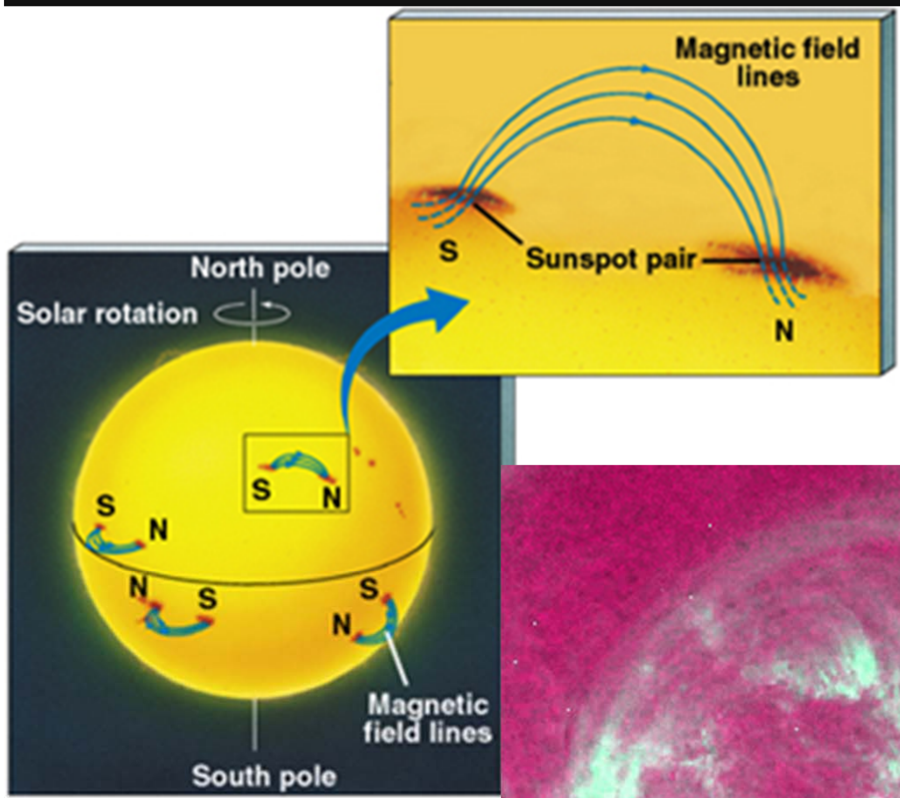
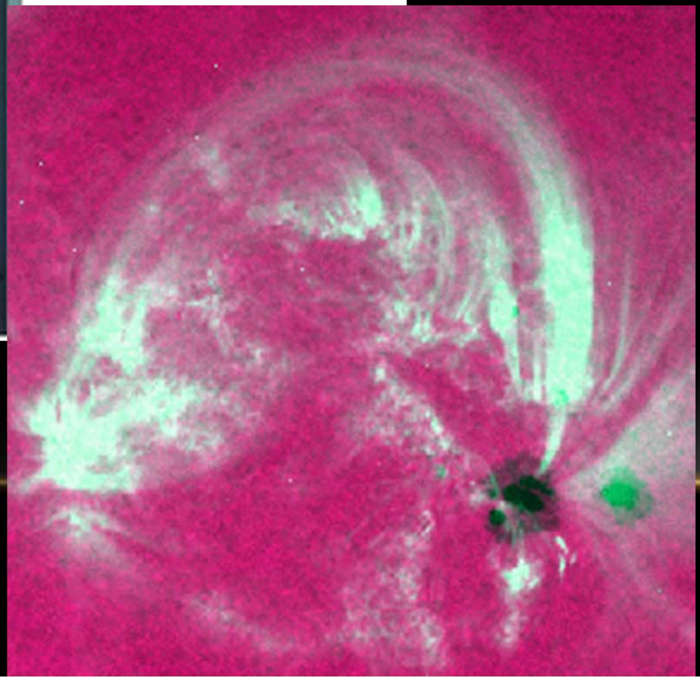
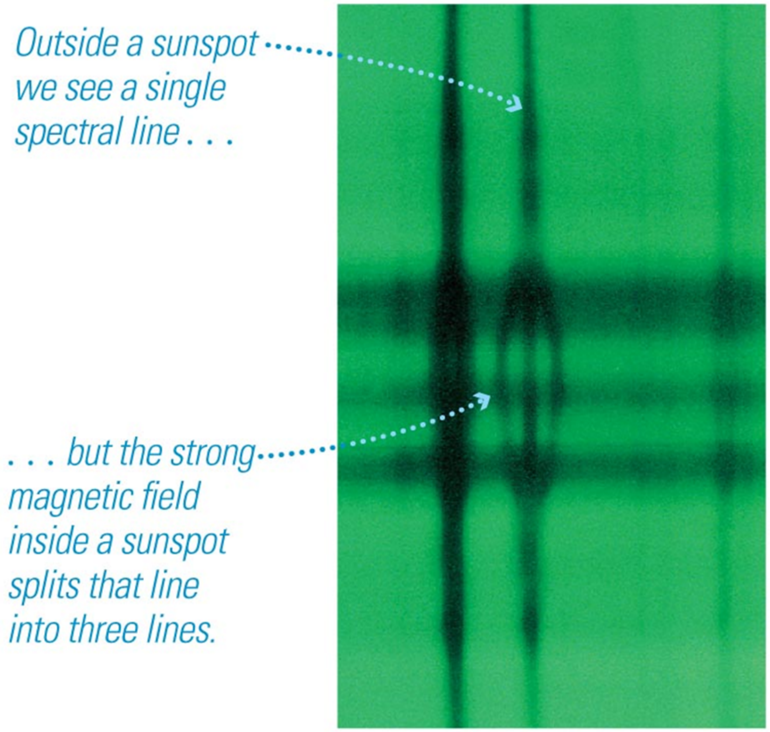
SOLAR MAGNETISM





- The Sun rotates, has a conductive core
  - Ionized gas
  - Has a strong magnetic field
- Sunspots have intense magnetic fields, often paired
  - A loop of field pops up out of the surface and dives back nearby
  - Intense field cools the photosphere where it passes through

HOW CAN WE TELL?



b Very strong magnetic fields split the absorption lines in spectra of sunspot regions. The dark vertical bands are absorption lines in a spectrum of the Sun. Notice that these lines split where they cross the dark horizontal bands corresponding to sunspots.

- "Zeeman effect"
- Magnetic fields split spectral lines
  - Size of split lets us measure size of field

Fig.11.13b

SOLAR FLARE

- Big explosion on surface of Sun
- Prominences, CME’s Flares similar and related: but not the same

SUNSPOT CYCLE

- Note 11-year cycle
  - Sunspots increase in number to a “Solar Maximum” then virtually disappear every 11 years

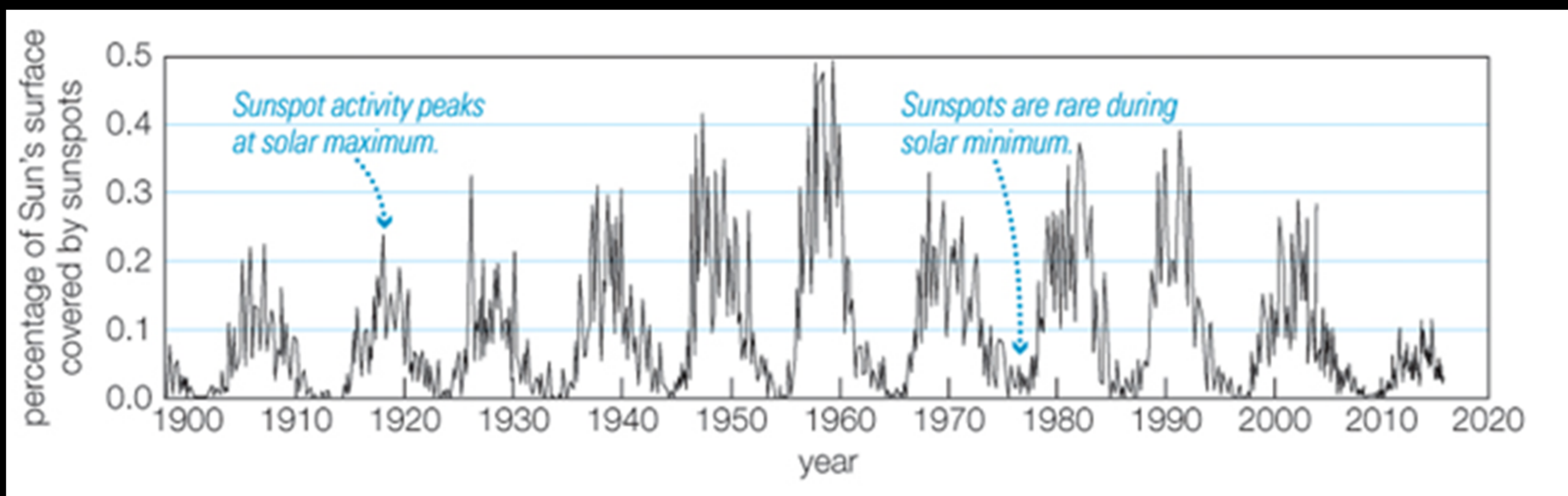


Fig.11.20a

SUNSPOT CYCLE

- "Butterfly Diagram"
  - Sunspot location and number
  - At beginning of cycle, they are near the poles
  - Move towards equator as cycle progresses

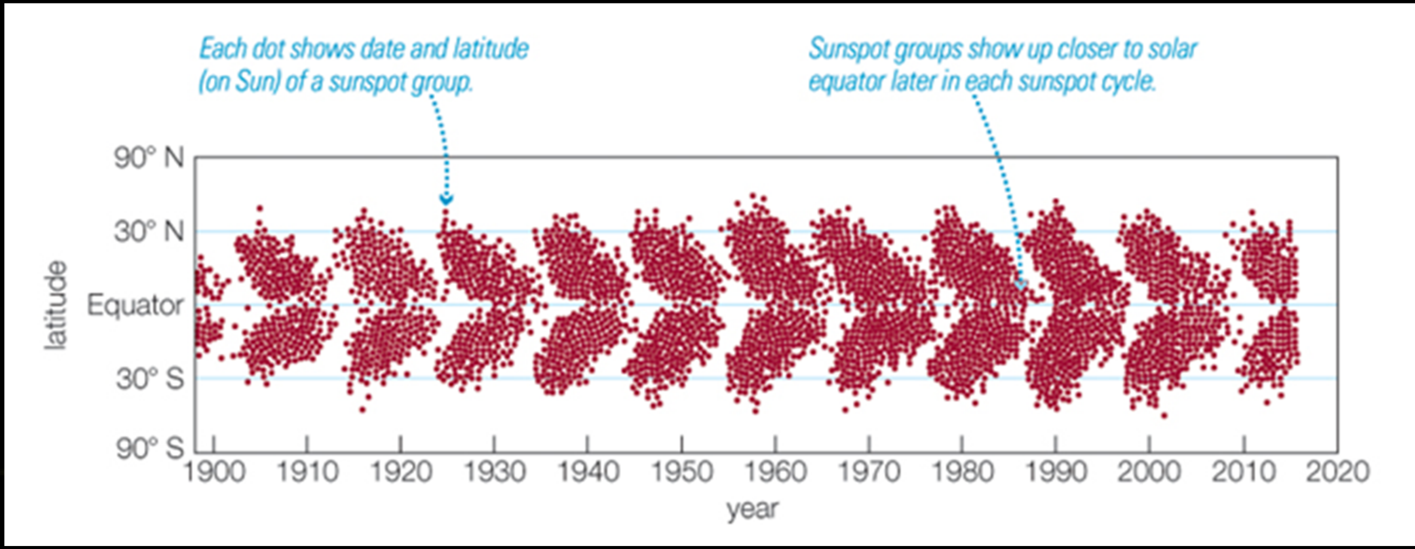
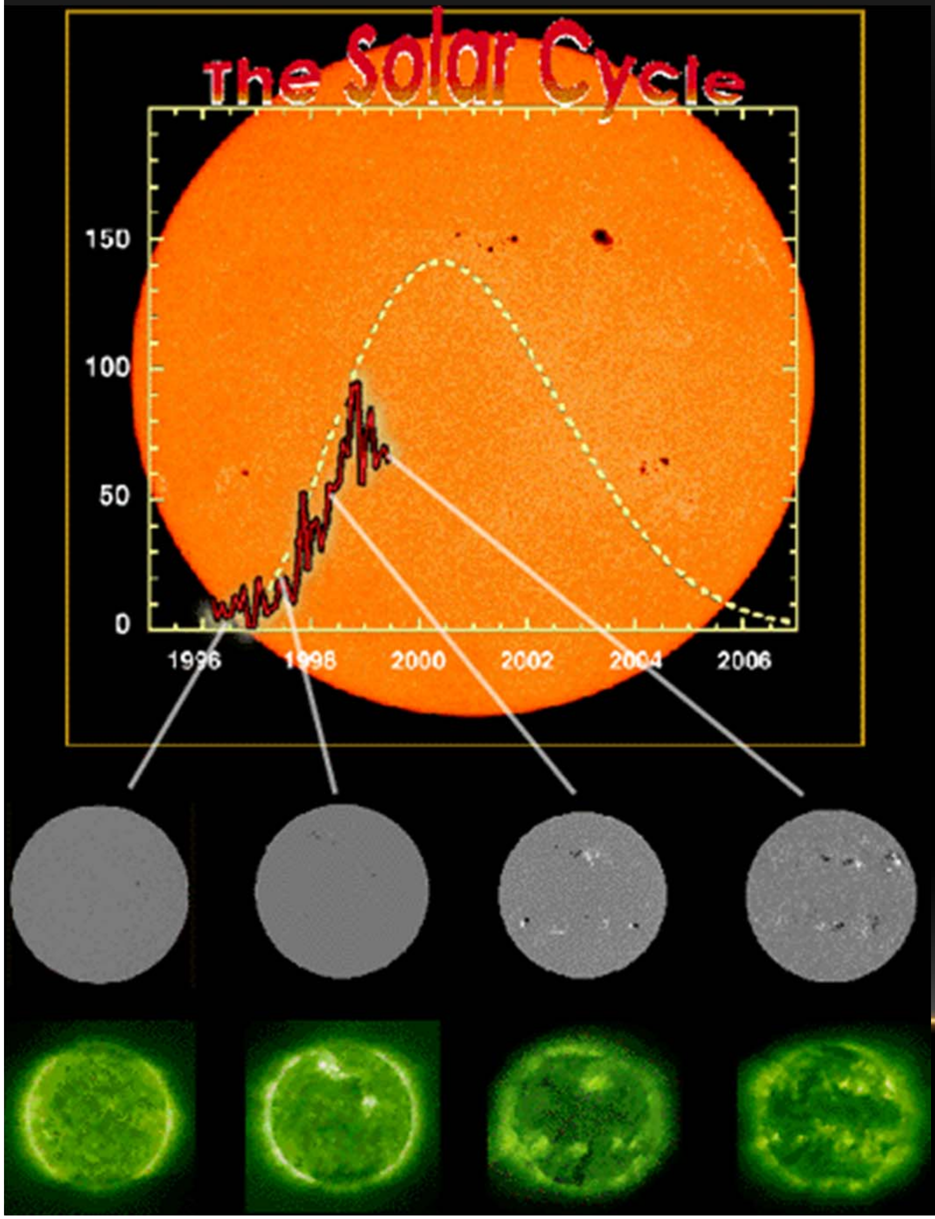


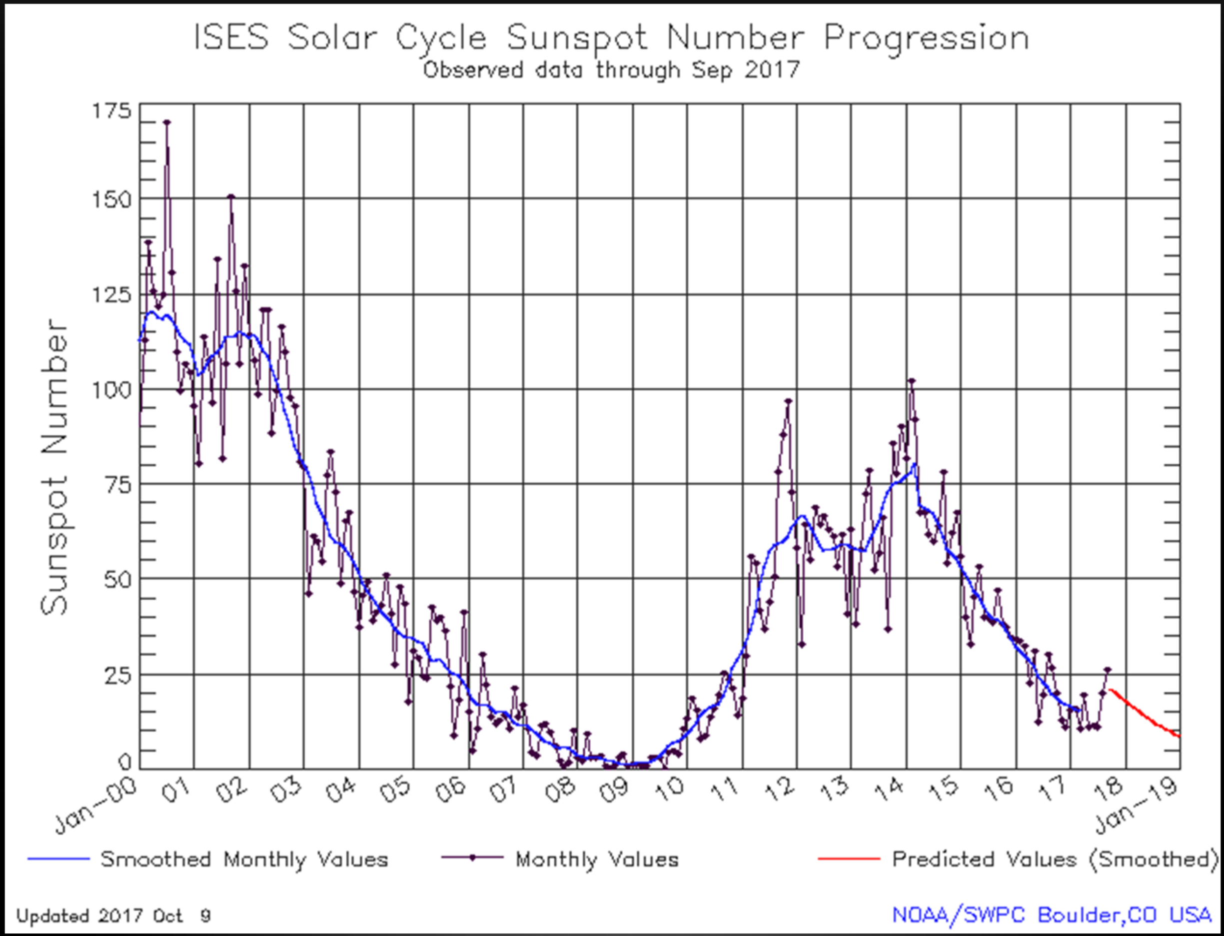
Fig.11.20b

SUNSPOT CYCLE



- Activity in outer atmosphere changes too
  - more sunspots, more stuff going on

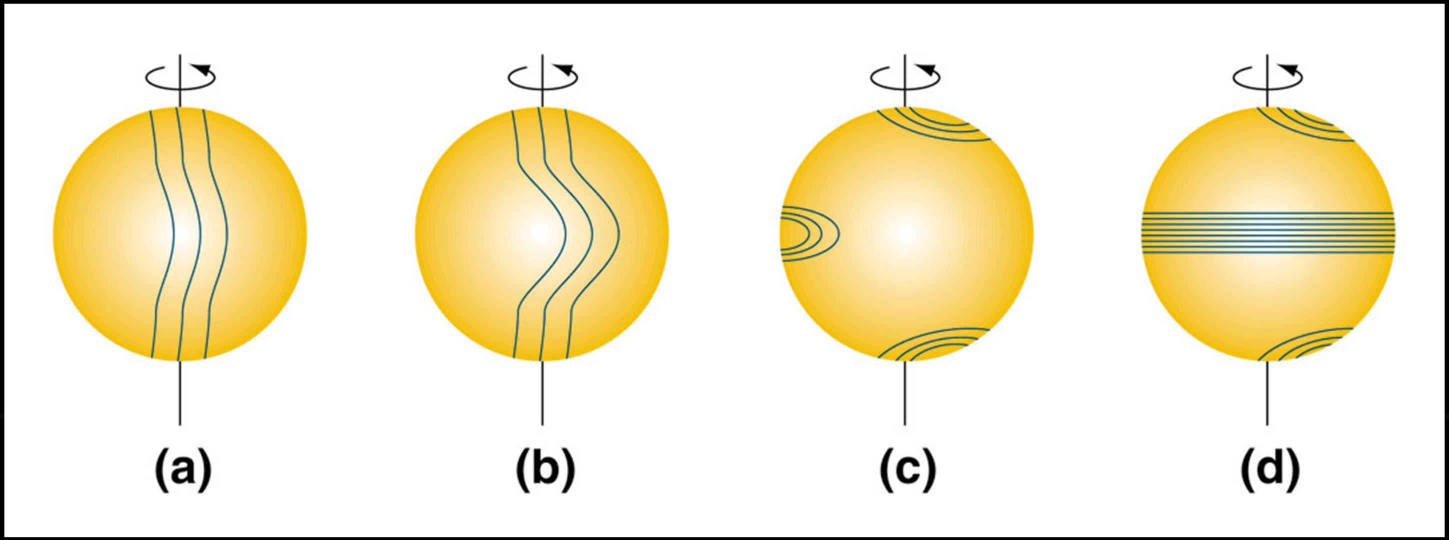
WHERE ARE WE NOW?



- http://www.swpc.noaa.gov/products/solar-cycle-progression

WHY?

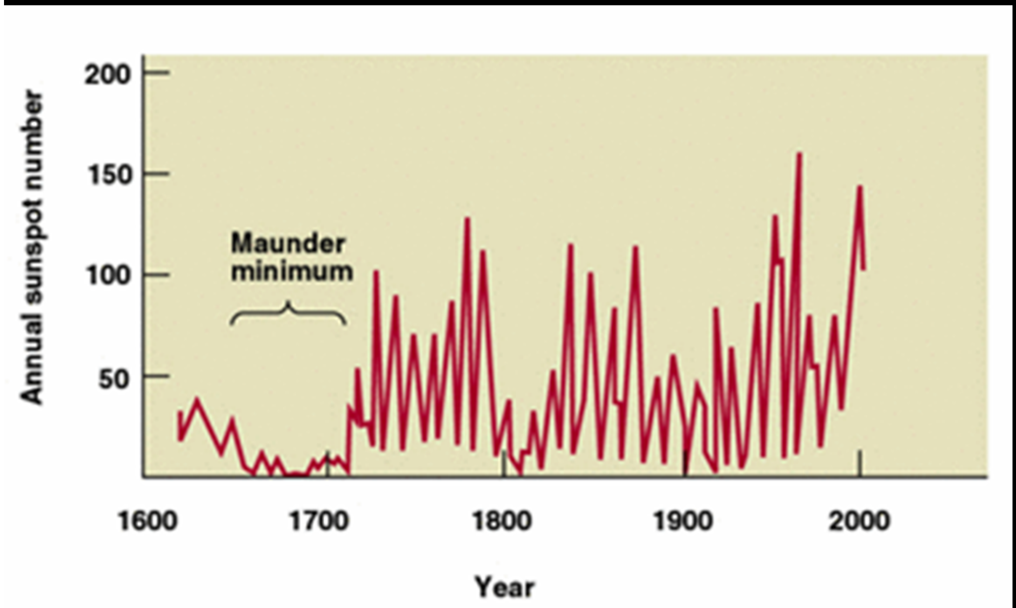
- The Sun rotates differentially
- Faster at equator (25 days)
- Slower at poles (36 days)
- Magnetic field gets wound up like rubber band



SOLAR CYCLE

- So, an 11-year Sunspot Cycle is ½ of the 22-year Solar Cycle
- Each 22 years, the Sun’s magnetic field is back to the same state it was 22 years ago

EFFECTS ON EARTH



- Solar Wind causes Aurora
- Solar Flares, CME's can disrupt satellites, communications
  - Look at www.spaceweather.com
- Sunspot activity seems to be correlated with solar energy output
- The Sun is a rather important thing to understand
  - For life on earth, not just for the test!

"Maunder Minimum" corresponds with the "Little Ice Age"

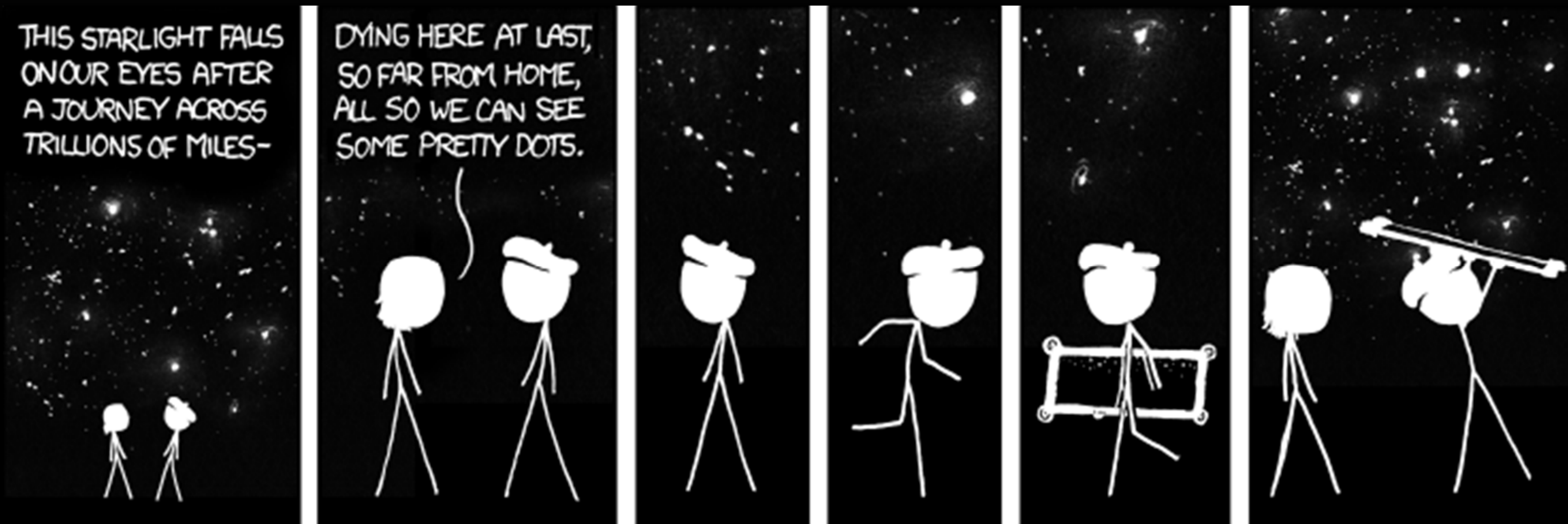
MEASURING THE STARS

Ch.12

STARS

- We look up, we see lots – several thousand with the naked eye
- Look more carefully, uncountable numbers wherever you look
- Different colors, brightness's, locations – but all just points of light

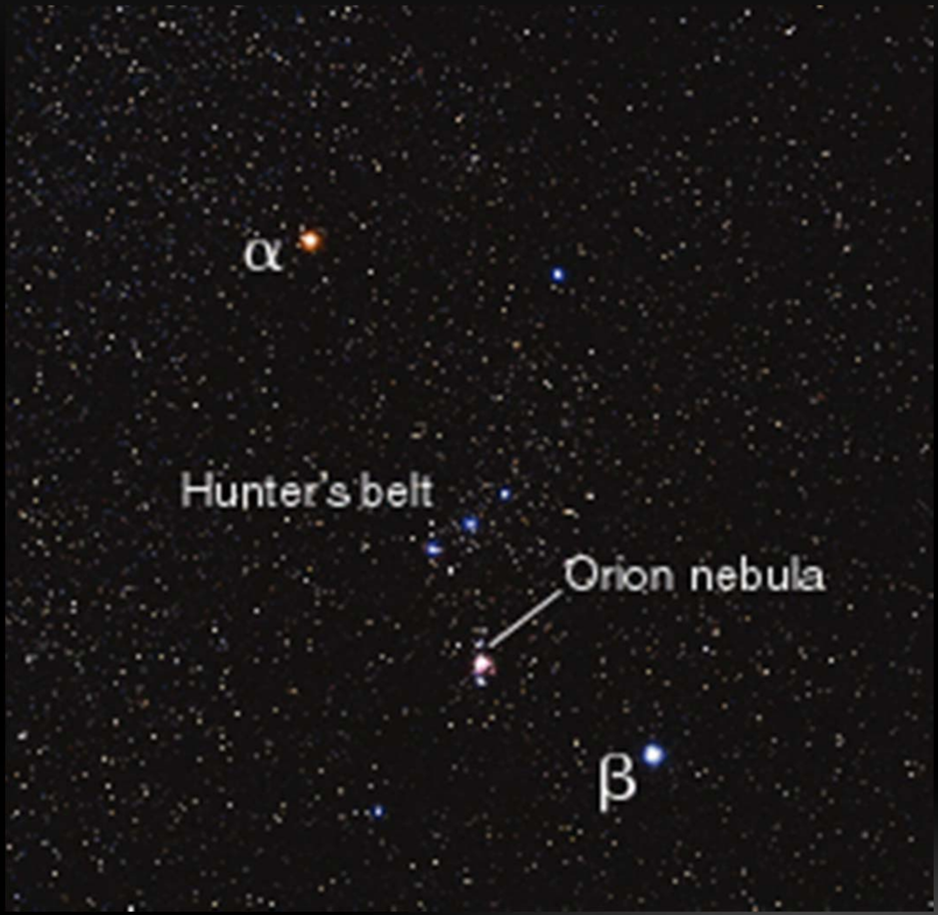
FROM XKCD.COM:



WHAT CAN WE SEE FROM A STAR?

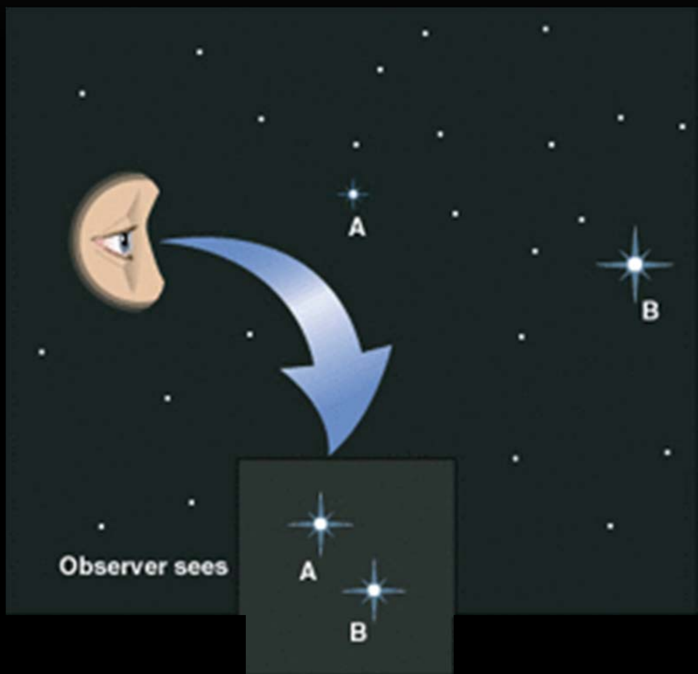
- We just see the light, from a point
- From Ch.5, we can measure:
  - Brightness – how much light we see
  - Position – where does the light come from?
  - Spectra – what color(s) the light is
  - and do these properties change with time?

BRIGHTNESS

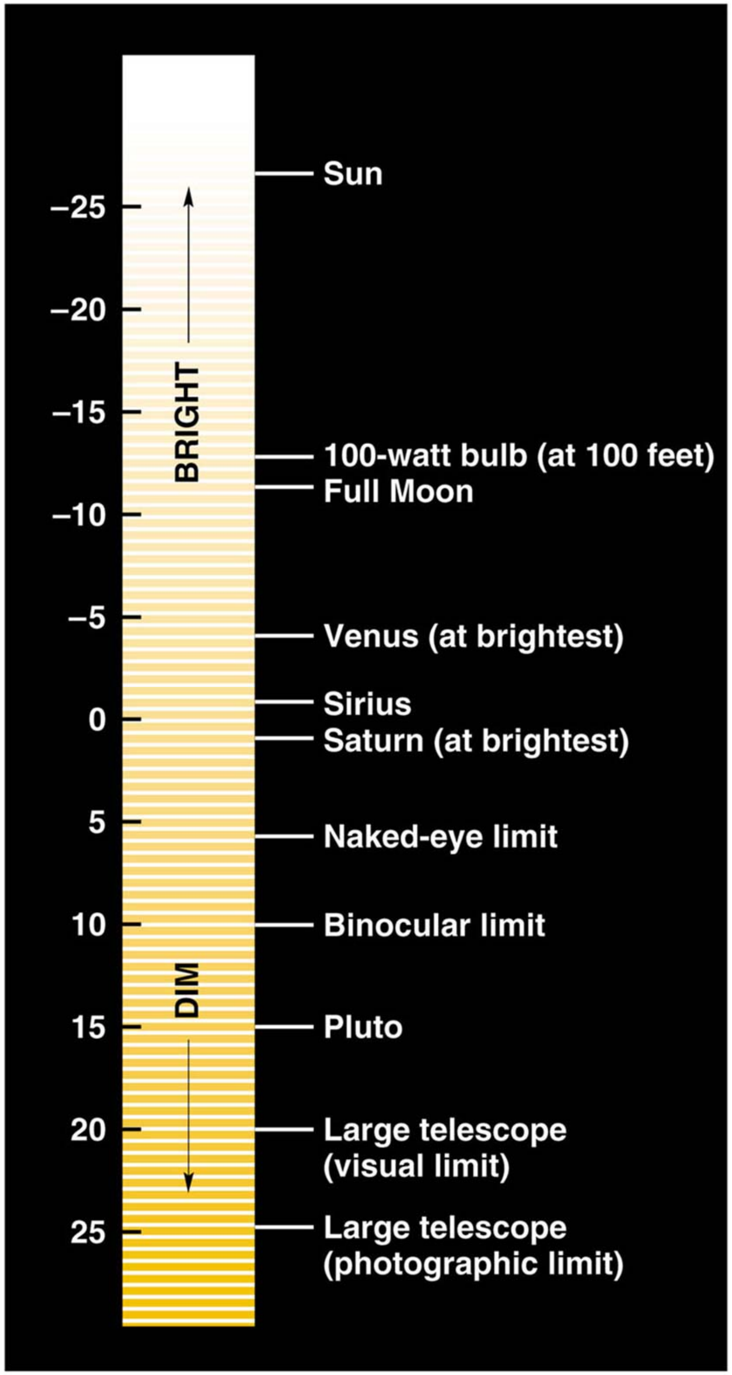


- α Orionis (Betelgeuse) appears to be about the same brightness as β Orionis (Rigel)
- But – Betelgeuse is only 430 ly away, Rigel is 730!

APPARENT MAGNITUDE



- If they're different distances, but appear to be the same brightness, then they have the same *Apparent Magnitude*
- However, the further star must be inherently brighter, having a larger *Absolute Magnitude*



APPARENT MAGNITUDES

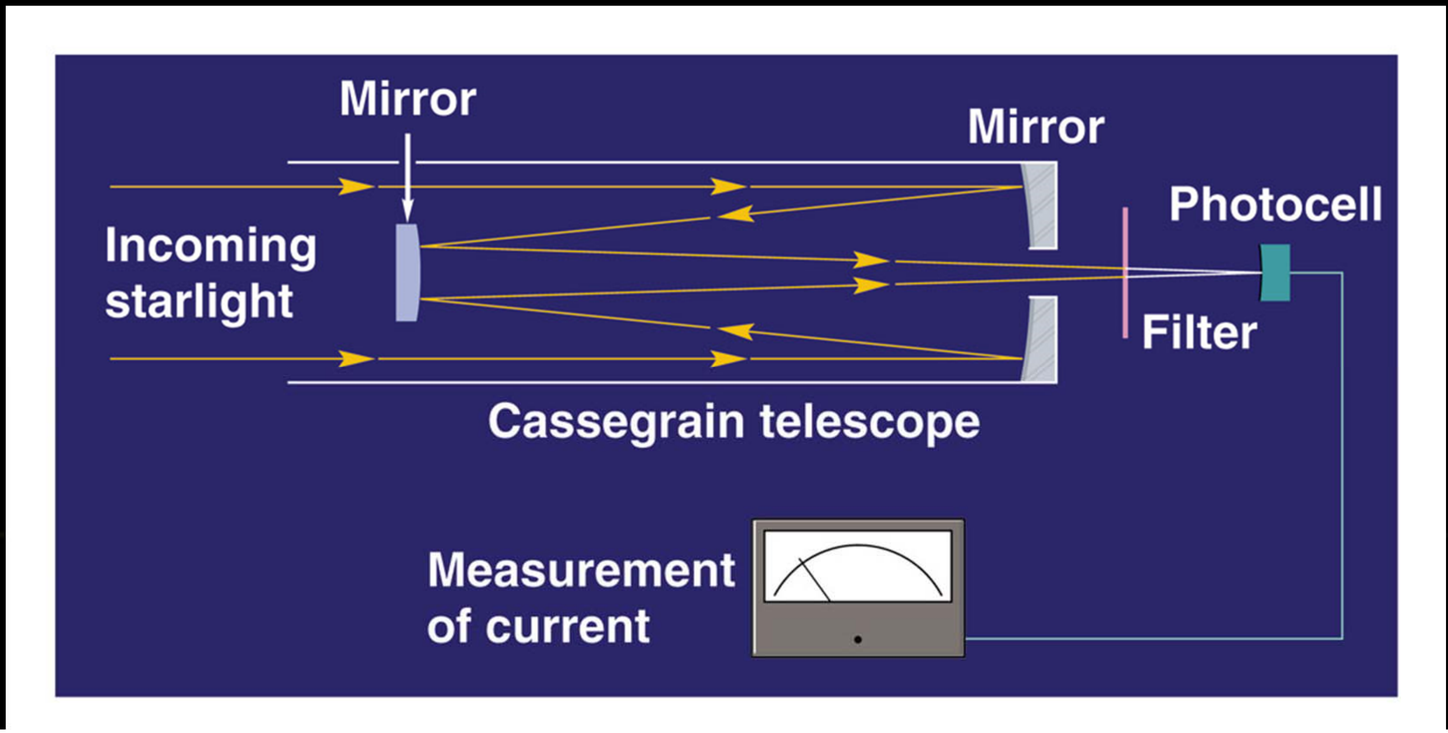
- Hipparchus cataloged 850 stars in ~200BC
- Classed them from brightest ("1st magnitude") to dimmest ("6th magnitude")
- Bigger number means fainter
- "Apparent" means <u>what we see</u>
- HST, Keck – can see +30
  - Brightness of a firefly seen from the other side of the Earth

MAGNITUDE DIFFERENCE

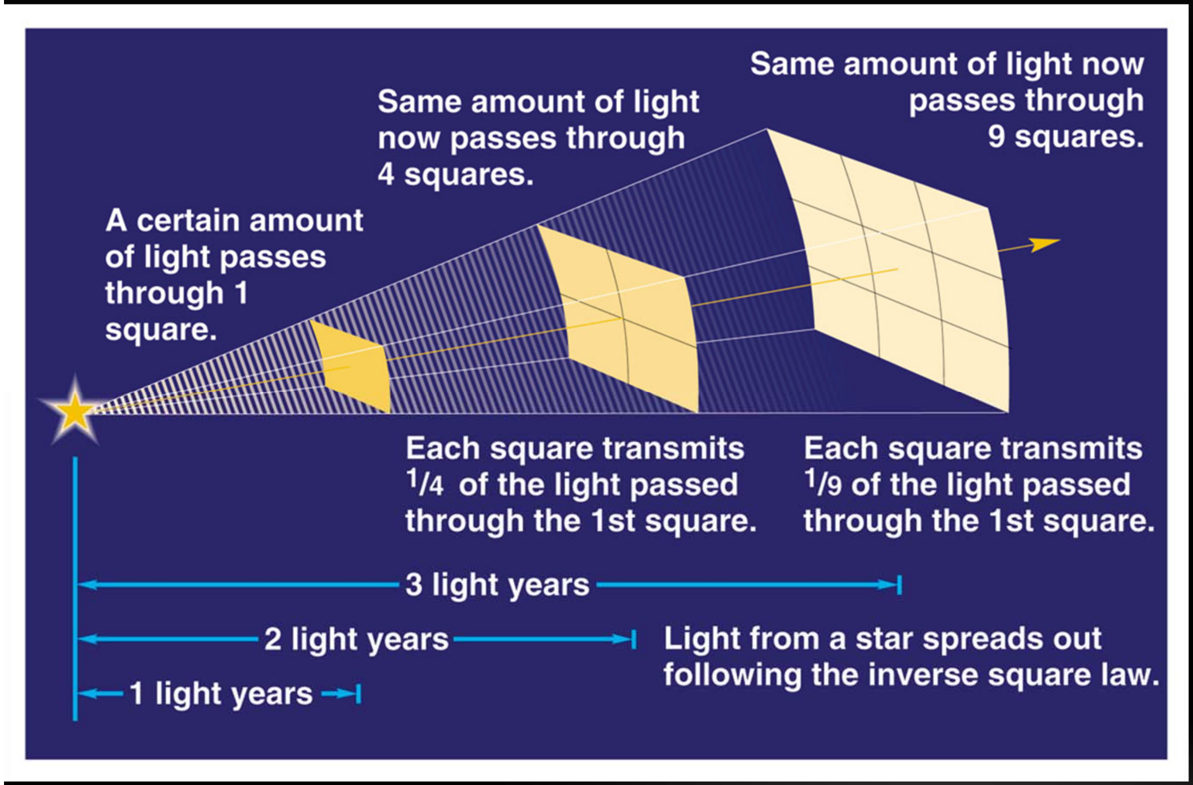
- Each step in magnitude corresponds to a change of about 2.5x in brightness
- So: brightness ratio = $2.5^{\Delta m}$
- For example:
  - How much brighter is a 2nd magnitude star than a 4th magnitude star?
  - $\Delta m = (4-2) = 2$
  - $2.5^2 = 6.3$ – so it is 6.3 times brighter

PHOTOMETRY

- The measurement of brightness is called photometry
- The advent of digital imaging has made this much easier to do on a lot of stars at once



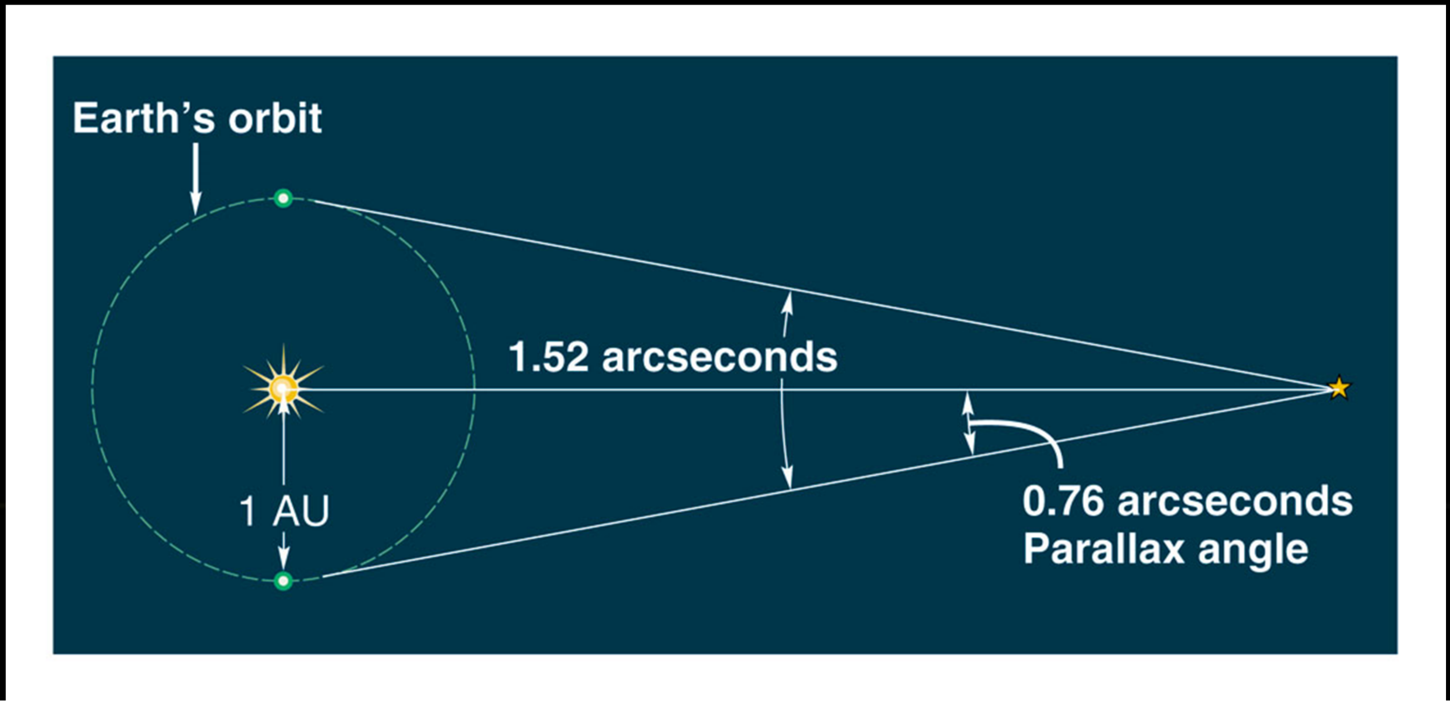
INVERSE SQUARE LAW



- Intensity, like gravity, falls off as $1/r^2$ where r is distance
- So, further things are fainter than they would be if closer
- So, to know how bright something really is, we need to know how far away it is and how bright it appears to be

DISTANCE

- Stellar parallax is first step
- Watch the star jump around
- Do some trig, calculate distance



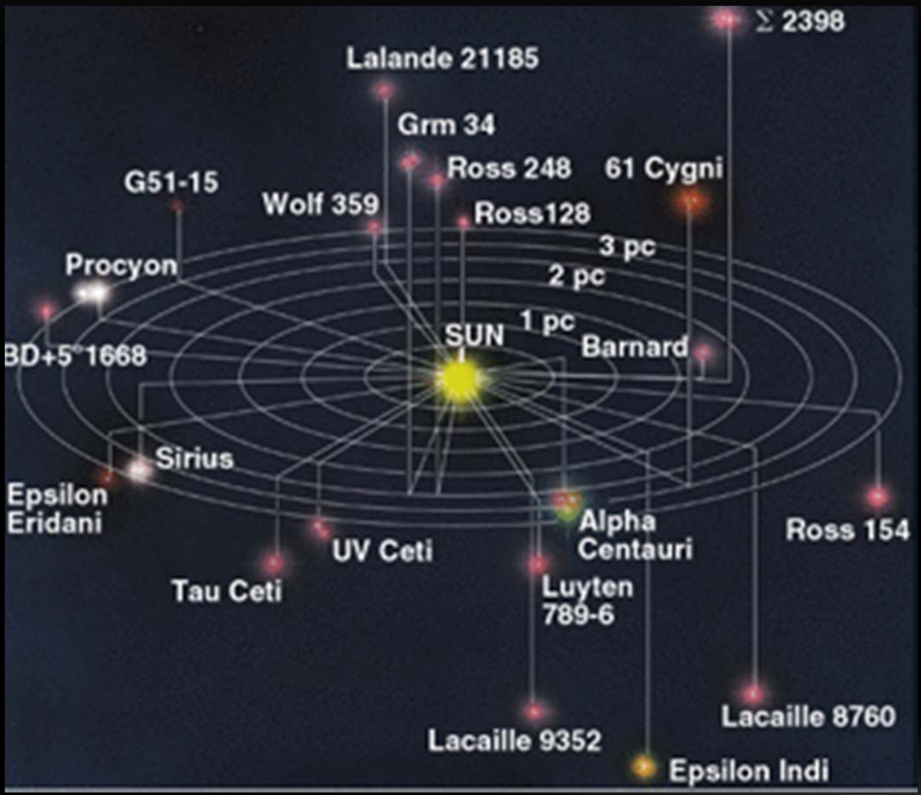
PLAY

PLAY

PARSEC

- Define a unit of distance:
  - How far away a star is that would have a parallax of 1 arc second (1/3600 of a degree)
  - This is 3.26 light years = 1 parsec (pc)
  - So: distance (parsecs) = 1/(parallax angle)
- Proxima Centauri has parallax of 0.76”
- So is 1/0.76=1.3 parsecs = 4.3 ly away

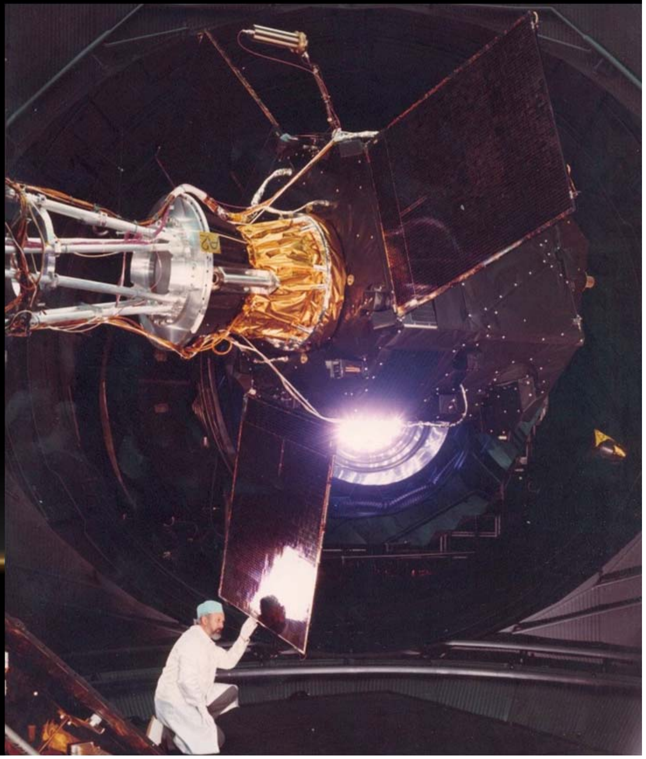
SOLAR NEIGHBORHOOD



- Within 4 pc (~13 ly) there are 30 stars
- A few are bright, as you might expect from a close star
- Many are still extremely faint, even though they are right next door

LIMITATIONS OF PARALLAX

- From the ground, we can make measurements good to only 0.03” (due to air turbulence)
  - Corresponds to ~30 pc (~100 ly): the nearest few 1000 stars
- Hipparcos the satellite (ESA, 1990’s) above the atmosphere measured a million parallaxes, out to ~100 pc
- Further out – need other tools (later)

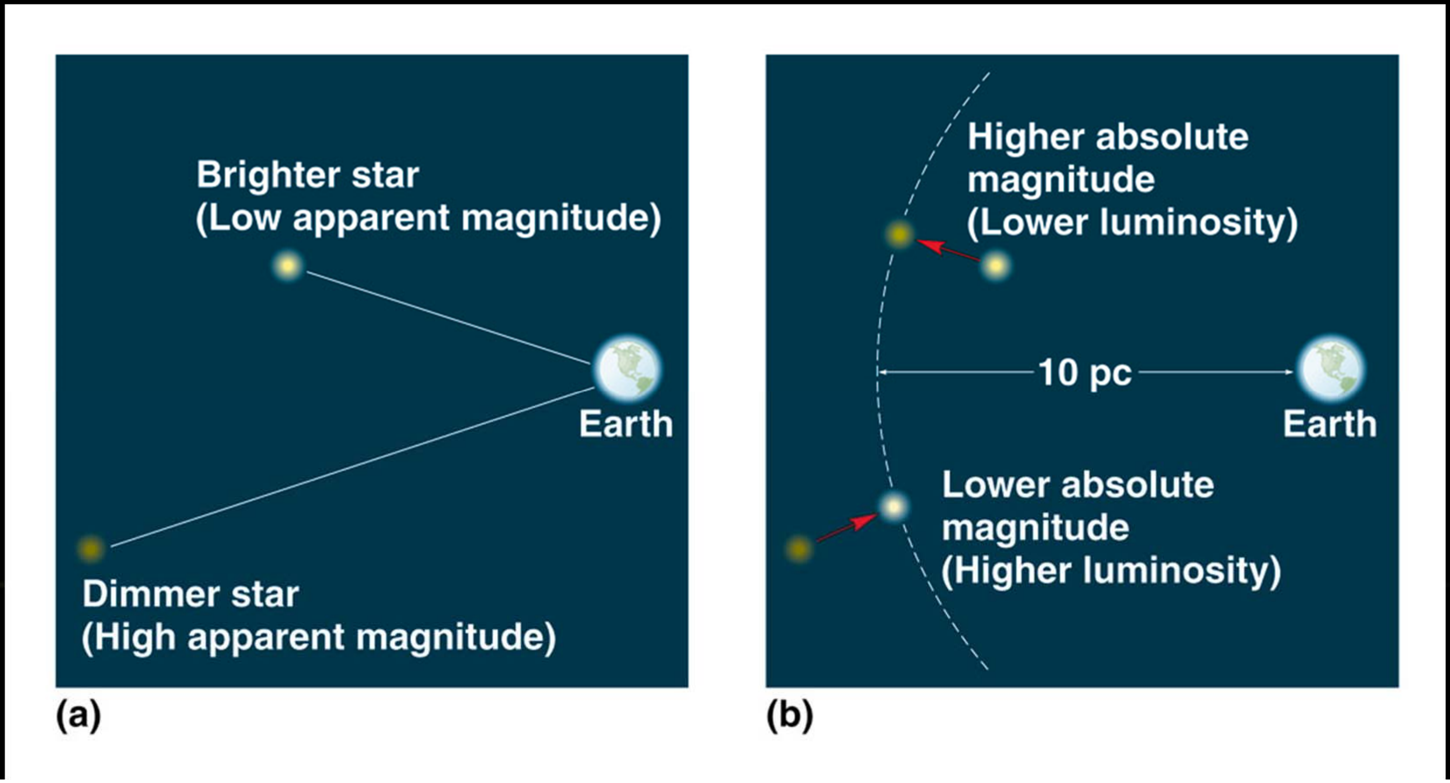


LUMINOSITY

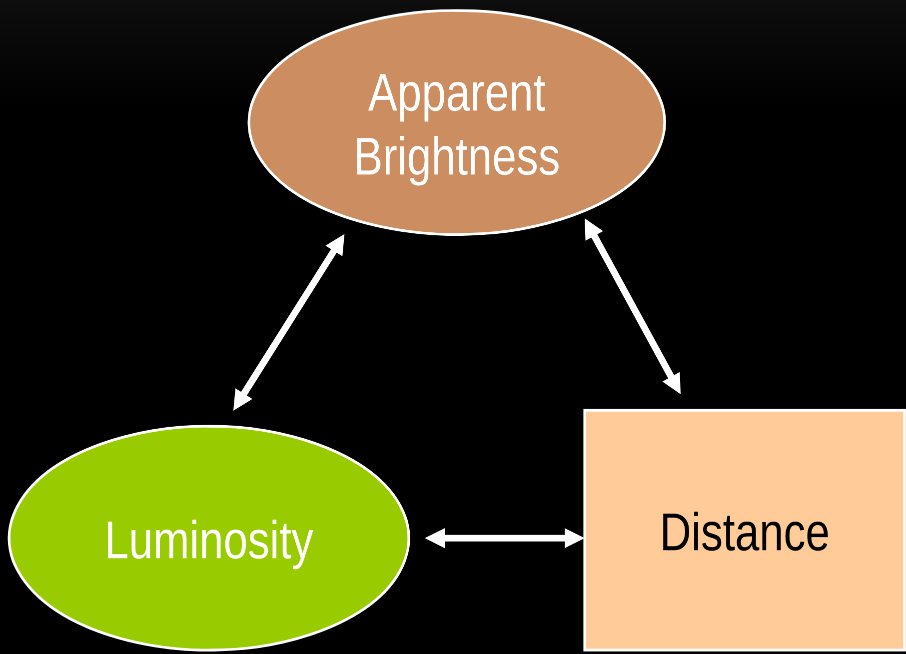
- With the Sun, Luminosity was how much energy it put put per second
- Same for other stars
  - Often expressed in units of “Solar Luminosity”, $L_\odot$
- If two stars are at the same distance:
  - More luminosity = more brightness

ABSOLUTE MAGNITUDE

- Calculate what a star would look like if moved to a distance of 10 pc
- This allows comparison of brightness's on an even footing



BRIGHTNESS IN SUMMARY



Find any two of the three,
You can calculate the third!

- Apparent magnitude is how bright something appears to us
- From the inverse square law, we can calculate how it would appear at any given distance
- Absolute magnitude is how a star would look at a distance of 10 pc
  - Directly related to Luminosity

IF A STAR WAS MOVED TWICE AS FAR AWAY, WHAT WOULD HAPPEN TO IT'S APPEARANCE?

a. It would get twice as faint
b. ✓ It would get four times fainter
c. It would get fainter and redder
d. It would get fainter and bluer
e. If moved only two times farther, you wouldn't notice much change