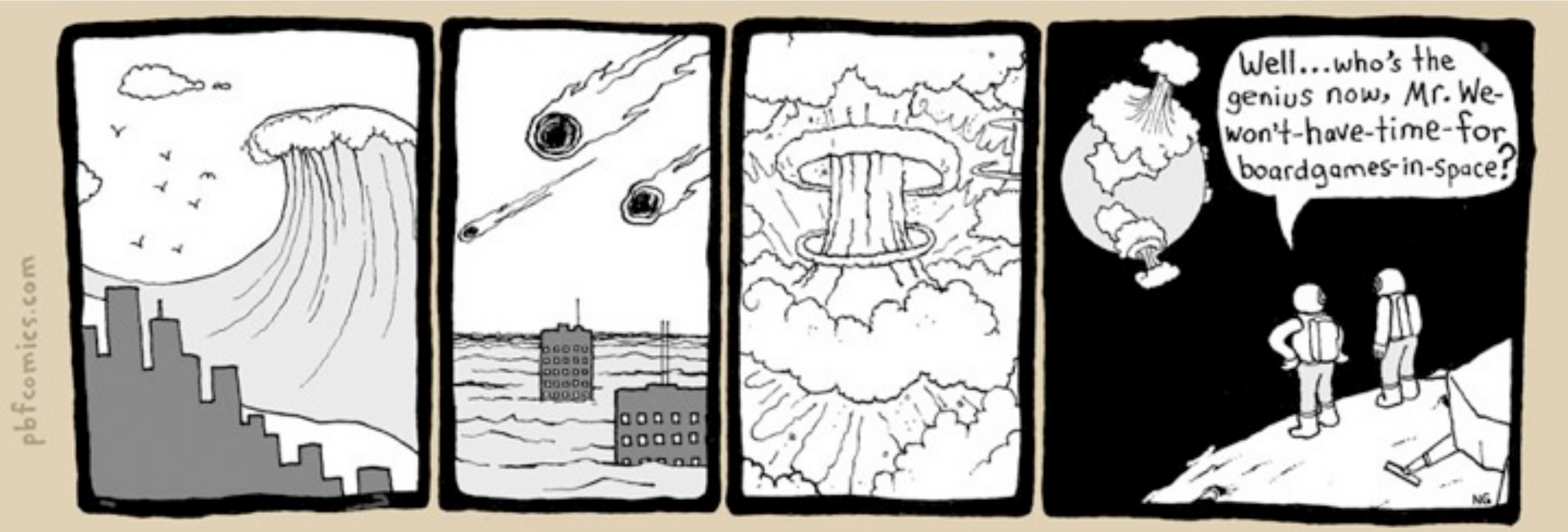
Killer Skies



- **Homework 5** due tonight
- Night Observing continuing
- Solar Computer Lab: decided to not do it
- Last time: Active Sun 2
- Today: Nature of Stars

Music: *We Are All Made of Stars*– Moby

Night Observing

Night Observing probably last week

- if you do it, need to go one night
- allow about 1 hour

When: M, T so far: 8-10pm

3 observing stations:

- Large telescope in observatory dome
- 2 outdoor telescopes
- Night sky constellation tour

Subscribe to Night Observing Status Blog

http://illinois.edu/blog/view/413

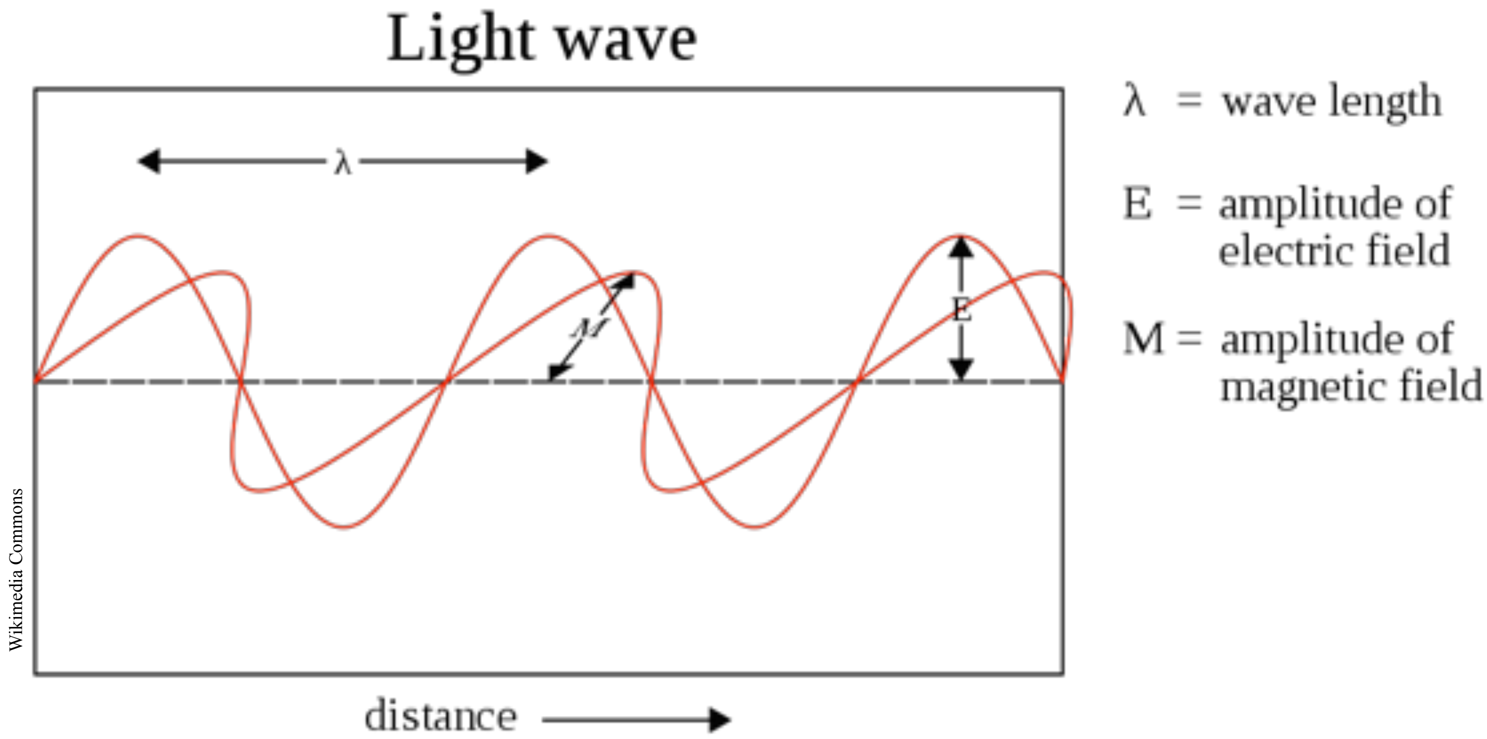
Get weather cancellation updates

Assignment details on class website

Read rubric before you go!

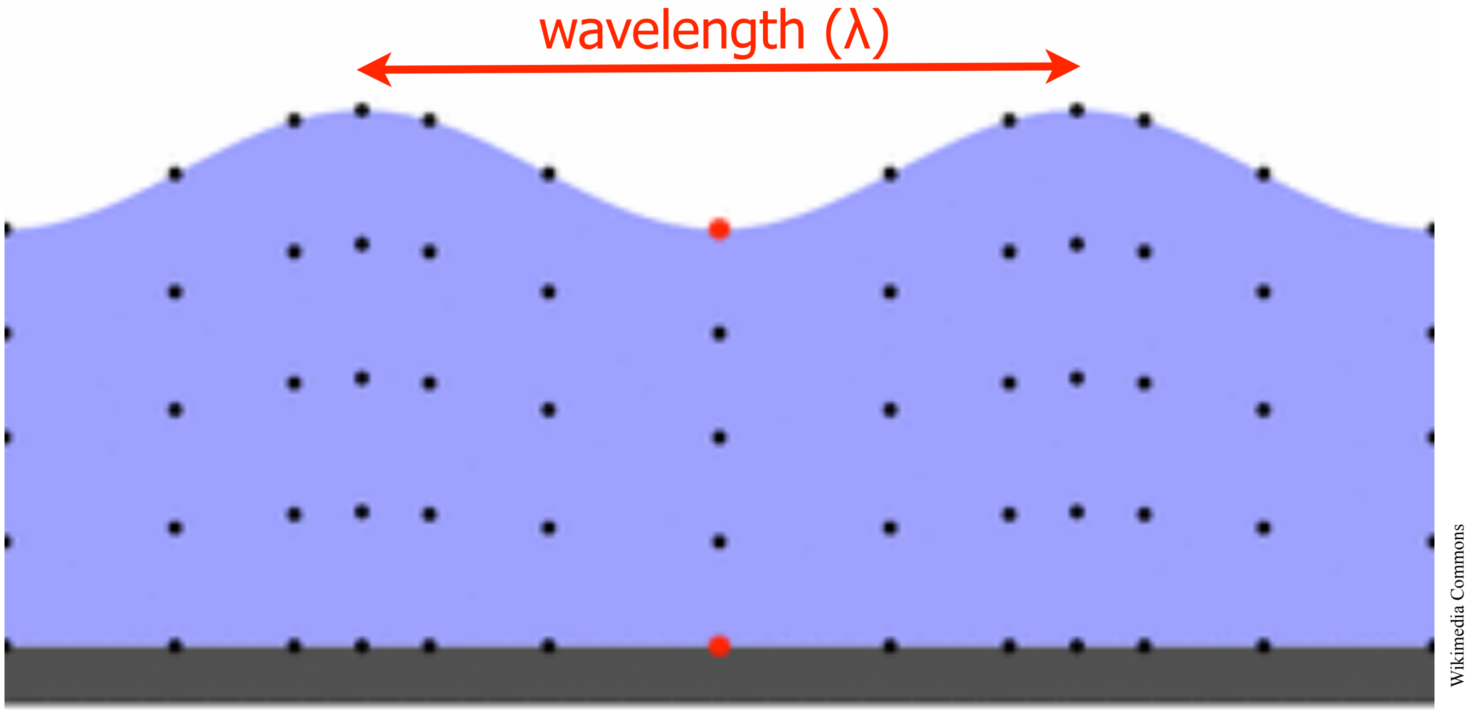
- Complete report due on or before Nov. 8th

Light is an *electromagnetic wave*



A light wave is a vibration of electric and magnetic fields

Measuring a wave



- **Wavelength** (λ): the distance between successive peaks of a wave
- **Frequency** (ν): the number of wave peaks that pass by an observer per second

Waves in what?

- Most waves need a medium to travel through
- Sound waves can't travel in the vacuum of space
- But, light waves **can** travel through empty space!
- Light is a wave of **radiant energy**

http://astro.unl.edu/classaction/questions/renaissance/ca_renaissance_newtonslaws.html

In space, no one can hear you scream

The Speed of Light

Light is very fast! So fast that it was a feat to measure the speed in lab now known quite well

$$\begin{aligned} c &= \text{constant} \\ &= 299,892,458 \text{ meters/sec} = 300,000 \text{ km/sec} \\ &= 670 \text{ million mph} \end{aligned}$$

enormous–but not infinite!

→ finite speed of light hugely important for astronomy

→ telescopes are time machines Q: how?

note: light speed c is same for all λ

Q: what would happen if this were not true?

Speed of light

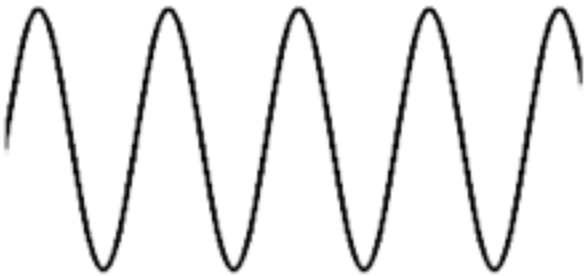
- The speed of light, **c**, is constant in space
- **c = 300,000 km/s**
- How fast is that?
  - Earth to the Moon in 1.25 second (Astronauts took 4 days)
  - Sun to the Earth in about 8 minutes
  - Sun to Pluto in about 5 hours
  - Closest star to Earth in about 4 years

Wikimedia Commons

Light travels from the Earth to the Moon in 1.25 seconds

Thought Question

Which of the following has the **longest wavelength**?

(A)


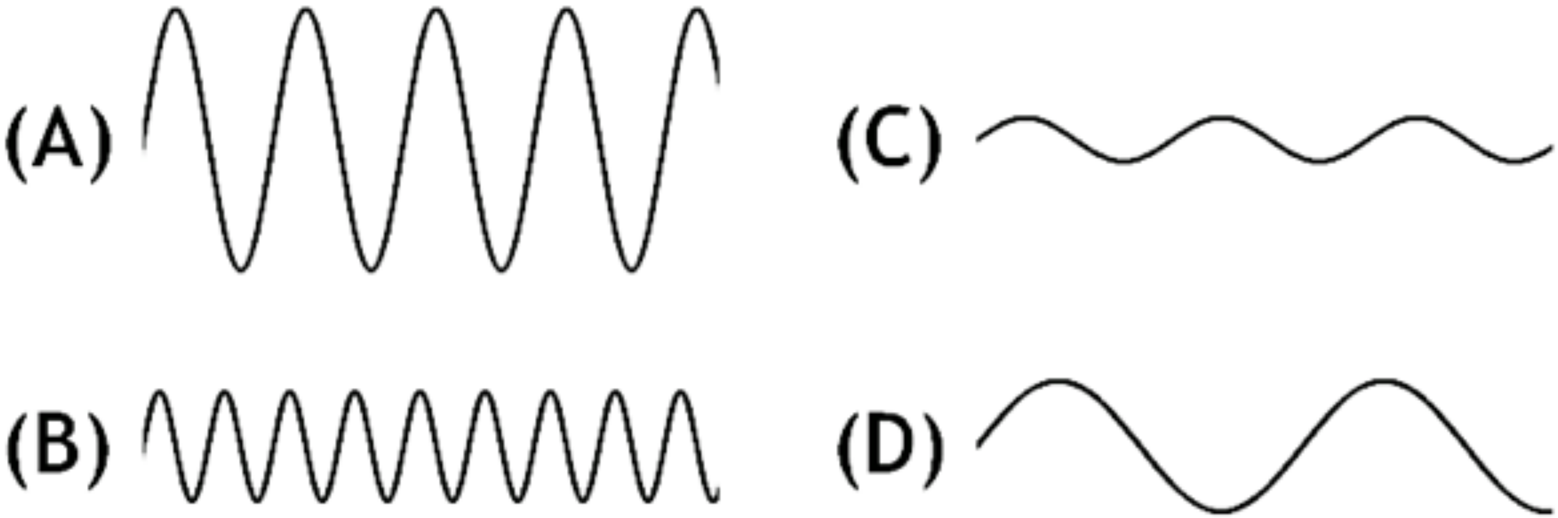
(C)


(B)

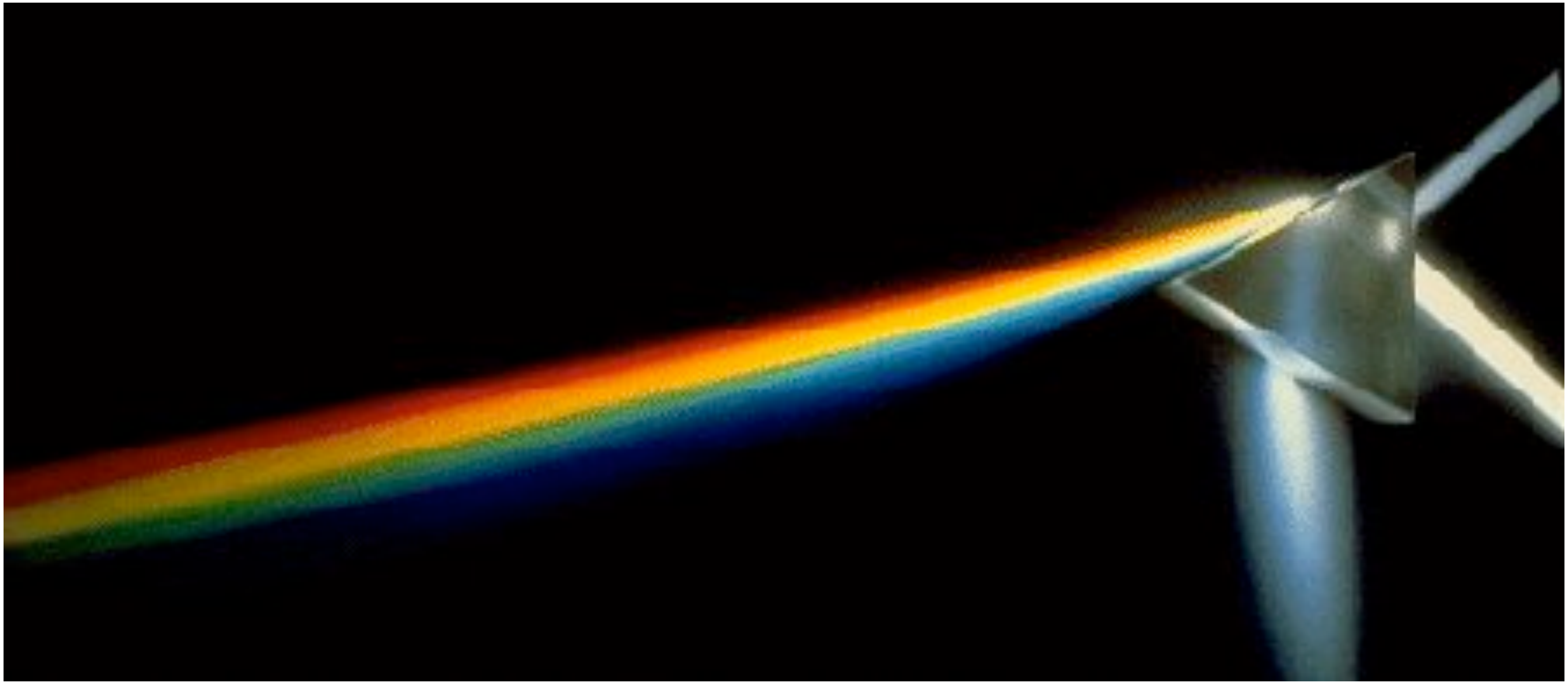

(D)


Thought Question

Assuming that each wave is moving with the same speed, which of the following has the **highest frequency**?



Where Do Colors Come From?

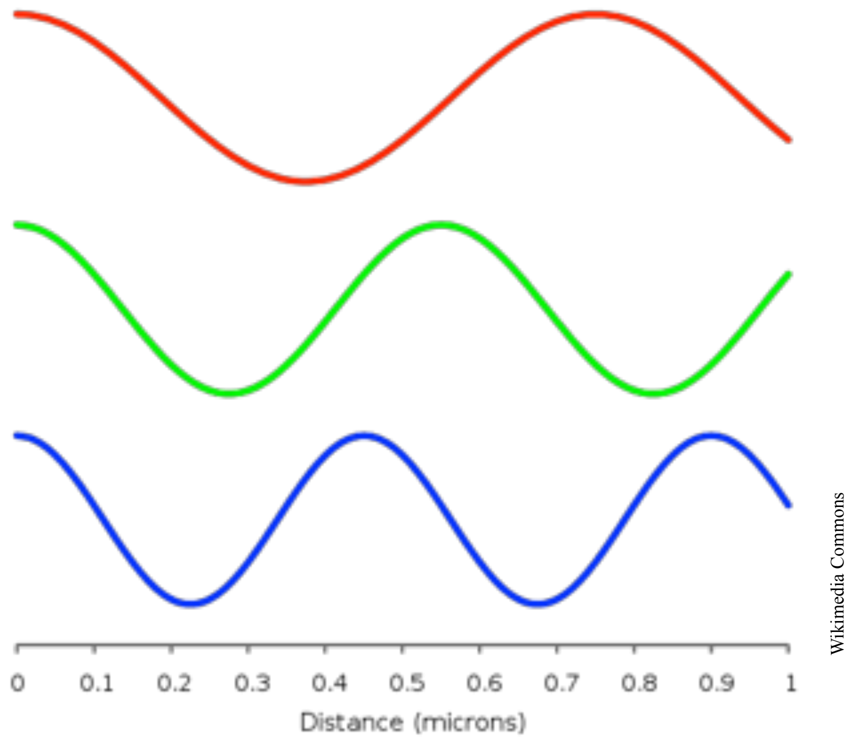


Wikimedia Commons

White light is composed of all the colors of the rainbow

The colors of visible light have different wavelengths

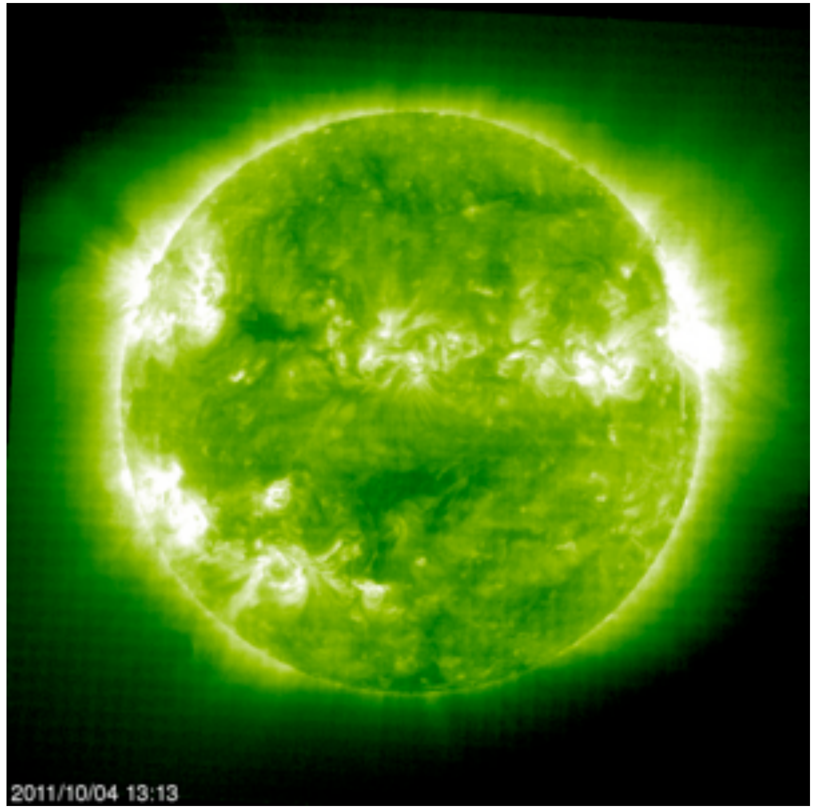
- Colors, from longest wavelength to shortest: **red**, **orange**, **yellow**, **green**, **blue**, **violet**
- Average wavelength of light = 0.0005 mm
- 50 light waves would fit end-to-end across the **thickness** of a sheet of paper



Relative wavelengths of red, green, and blue light. Wavelength scale in microns (10^{-6} m)

Invisible Forms of Light

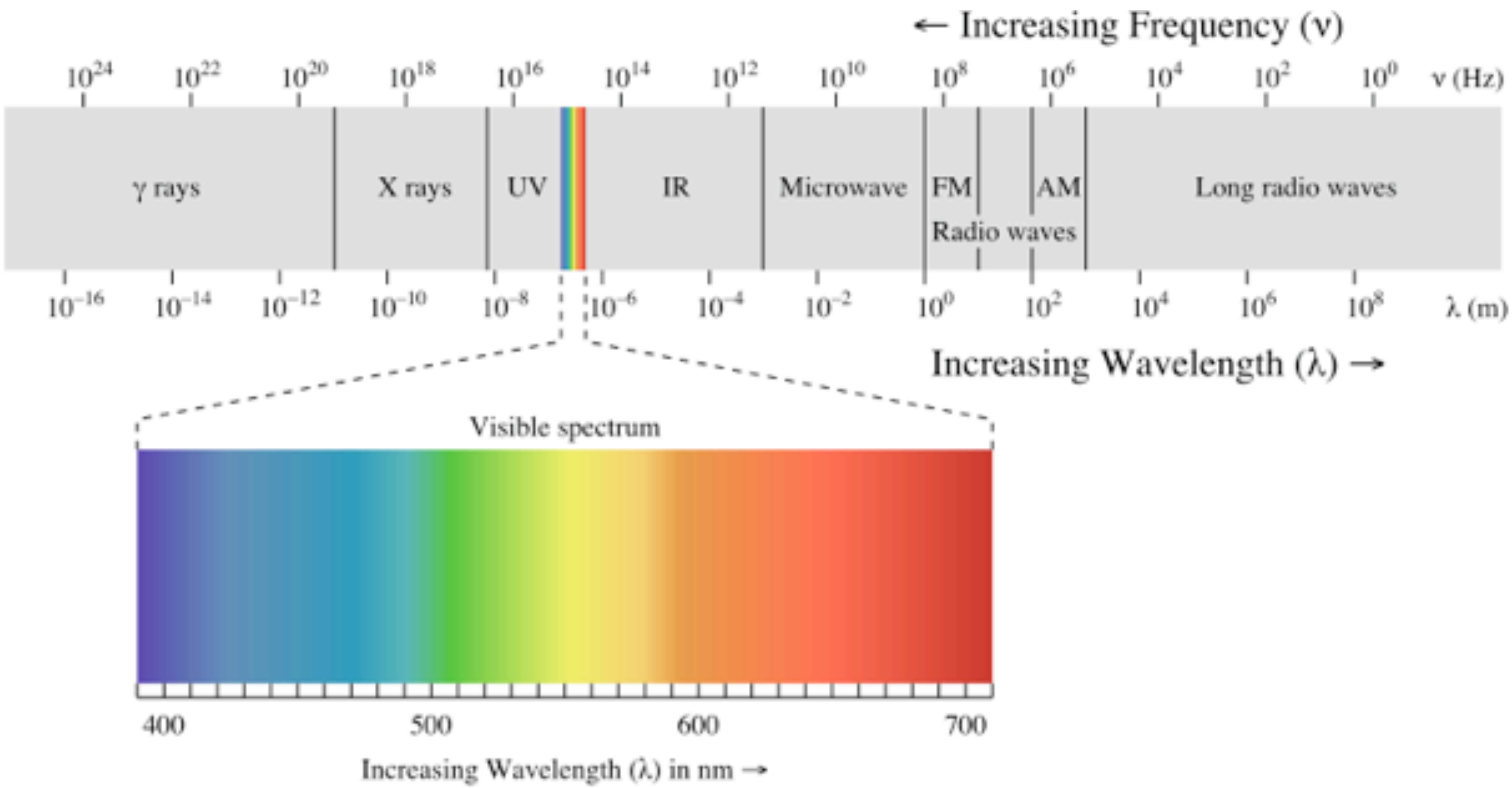
- Visible light has a range of wavelengths from 400-700 nm
- But what about light with longer or shorter wavelengths?
  - Longer wavelengths: infrared, microwaves, radio waves
  - Shorter wavelengths: ultraviolet, x-rays, gamma rays



NASA/ESA

The Sun observed in ultraviolet light

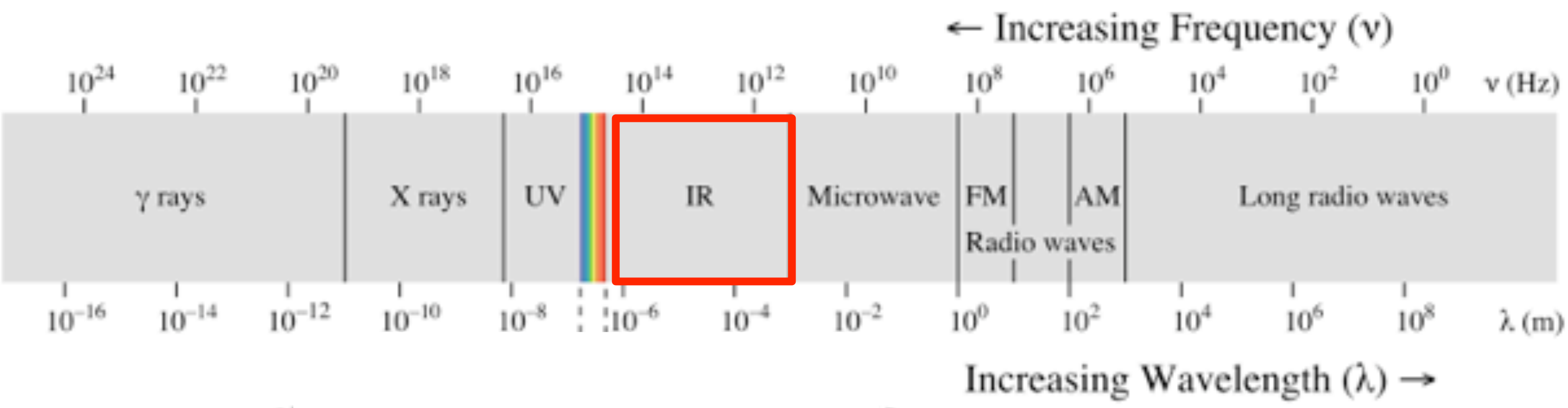
Visible light is only a small part of the *electromagnetic spectrum*



Wikimedia Commons

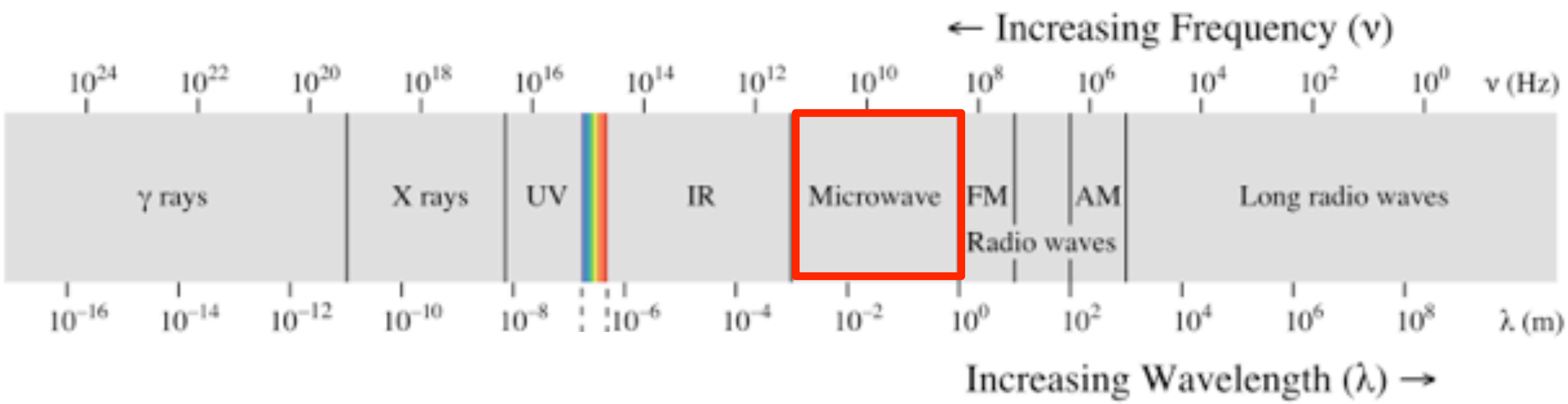
The electromagnetic spectrum with the visible light range highlighted

Electromagnetic Spectrum - Infrared

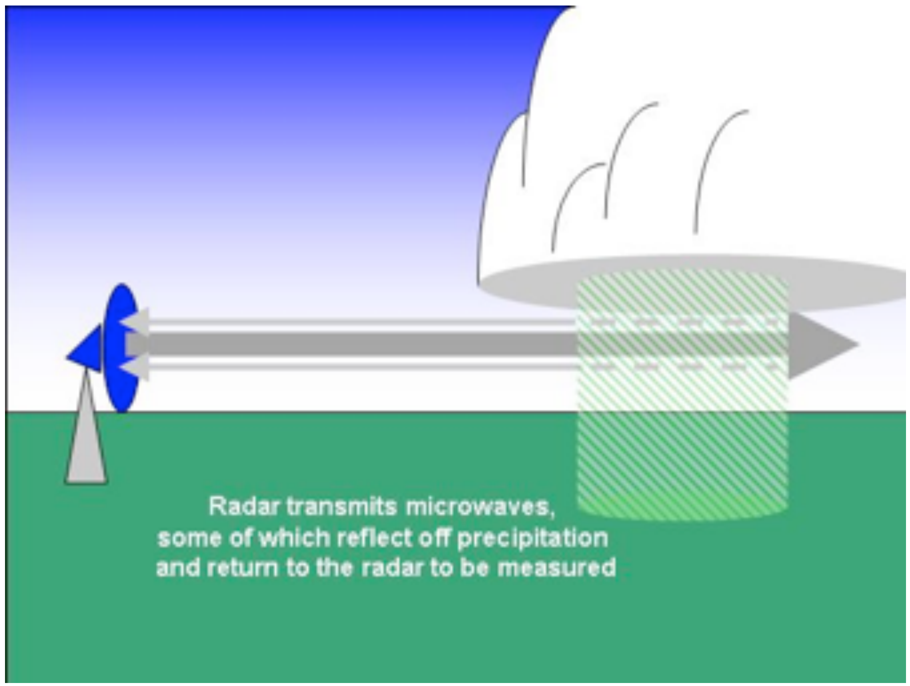


Our bodies emit infrared light

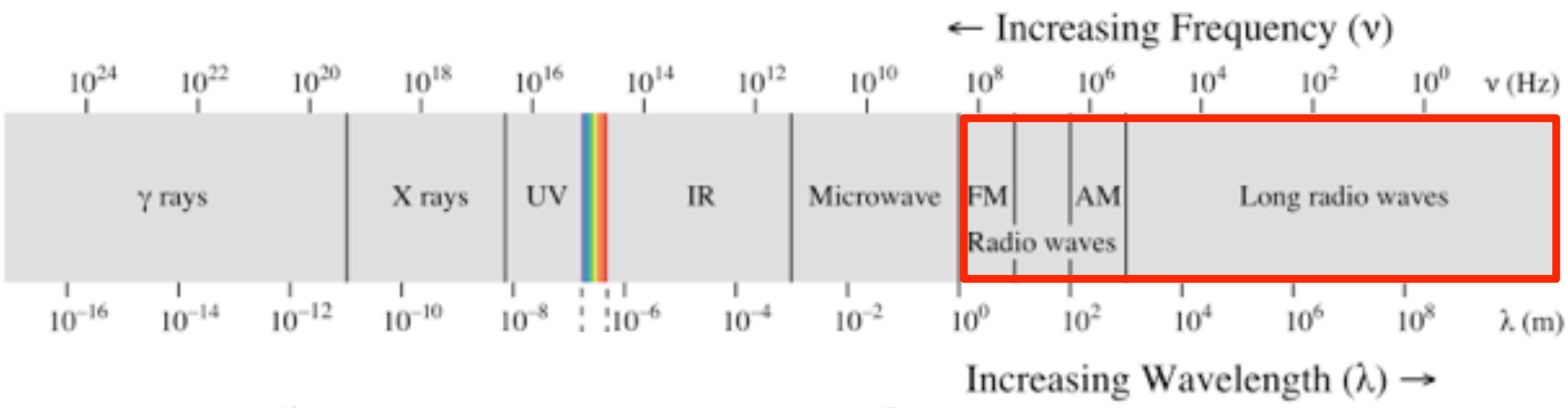
Electromagnetic Spectrum - Microwaves



Precipitation maps are produced using microwave radar

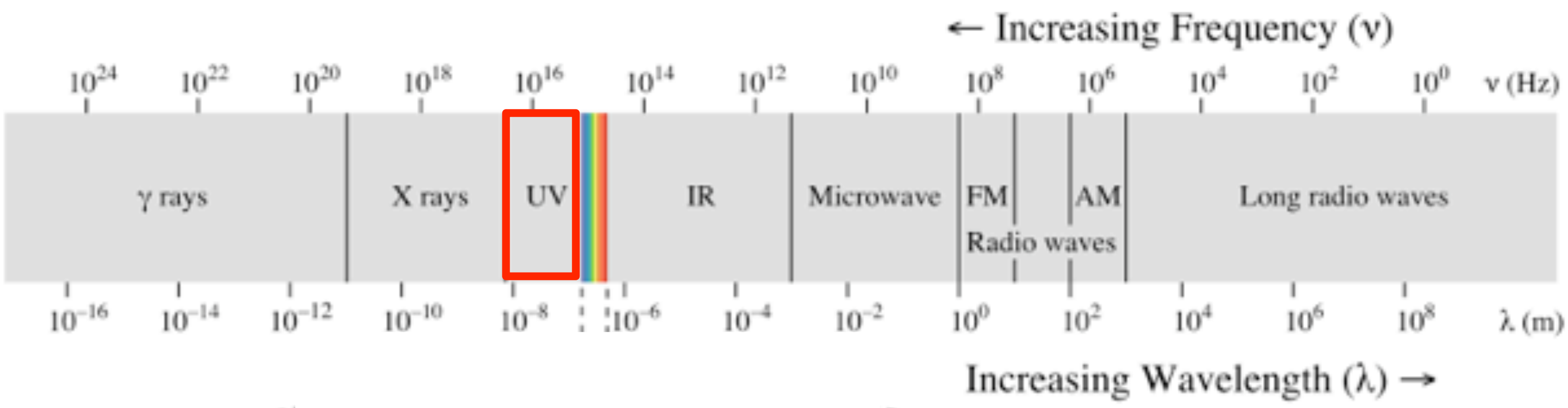


Electromagnetic Spectrum - Radio



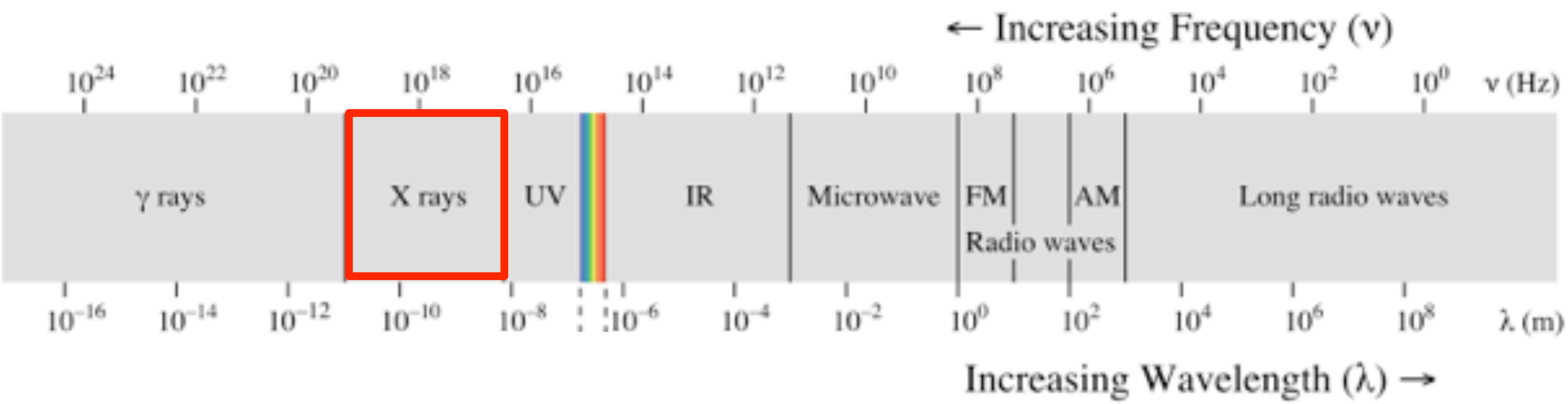
Your laptop's or iPhone's Wi-Fi works using radio waves

Electromagnetic Spectrum - Ultraviolet

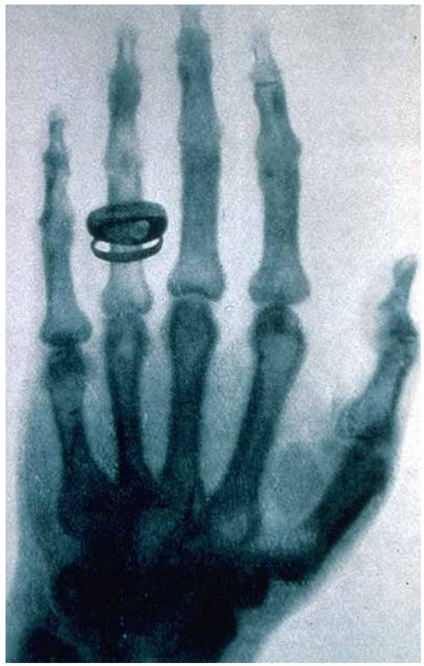


UV rays from the Sun can cause our skin to burn

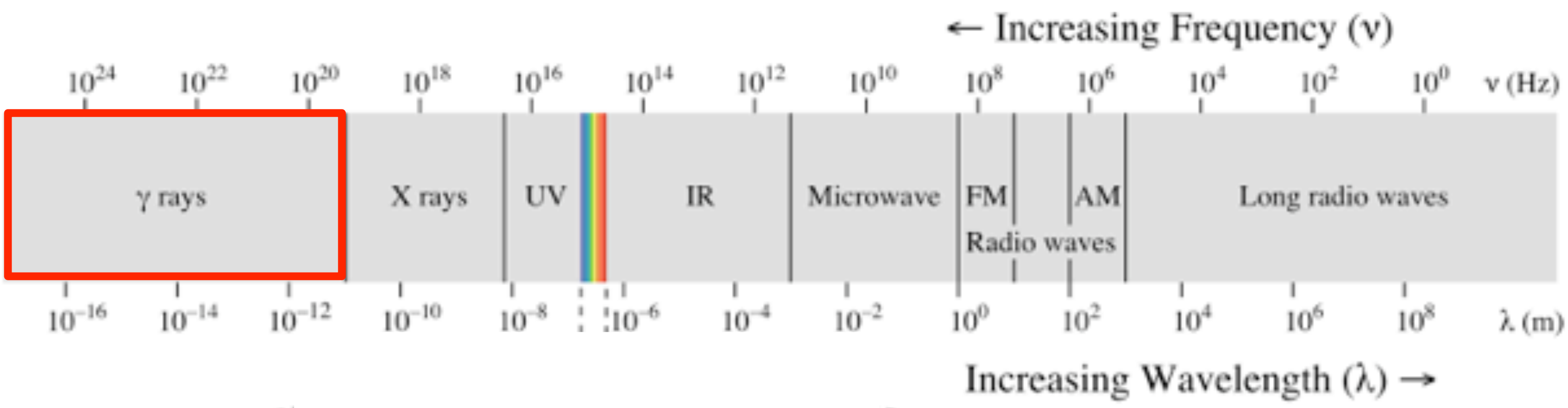
Electromagnetic Spectrum - X-rays



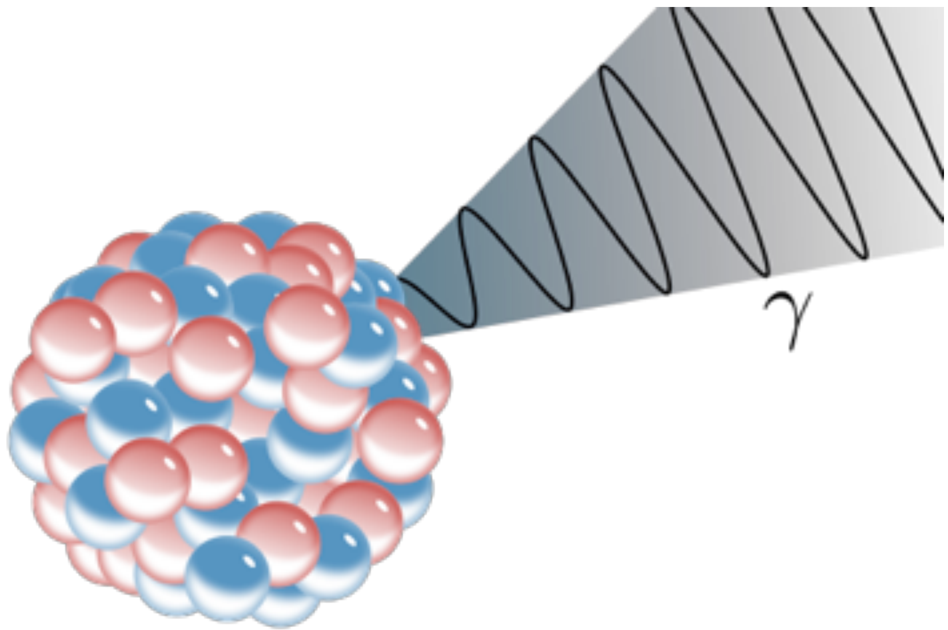
Doctors use x-rays to examine your bones



Electromagnetic Spectrum - Gamma-rays



Gamma-ray are generated by sub-atomic particle interactions



Thought Question

Which of the following bands of the electromagnetic spectrum has photons that travel with the **greatest speed**?

A. X-rays
B. Visible light
C. Microwaves
D. They all have the same speed

Glowing Bodies

Everything we know is in fact giving off light– as long as it has a temperature (above absolute zero = 0 K), it is glowing.

The higher the temperature the shorter the wavelength it glows in– compare the person on the right (in the near infrared) and a light bulb (in the visible).

http://www.x20.org/thermal/thermal_weapon_sight_TIWS320.htm

Practical Application of Science Alert!

The human body emits mostly infrared light

Ear thermometers measure the “color” the IR light to find temperature!

Absolute Zero

Recall:

matter made of atoms

atoms always in random motion

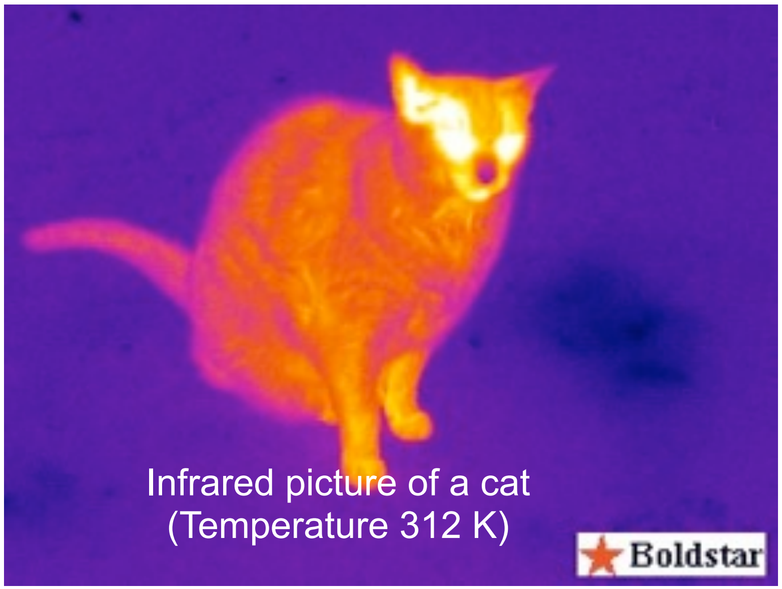
- **faster random speeds: hotter**
- **slower random speeds: coller**

If cool until no random motion:

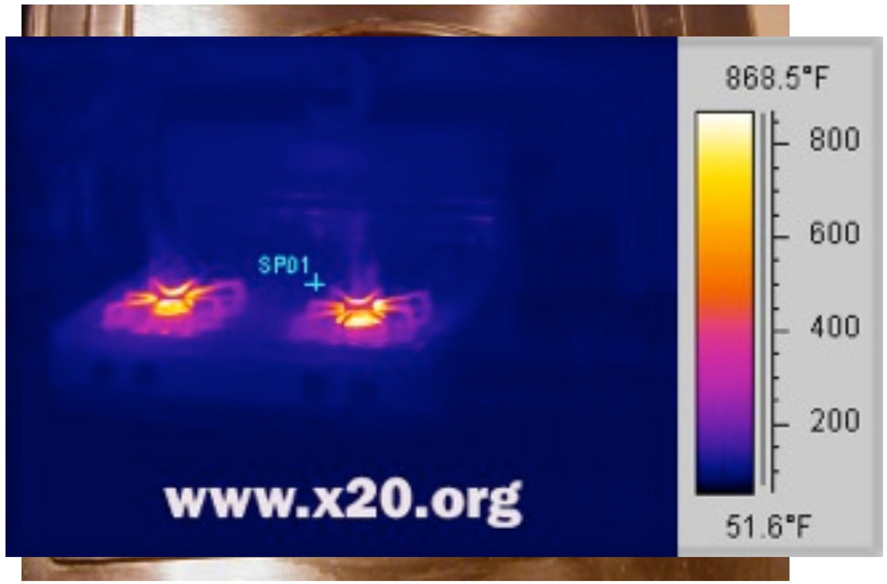
- **can't cool any further**
- **coldest possible temperature**
- **absolute zero**

Thermal Radiation

- Light that objects emit because of their temperature is called thermal radiation
- Thermal radiation is composed of a continuous spectrum of wavelengths
- The hotter an object gets, the more intense and shorter wavelength (blue-er) its thermal radiation becomes

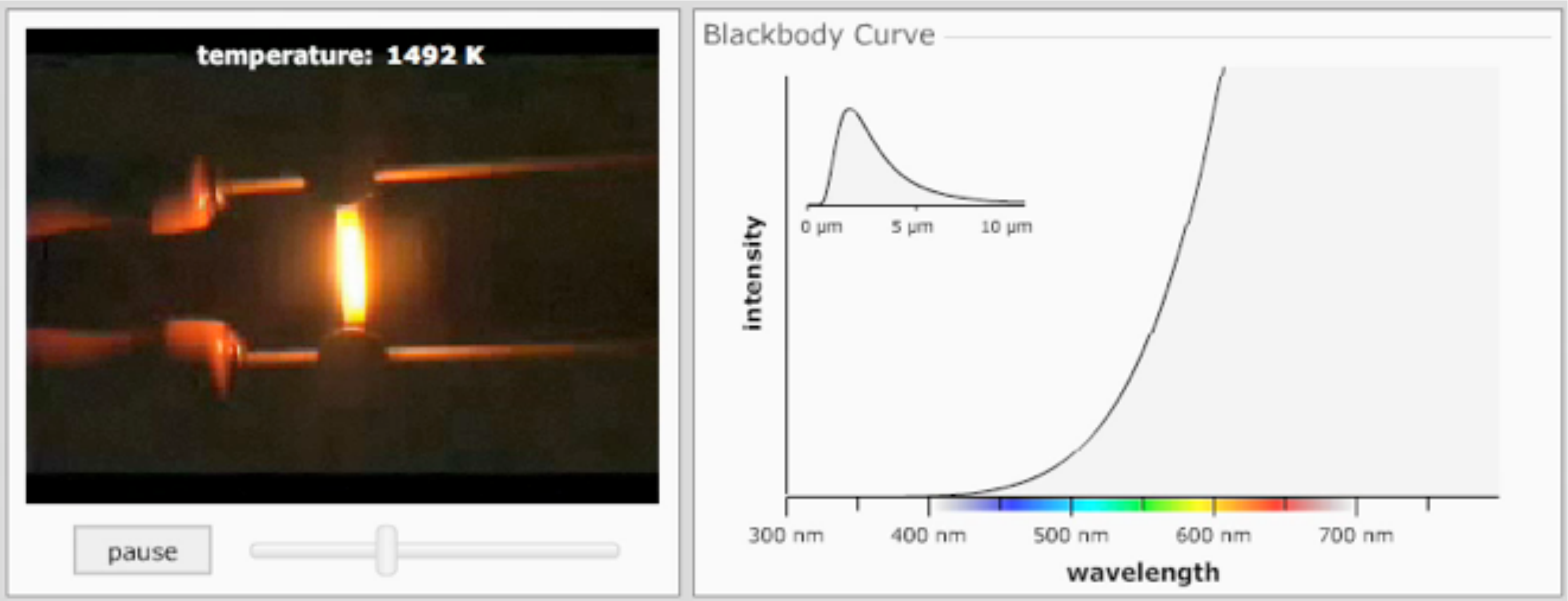


Infrared picture of a cat
(Temperature 312 K)



Visible-light picture of a stove element
(Temperature ~ 400 K)

Thermal Radiation



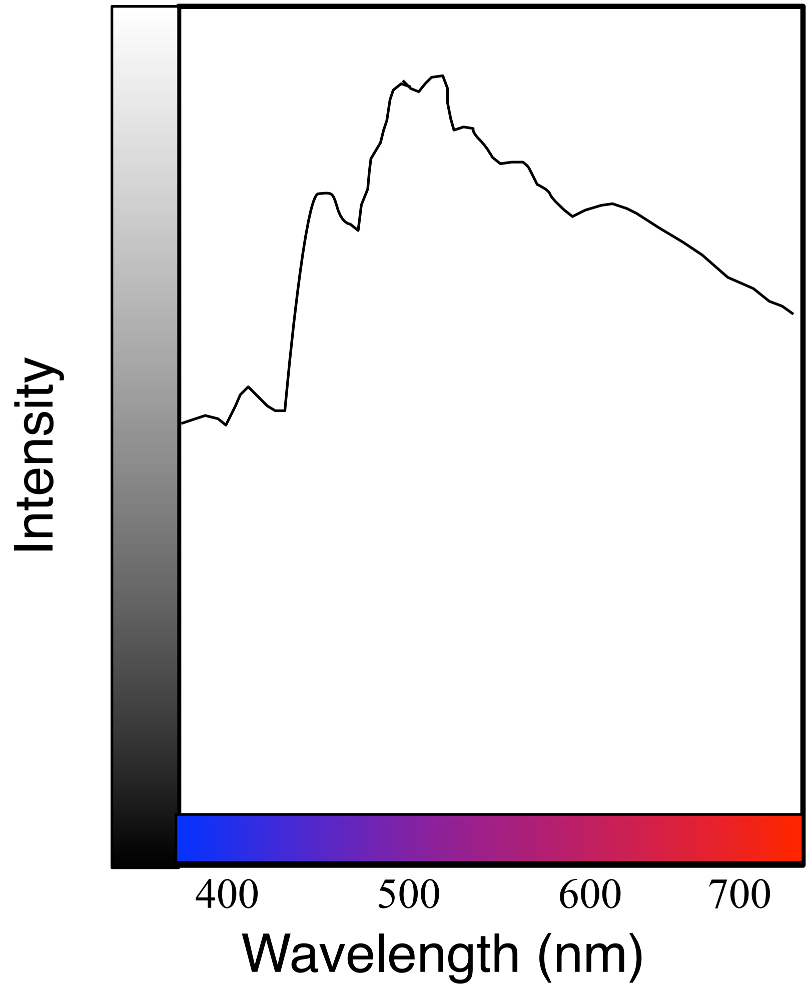
The Nebraska Astronomy Applet Project

- Hot, opaque objects emit **thermal radiation**, including stars, hot metal, you…
- This light has a **spectrum** that depends only on the object's **surface temperature**

What is a spectral curve?

- We represent the composition of the light from an object with a **spectral curve**
- **Wavelength** (or color) of the light on the horizontal axis
- **Intensity** (or energy output per second) on the vertical axis

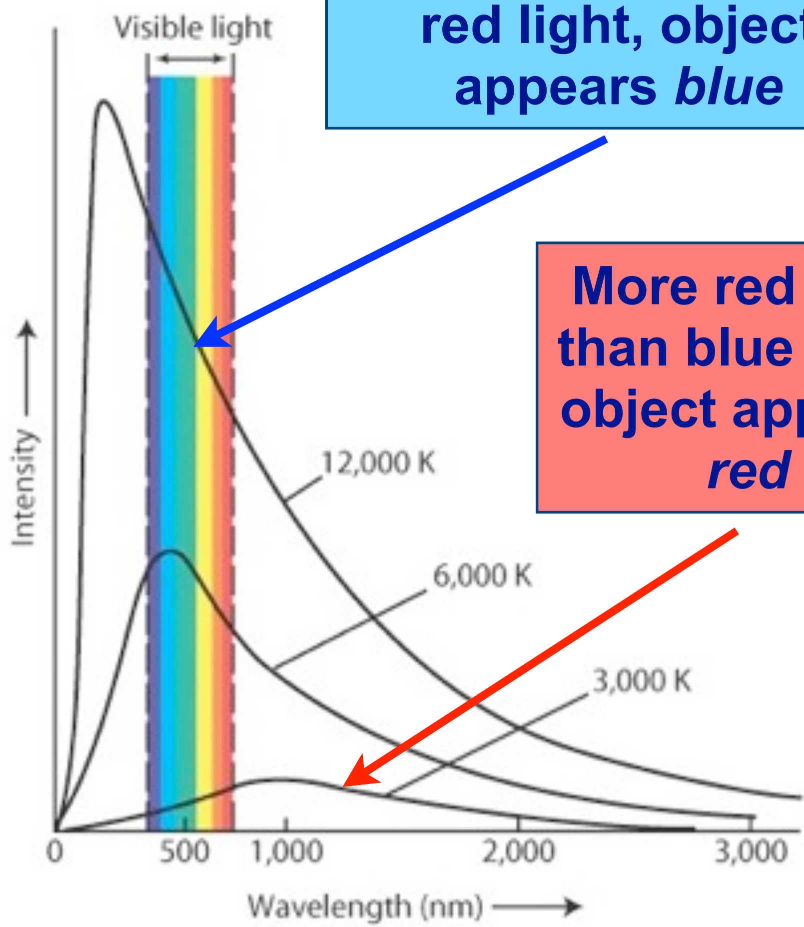
The spectral curve of sunlight



Two Properties of Thermal Radiation

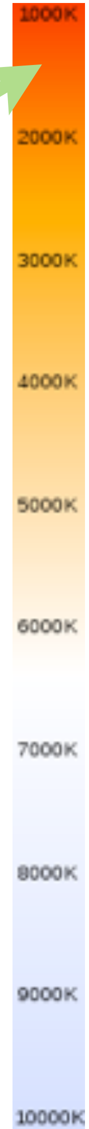
1. Hotter objects emit more light per unit surface area at all wavelengths
2. The hotter an object is, the shorter is the wavelength of its maximum output
3. color reveals temperature!

More blue light than red light, object appears *blue*



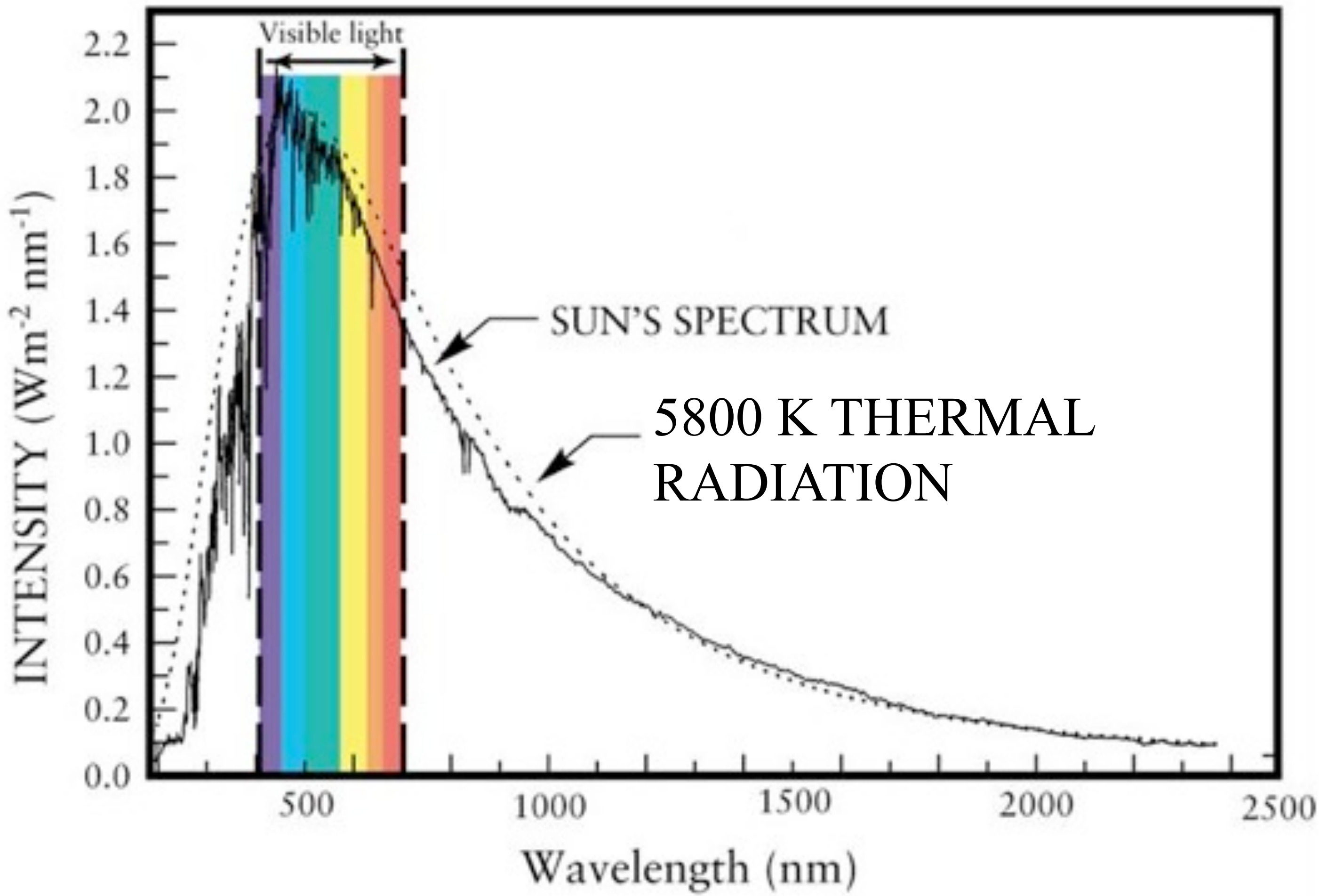
More red light than blue light, object appears *red*

The color of thermal radiation can tell us an object’s temperature!



The temperature of a lava flow can be estimated by observing its color (about 1500 K)

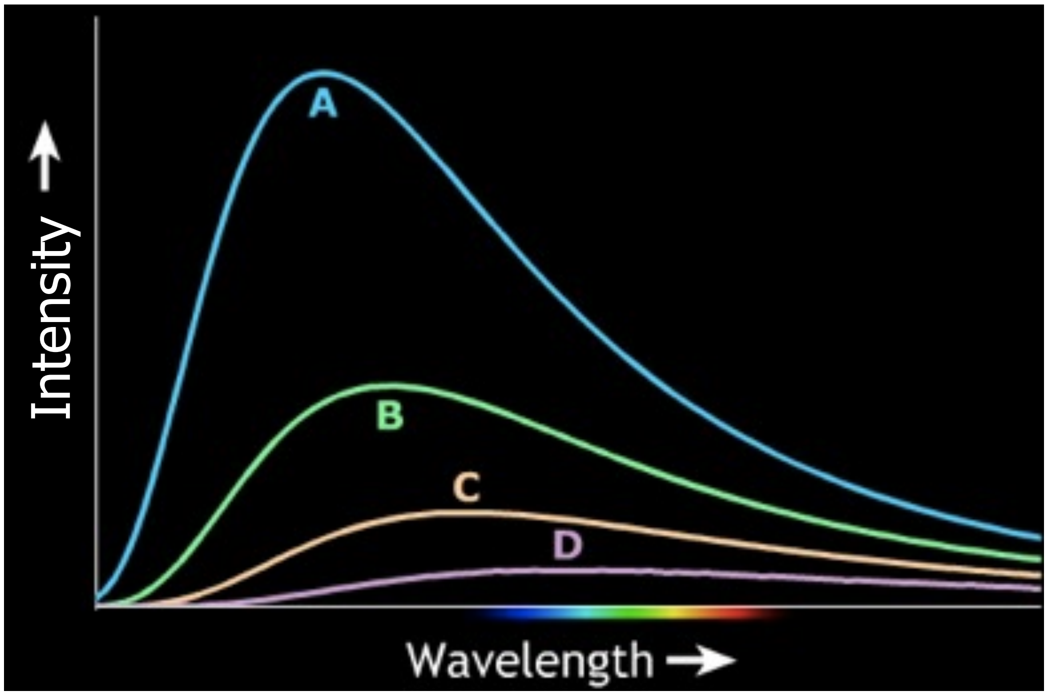
The Sun's Spectral Curve



The Sun's spectral curve reveals its surface temperature to be 5,800 K!

i>clicker question

The graph below shows emission curves for stars at different surface temperatures. Which has the highest surface temperature?



Thought Question

Which star is hotter?

A. Capella (yellow)
B. Vega (blue)
C. Antares (red)

Stars, Jim Kaler

Color me..

White hot Sirius to a red supergiant Betelgeuse

Still Why Different Colors

So, stars have different colors, thus temperatures.

Why different temperatures?

Stay tuned....

What about the brightness of stars?

iClicker Poll: Naked Eye Stars

Vote your conscience!

On a clear night, outside of a city,

about how many stars can you see with the naked eye?

A. More than the number of people in a packed movie theater
B. More than the number of people at sold-out Memorial stadium
C. More than the population of Illinois
D. More than the population of the Earth

Star Light, Star Bright

to naked eye, in clear sky: about 6000 (!) stars visible over celestial sphere

- about 3000 at any one night
- Memorial Stadium capacity: 60,000 people = 10 x visible stars!
- ...but this is just the "tip of the iceberg"

Memorial Stadium: More Illini fans than visible night sky stars

many many more stars exist but unseen by naked eye

stars appear to have different brightnesses

- brightest (other than Sun): Sirius – "dog star"

iClicker Poll: Star Brightness

Vote your conscience!

Stars observable by the naked eye appear to have a wide range of brightnesses

Why?

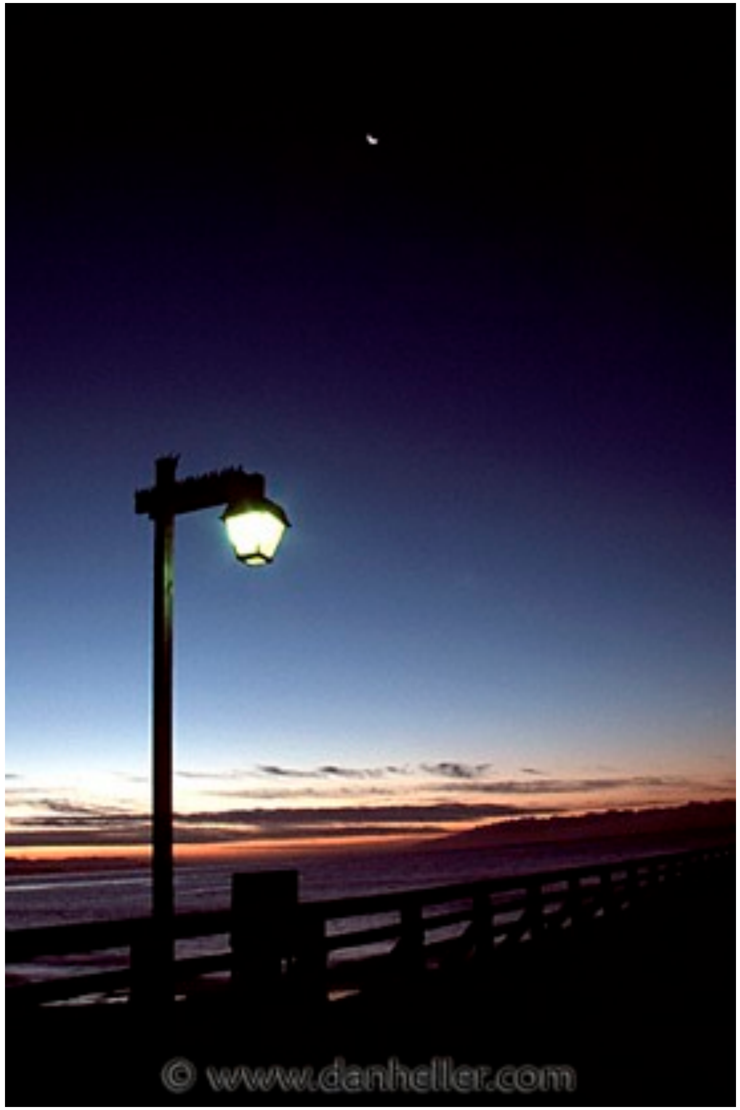
A. they emit similar amounts of light (similar luminosities L), but are at different distances
B. they emit very different amounts of light (different L) but are at similar distances
C. they emit very different amounts of light (different L) and are also at very different distances

Which is Brighter?

a) Moon
b) Streetlamp

Why?

"Apparent brightness" vs "Intrinsic brightness".



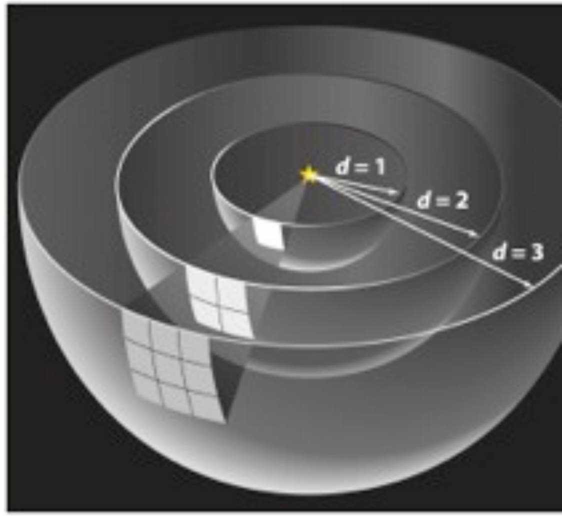
http://www.danheller.com/images/California/CalCoast/SantaCruz/Slideshow/img13.html

Luminosity vs Brightness

Apparent brightness ≠ luminosity!

Luminosity:

- total energy output: “wattage”
- that is, total energy flow in all directions



Apparent brightness

- energy flow that passes through your detector (telescope, eyeball, etc)
- depends on distance away.
- The farther, the dimmer.
- That’s why it’s called apparent brightness.

Intrinsic brightness is measured by <u>luminosity</u>

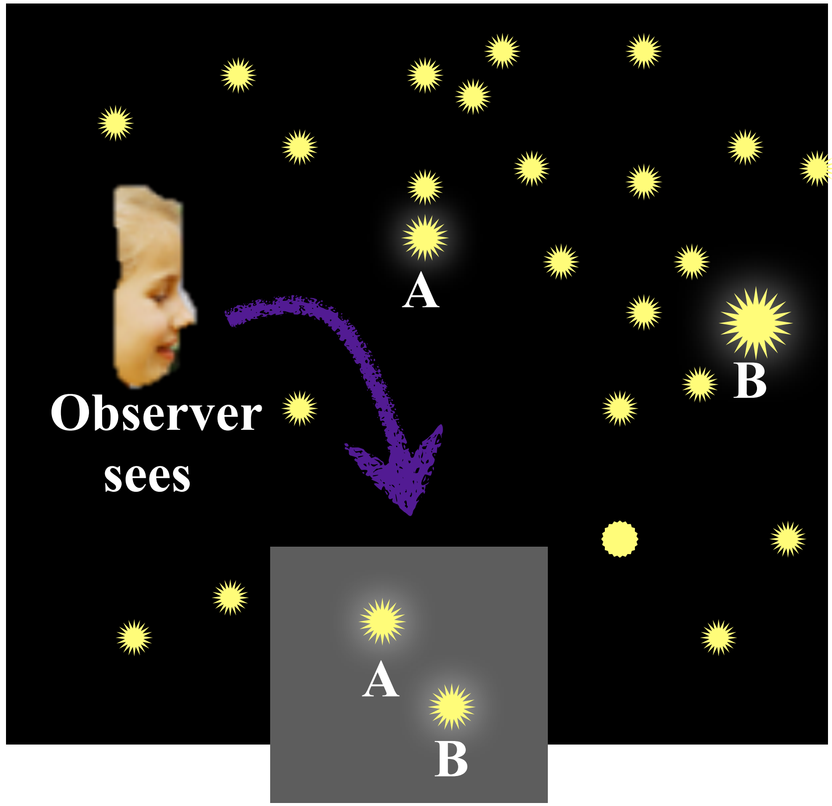
Luminosity measures total light energy output per second

In light bulbs, we measure luminosity in watts

For stars we measure in *solar luminosities*, Sun = 1 L_{Sun}

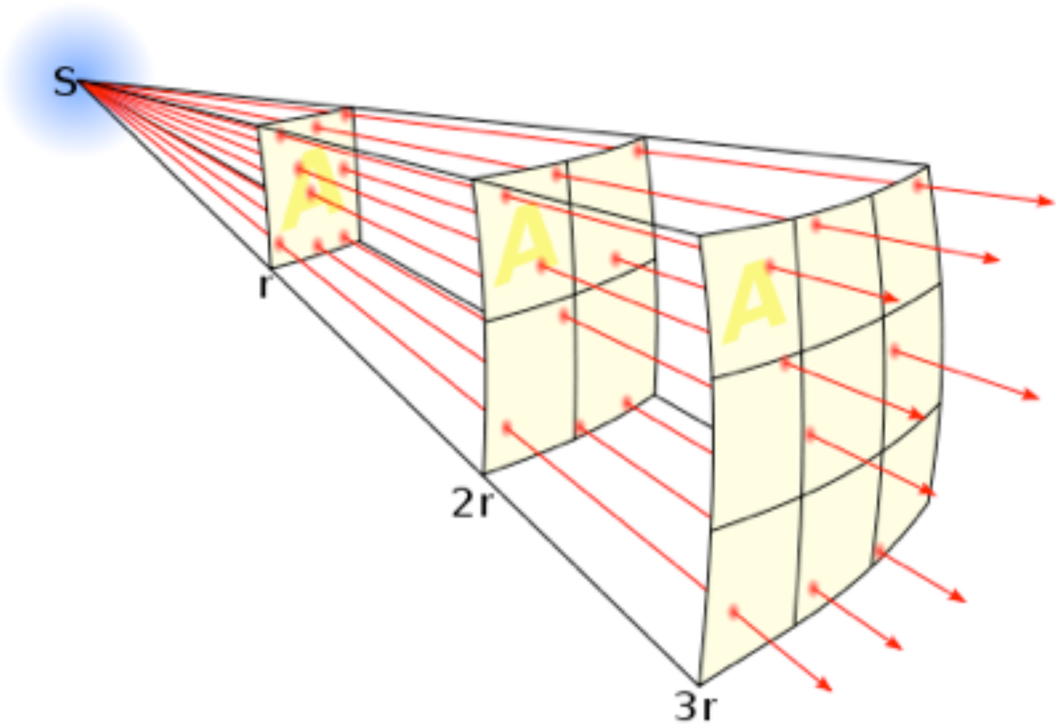
Apparent brightness vs. Intrinsic brightness

- **Apparent brightness**: the brightness of a star as it appears to our eyes
- Depends on:
  - **Intrinsic brightness** of the star
  - **Distance** to the star
- **Intrinsic brightness:** a measure of the total light emitted by a star



Star A and Star B have the same apparent brightness, but different intrinsic brightnesses

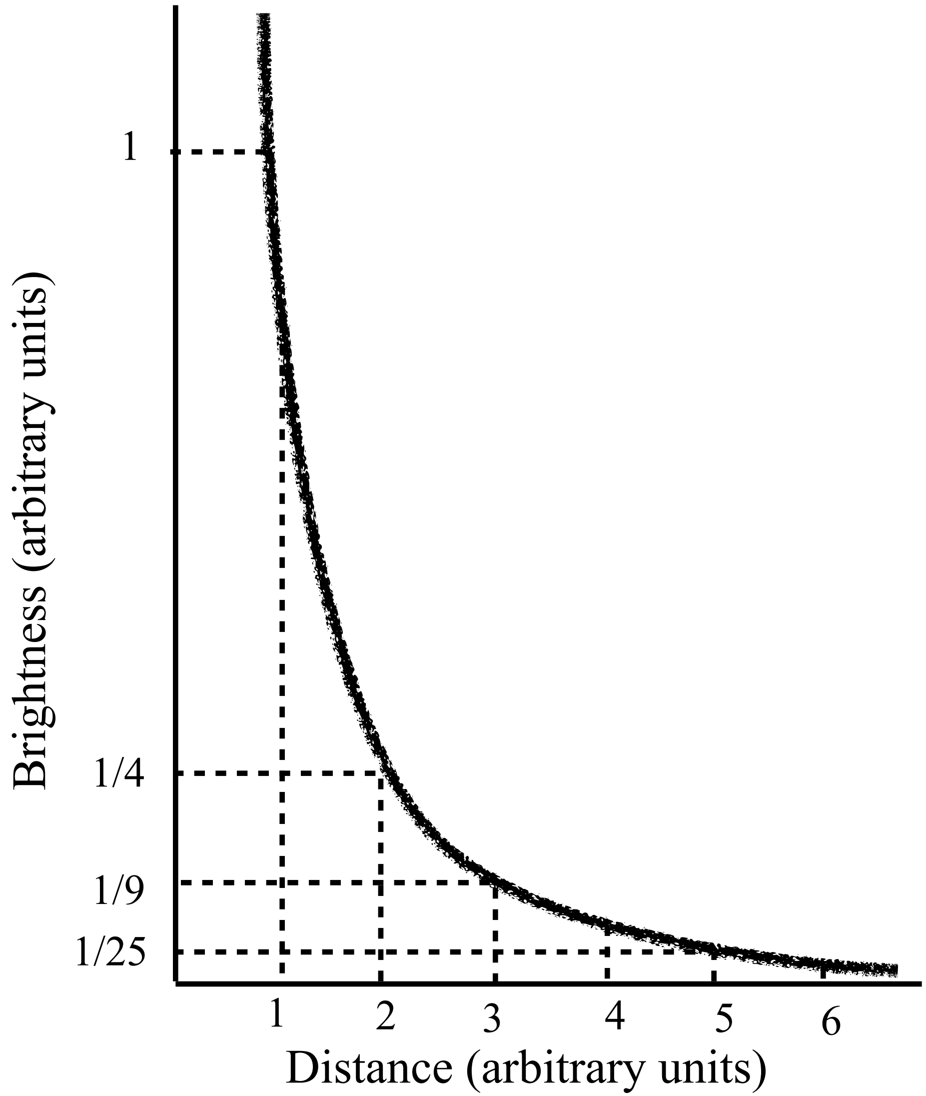
Apparent brightness and distance



The greater distance from the star, its light is spread out over a larger area and its apparent brightness is less

Brightness vs. distance follows the inverse-square law

If the distance between two objects doubles, the apparent brightness drops by a factor of 4!



Thought Question

How would the apparent brightness of Alpha Centauri change if it were three times farther away?

A. It would be only 1/3 as bright
B. It would be only 1/6 as bright
C. It would be only 1/9 as bright
D. It would be three times brighter

So Now We Need the Distance

We know that the stars must be very far away.

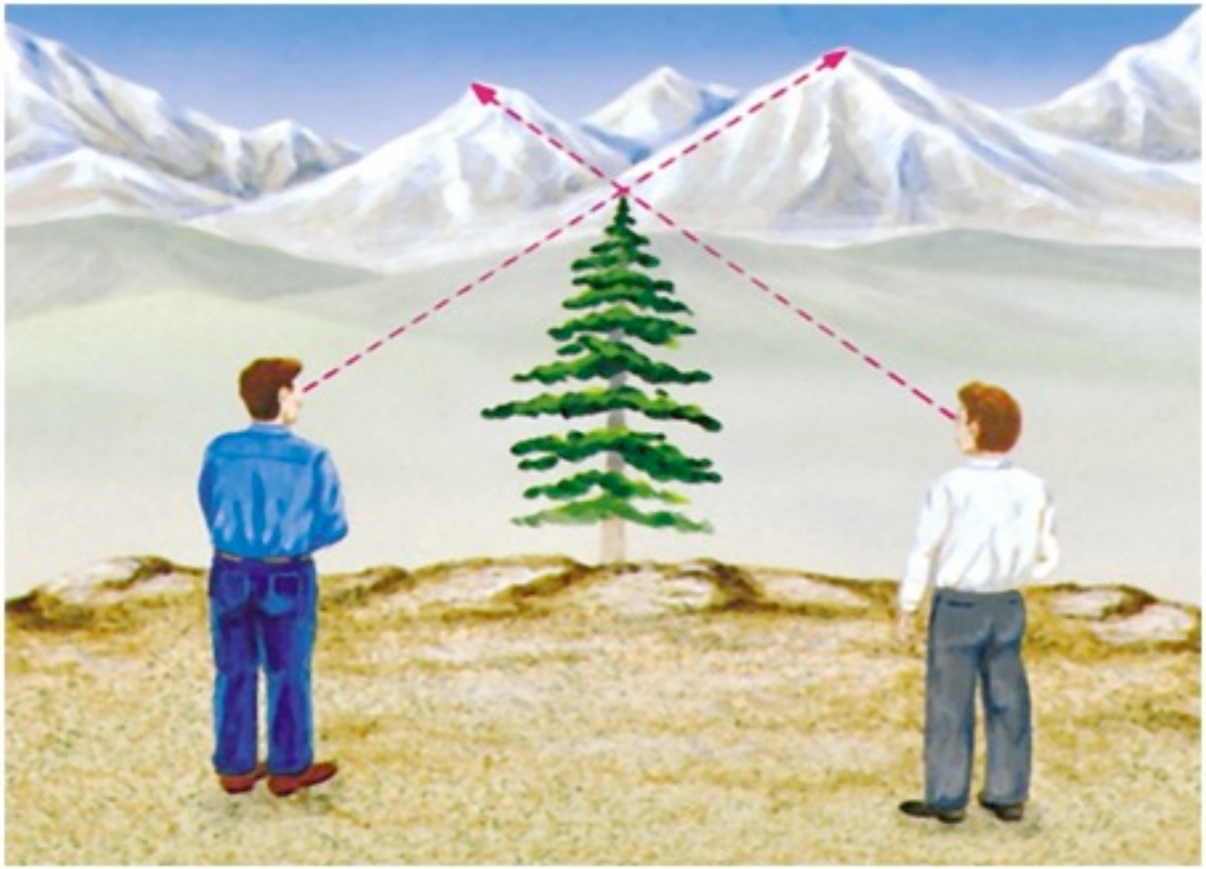
- They don't move much as we orbit the Sun.

But measuring the distance is a hard problem.

We've only had the technology to do it for the last 200 yrs.

Parallax

How do astronomers measures distances to nearby stars?



How to Measure Parallax

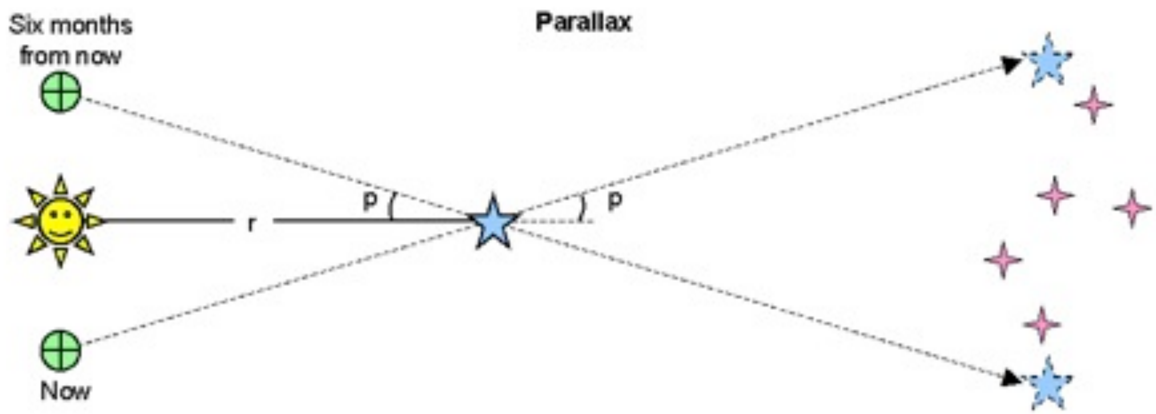
Look at a star compared to background stars.

Wait 6 months and look again.

How much, if any, has the star moved?

The amount moved is called parallax.

Experiment: thumbs-up

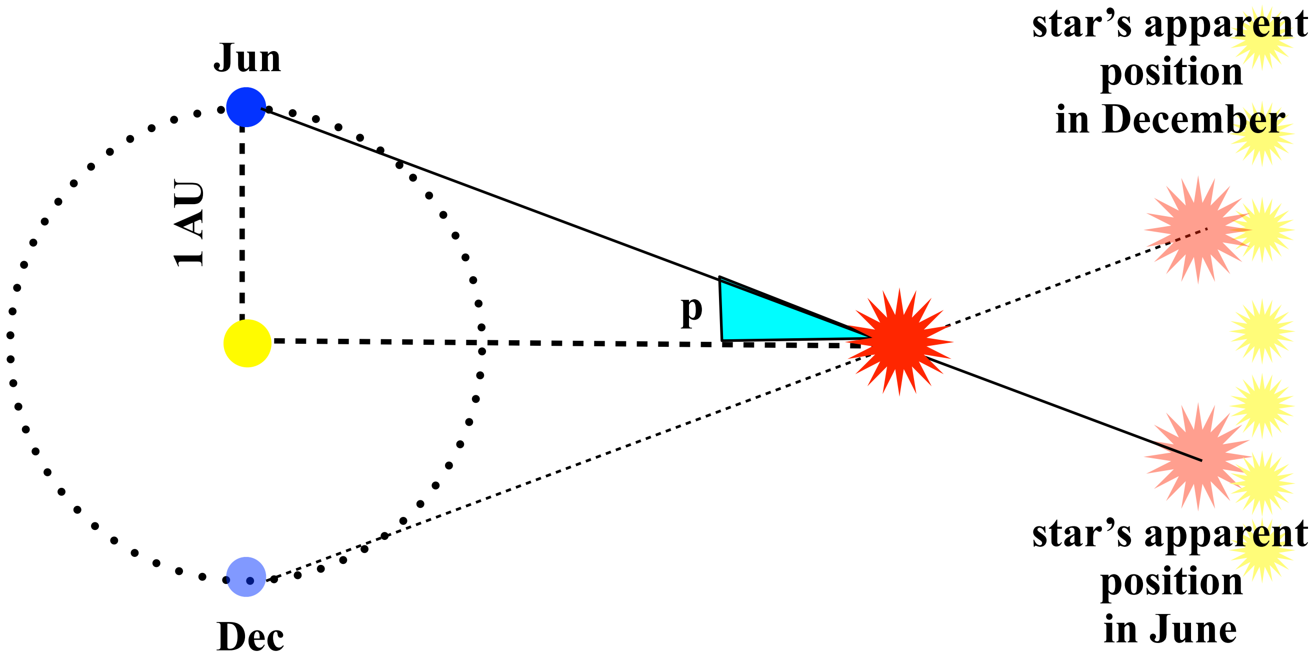


Thumb Experiment

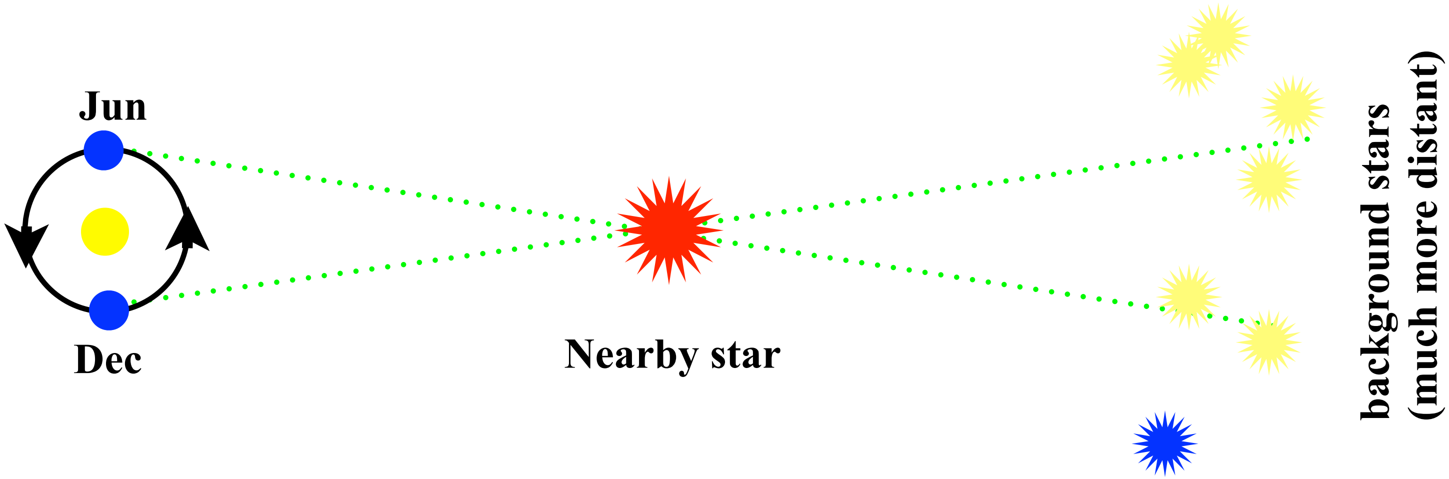
1 2 3 4 5 6 7 8 9

Measuring stellar distances with parallax

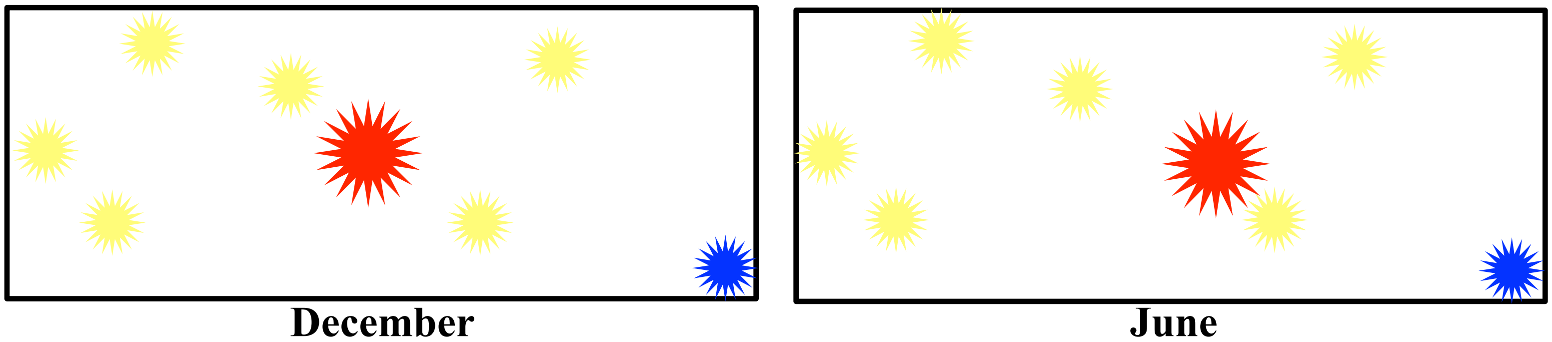
- As seen from the Earth, the nearby star appears to sweep through the angle shown.
- Half of this angle, is the parallax, **p**.



Stellar Parallax



What is seen in the sky



Parallax is used to measure the distance to stars that are relatively nearby

iClicker Poll: Parallax

Star A is closer than star B

The parallax p_B of the more distant star B will be

A. larger than p_A = bigger shift on sky for B

B. smaller than p_A = smaller shift on sky for B

C. the same as p_A: same Earth orbit = same shift

Hint: in thumb's up experiment, can adjust thumb distance!