ASTR 1040: Stars & Galaxies

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Lecture 4 Thur 26 Jan 2017

zeus.colorado.edu/astr1040-toomre

Topics for Today (and Tues)

- Basic principles of eyes, camera, telescopes
- Nature of astronomical telescopes
- What our atmosphere does to "light"
- Telescopes in space -- and why
- Tues: Our Nearest Star the Sun in overview

- *Finish reviewing Chap 6 (Telescopes)*
- *Begin reading Chap 14 (Our Star) in detail*
- *Homework #2 passed out; Observ #1 tonight*

Clicker Q: Radio Waves D.

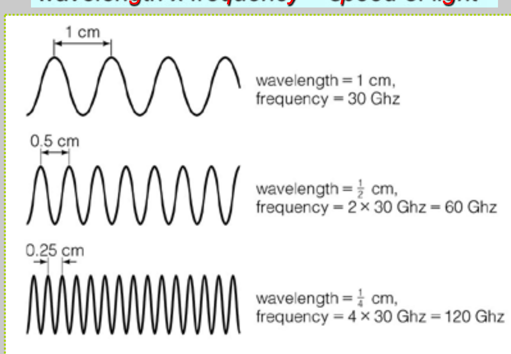
- *You are listening to a radio station broadcasting at a FM frequency of 97 MHz. Which is true?*
- *A.* The radio waves from the station have a wavelength of 97 million meters.
- *B.* The "radio waves" received by your radio are not light waves, but rather a special kind of sound wave.
- *C.* The radio station broadcasts it signal with a power of 97 million watts.
- *D.* The radio waves are causing electrons in your radio's antenna to move up and down 97 million times per second.

D. $c = \lambda \cdot f$ *Radios*

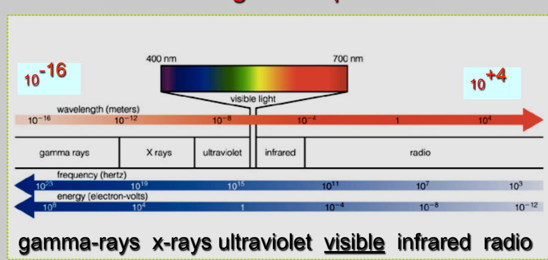
- *You are listening to a radio station broadcasting at a frequency of 97 MHz. Which is true?*
- D. The radio waves are causing electrons in your radio's antenna to move up and down 97 million times per second.

Wavelength = Speed of light / frequency
$= 3.0 \times 10^{10}$ cm sec^{-1} / 9.7 10^{7} sec^{-1}
$= 309$ cm

wavelength x frequency = speed of light



Electromagnetic Spectrum



Where are the cell phones?

Discussion of CELL PHONE frequencies and wavelengths

and what is involved with them

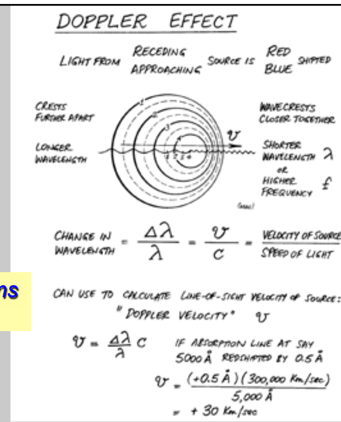
850 MHz 1850 MHz

850 MHz:
Wavelength = Speed of light / frequency
= 3.0×10^{10} cm sec^{-1} / 8.5×10^{8} sec^{-1}
= 35.3 cm 1850 MHz: 16.2 cm

REMINDER

DOPPLER EFFECT

Applied to positions of spectral lines



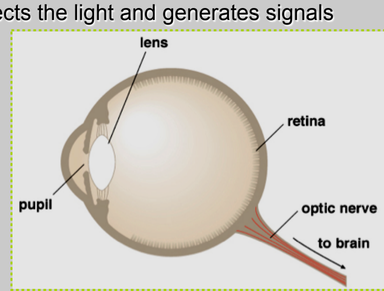
In what ways is an electron orbiting the nucleus of an atom different from a planet orbiting the Sun ?

E.

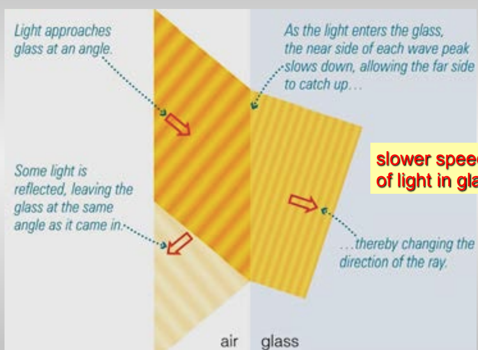
- A. The central force is electromagnetic (+ and - charges attract), not gravity
- B. Not all orbits are allowed–only certain sizes (they are quantized)
- C. Because atomic orbits behave differently from "regular" orbits we call them orbitals
- D. An electron can jump or make a transition from one orbital to another
- E. All of the above

Imaging with our Eyes

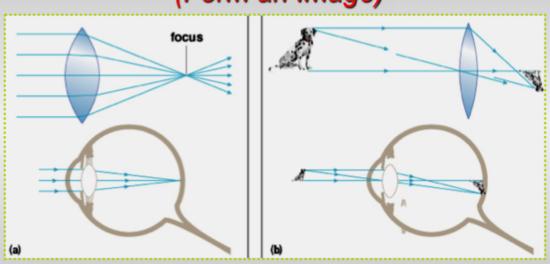
- **pupil** – allows light to enter the eye
- **lens** – focuses light to create an image
- **retina** – detects the light and generates signals sent to brain



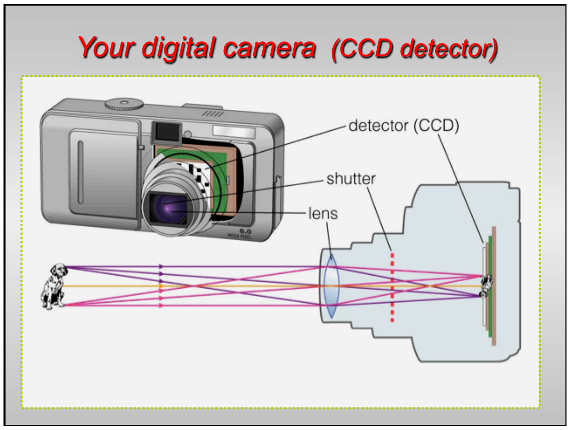
Reflection and refraction ("bending" of light)

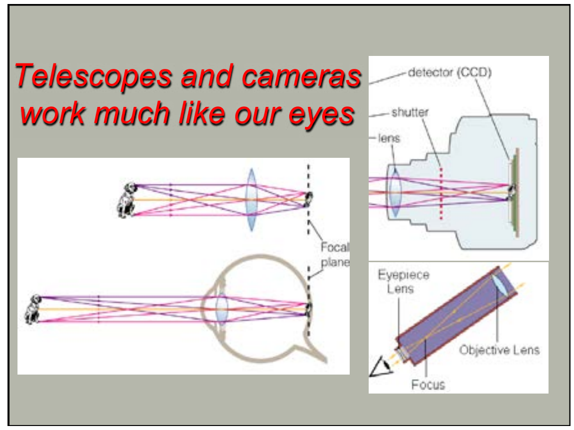


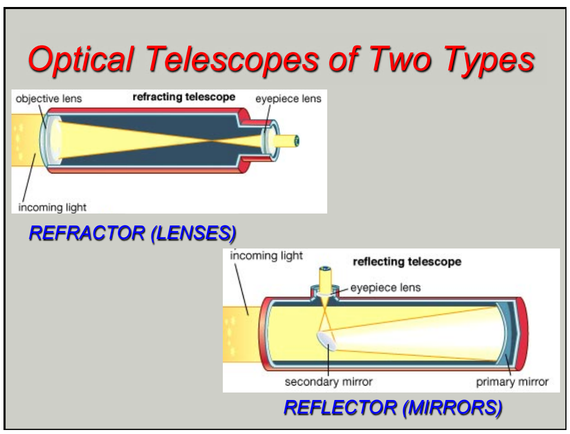
Bending of Light to Focus (Form an Image)

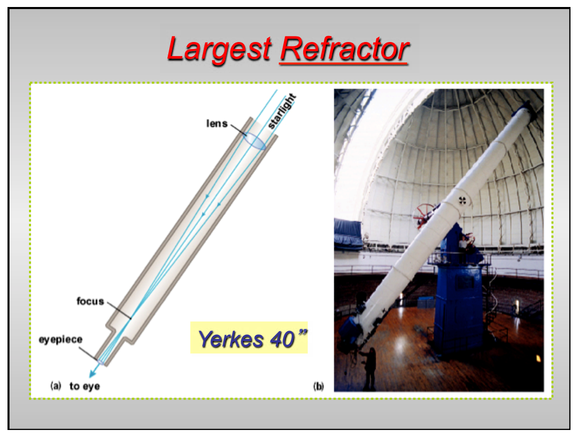


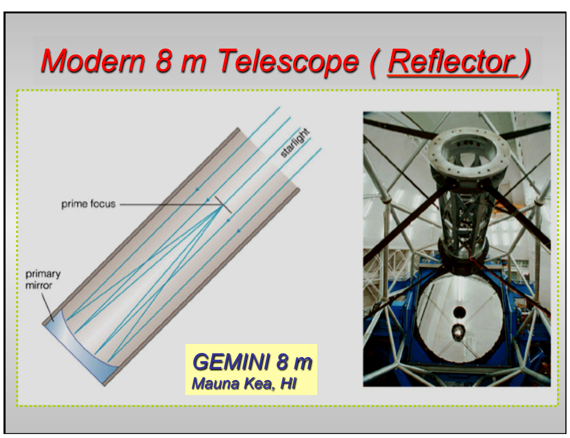
Telescopes and cameras work much like our eyes

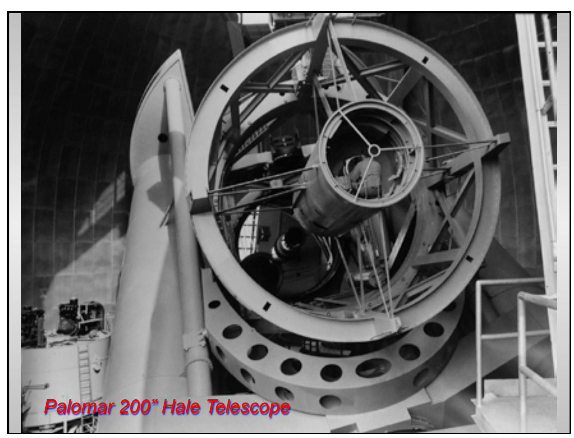

Your digital camera (CCD detector)
detector (CCD)
shutter
lens


Telescopes and cameras work much like our eyes
detector (CCD)
shutter
lens
Focal plane
Eyepiece Lens
Objective Lens
Focus

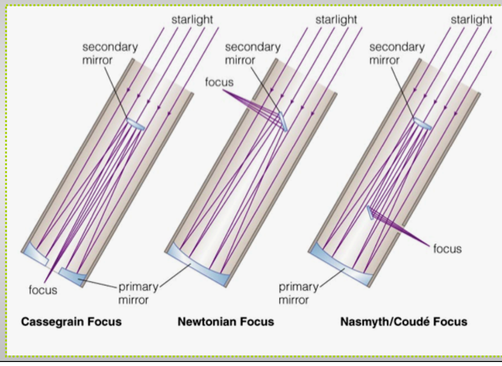

Optical Telescopes of Two Types
objective lens
refracting telescope
eyepiece lens
incoming light
REFRACTOR (LENSES)
incoming light
reflecting telescope
eyepiece lens
secondary mirror
primary mirror
REFLECTOR (MIRRORS)


Largest Refractor
lens
starlight
focus
eyepiece
(a) to eye
(b)
Yerkes 40"


Modern 8 m Telescope (Reflector)
prime focus
primary mirror
starlight
GEMINI 8 m
Mauna Kea, HI


Palomar 200" Hale Telescope

Different FOCUS arrangements (to get image)



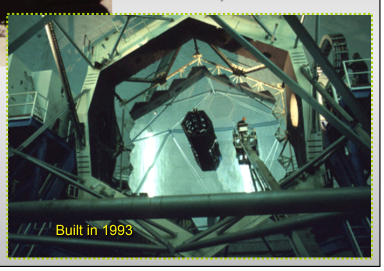
Modern Reflectors

6.5 m MMT – Mt. Hopkins, AZ

8.3 m SUBARU – Mauna Kea, HI

Keck 10 m Twins (Segmented Reflectors)

Mauna Kea, HI

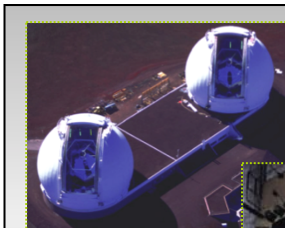


Built in 1993

Another view

Twin Keck 10 m TELESCOPES

Mauna Kea, HI



Discussion Topic

Why are most modern research telescopes REFLECTORS (using mirrors and not lenses)?

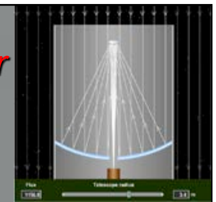
Why big aperture telescopes are reflectors

- Can support mirror from back, not just at edges as with lenses (biggest: 1 m lens, 10 m diam mirror)
- Mirror needs only one good optical surface to be ground, not four as with achromatic (2 elem) lens
- Can recoat mirror surface easily with highly reflective aluminum (even silver)
- Lens has to be optically pure and uniform, but mirror can be made of anything that holds its shape (fuzed quartz, zero expan pyroceramics, even beryllium)

Size DOES Matter!

1. *Light-Collecting Power*
2. *Angular Resolution*

Light-Collecting Power

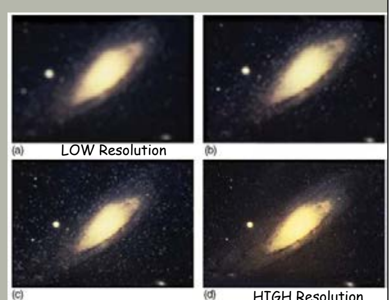


- *A telescope is a "photon bucket" collecting photons raining from the sky*
  - Bigger bucket = more photons
- The larger the telescope diameter, the more light rays it intercepts (larger area)
  - Most telescopes are circular… what's the area of a circle?
    - Light Collecting Power ~ Radius² (or Diameter²)

Angular Resolution for telescopes

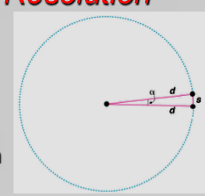
- The angle between two objects that can be seen as separated
  - SMALLER angle is BETTER

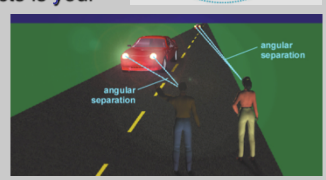
WATCH OUT!
- High resolution = small angular resolution



Concept of "Angular Resolution"

- Ability to separate two objects
- Angle between two objects decreases as your distance to them increases
- *Smallest angle* at which you can distinguish two objects is your *angular resolution*



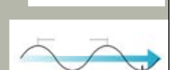


Diffraction Limit

- Best angular resolution a telescope can get
- The diffraction limit is given by

$$\theta_{diff} \sim \lambda / D$$

  - λ is wavelength of light being observed
    D is mirror diameter
- Better *(smaller)* for shorter wavelengths or larger telescopes
  - *See Math Insight Box 6.1 & 6.2 for more details*



How large an angle is an arcsecond?

- *1 arcsecond* is the angular separation of car headlights 200 miles away, or the diameter of a dime from 2.5 mile away
- The red dot above is about 100 arcseconds across (depending on where you are sitting)
- Hubble Space Telescope: 0.05 arcseconds = about 1/2000 of the above dot!