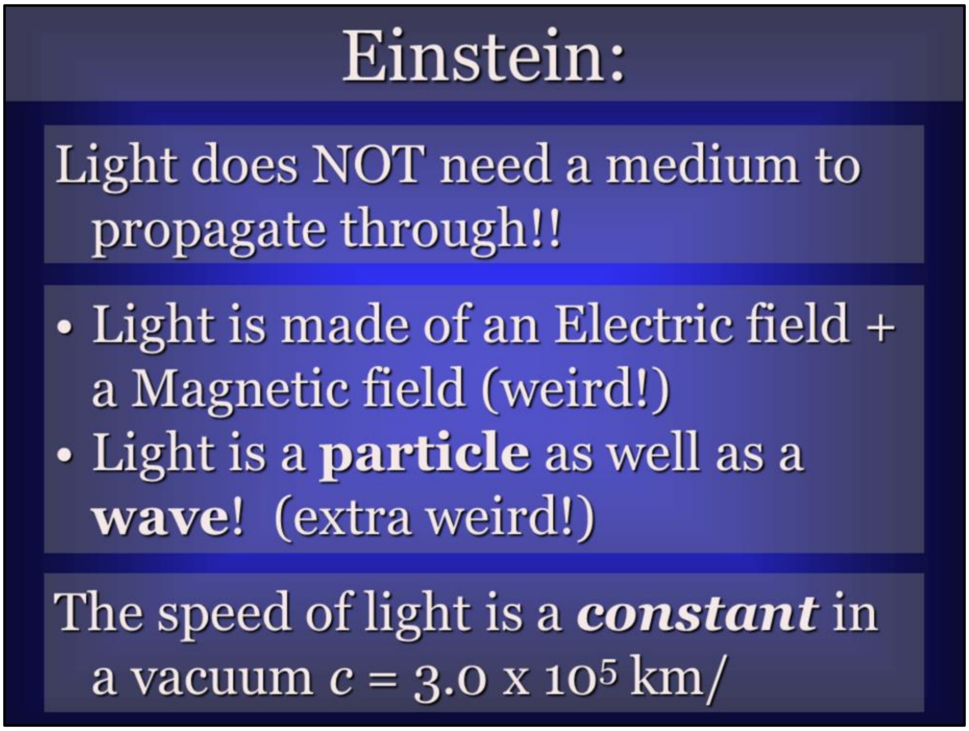
A *wave* (Electromagnetic radiation)

A *particle* (photon)

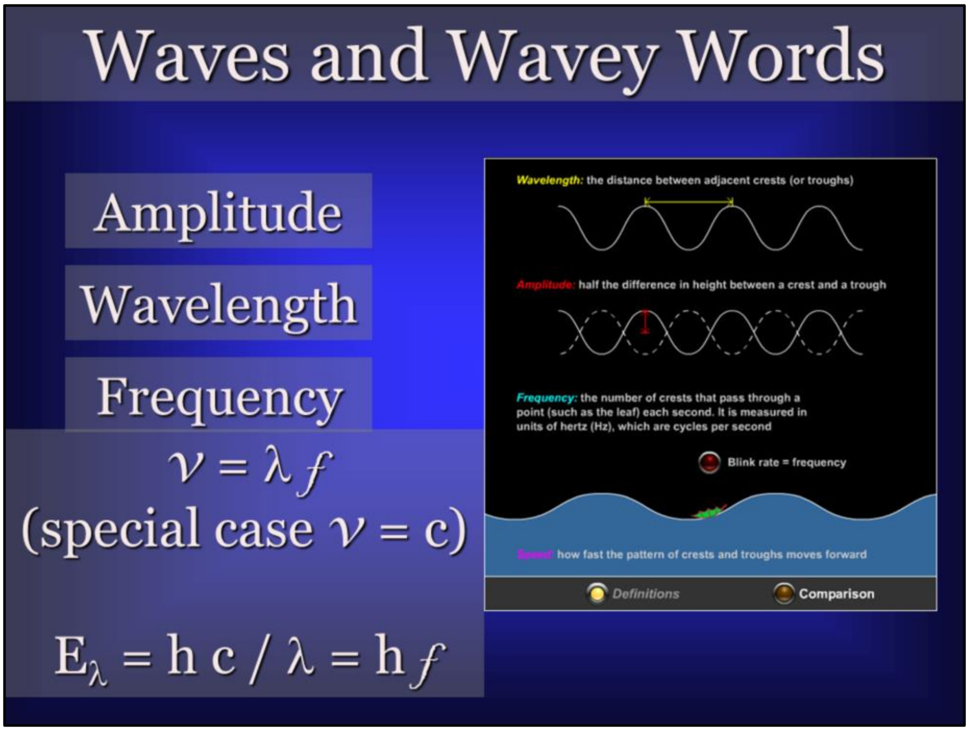
A form of **energy**



The velocity of propagation of the wave depends on MY velocity through the medium (called Ether for light). Except that Michelson and Morley's experiment found there is no difference in the speed of light no matter what direction we're moving. Uh oh....



Why not? Light is a particle as well as a wave! Also, it is a wave made up of an electric and a magnetic field combined, unlike other waves (such as water or sound). Electric and magnetic fields can exist without a medium to be in… so if they wiggle, you will get light!



Because light is a wave, we need to use wavey words to describe it.

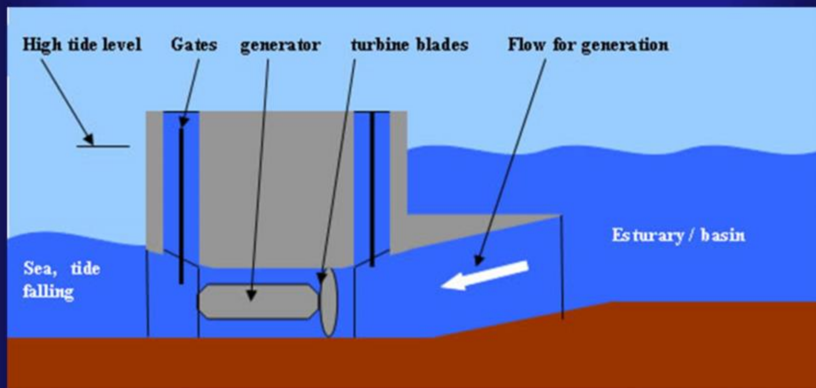
Wavelength: The distance between wave crests.
Frequency: The number of wave crests per second crossing a point.

Frequency and wavelength are related through the velocity:
For light: c = Frequency*Wavelength, where c is the speed of light.

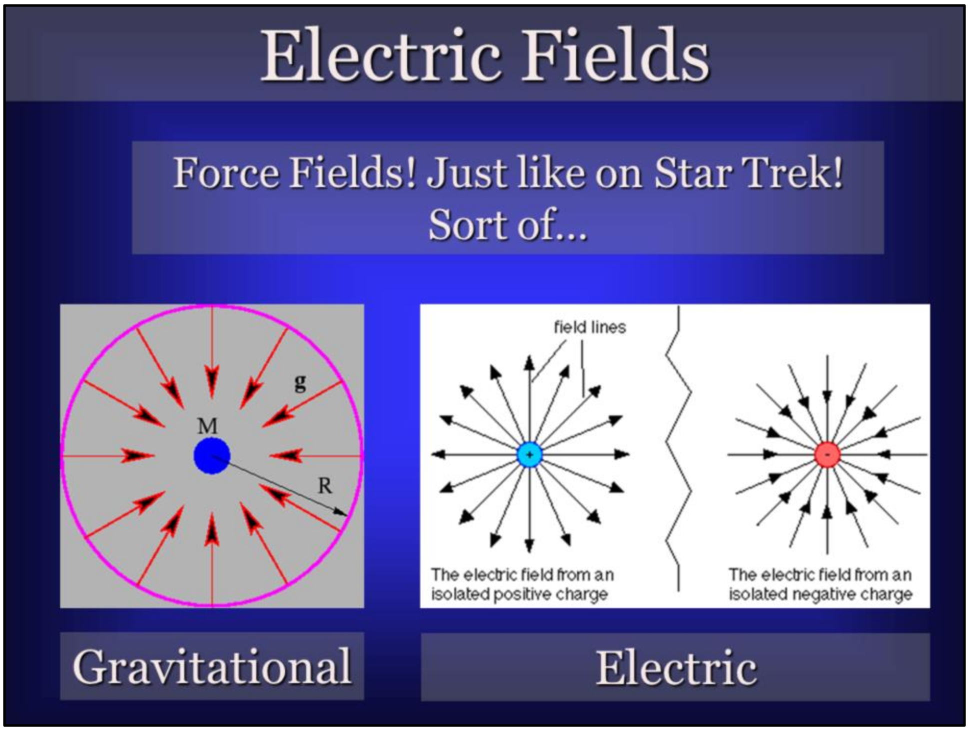
So if I give you the frequency of light, you can calculate the wavelength.
if I give you the wavelength of light, you can calculate the frequency.

What we perceive as color is really our eyes responding differently to different wavelengths (or frequencies) of light.

ALL Waves Carry Energy



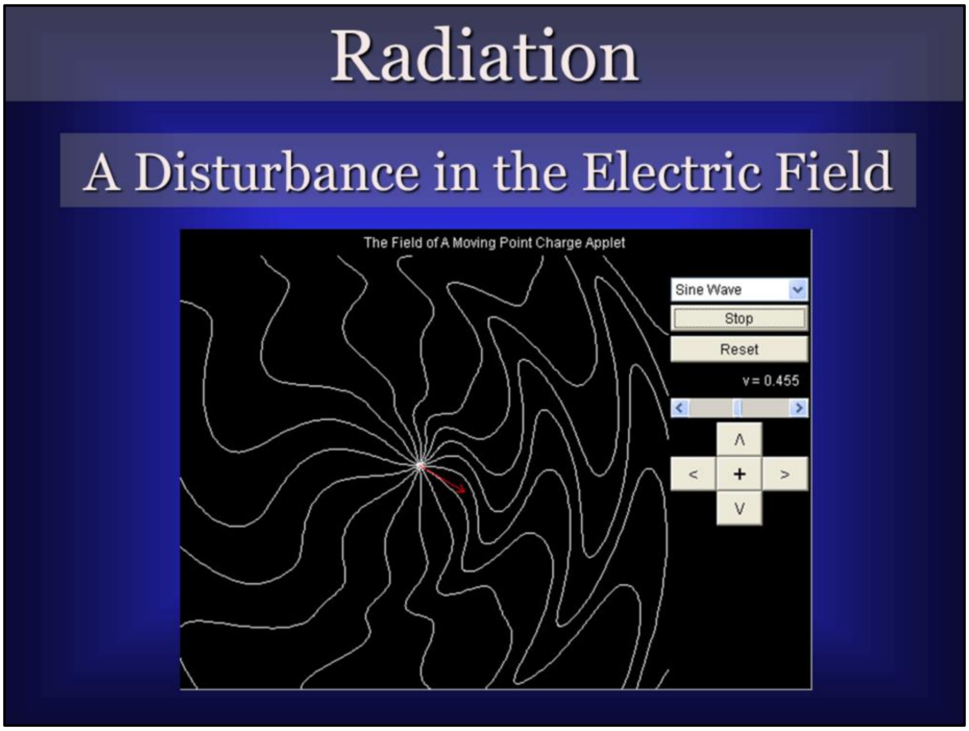
Capturing Tidal Energy



Imagine gravity as “Lines of Force” emanating outward from the center of a massive object.
The Electric force is similar… The “field lines” are also radially directed.

The electric field of a charged particle permeates ALL space.
If another charged particle is placed some distance way, even if it is very very far, they feel each others presence.

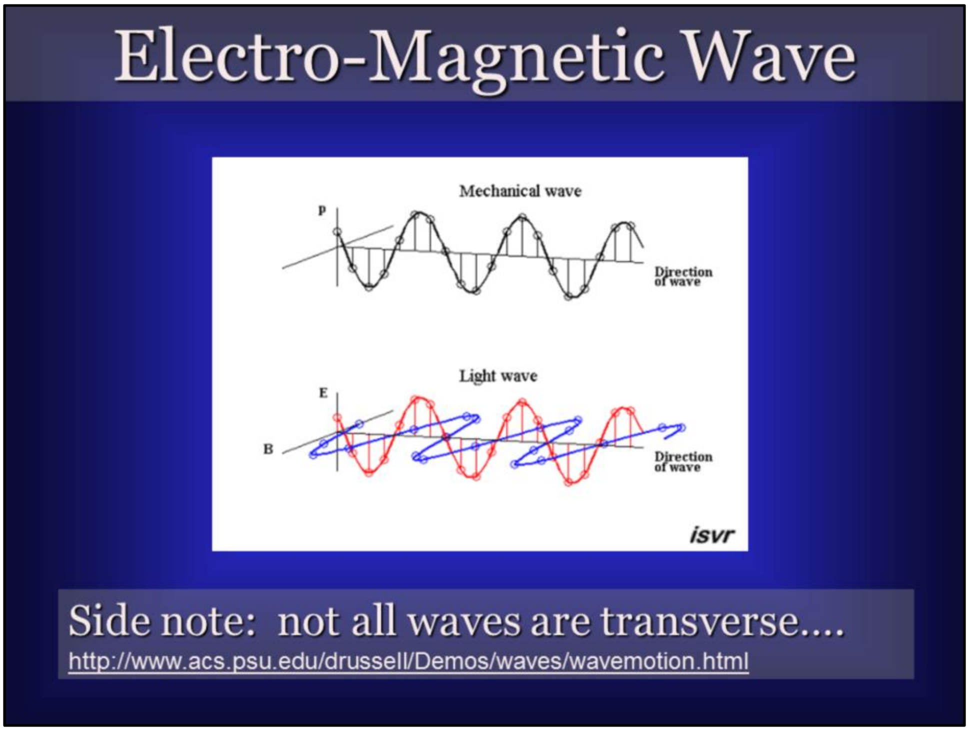
DEMO: vandegraff wand



The electric field of a charged particle permeates ALL space.

If the particle moves, the electric field changes.
This change in the electric field propagates outward from the particle at the speed of light.
Some time later, a distant electron feels this change.

It is this change, the disturbance in the electric field, that we call “light”
This change propagates outward as a wave in the electric field.



What kind of wave is light, then?

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