ASTR 1020: Stars & Galaxies

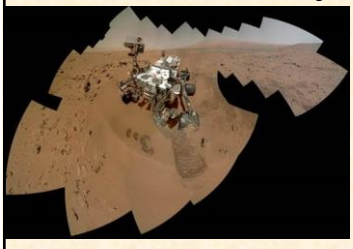
October 18, 2013

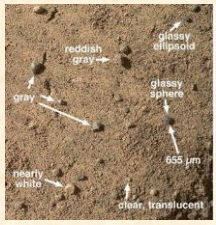
- Reading: Chapter 15, section 15.1.
- *MasteringAstronomy* Homework on The Lives of Stars is due tonight at midnight.
- Exam 2 is next Wednesday, October 23.

Astronomy in the News

Curiosity finds water on Mars as common as dirt

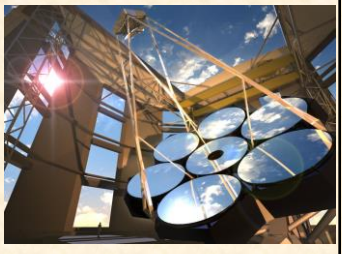
Joel Rodgers





Today's Class: Telescopes

- Focusing Light.
- **Telescopes**: Light collecting area & angular resolution.
- Radio Telescopes
- What are telescopes used for?



Clicker Question from Reading

Why can cameras see objects too faint to be seen by the eye?

a) They have higher resolution detectors.
b) They can record light for a longer period of time.
c) Their detectors are more sensitive to light than the eye.
d) They have larger lenses.

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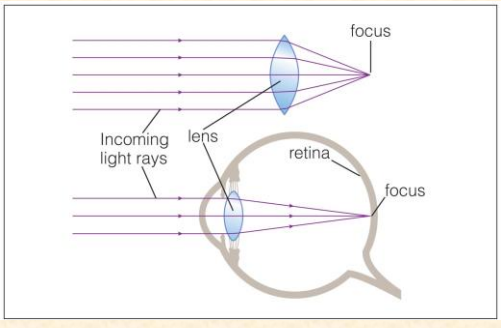
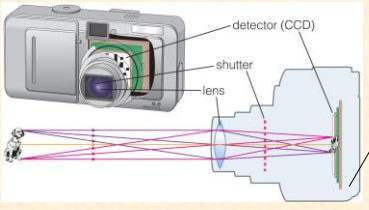
The Pleiades with increasing exposure times

Focusing Light



- Refraction can cause parallel light rays to converge to a focus.

Recording Images

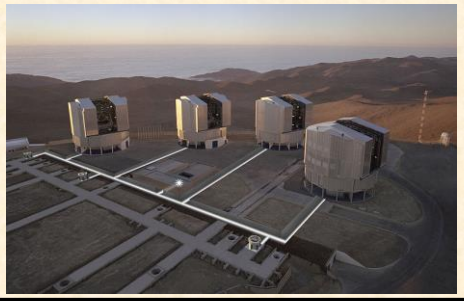


Digital cameras detect light with charge-coupled devices (CCDs).

- A camera focuses light like an eye and captures the image with a detector.
- The CCD detectors in digital cameras are similar to those used in modern telescopes (millions of pixels).
- Uses the particle property of light. Counting photons.

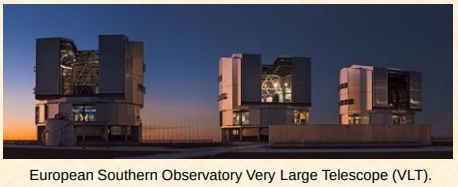
Telescopes: Giant Eyes

- What are the two most important properties of a telescope?



Light-Collecting Area

- A telescope's diameter (d) tells us its light-collecting area: $A = p(d/2)^2$
- The largest telescopes currently in use have a diameters of 8-10 meters.



European Southern Observatory Very Large Telescope (VLT). Four 8.2 meter diameter telescope mirrors.

Clicker Question

How does the collecting area of a 10-meter telescope compare with that of a 2-meter telescope?

a) It's 5 times greater.
b) It's 10 times greater.
c) It's 25 times greater.

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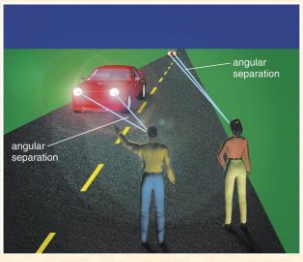
Angular Resolution

- The minimum angular separation that the telescope can distinguish
- Diffraction limit for a telescope = 2.5×10^5 arcsec x **λ / D**
  λ = wavelength
  D = telescope diameter



- Better resolution corresponds to small values of the ratio **λ / D**. For example, the Hubble Space Telescope: D=2.4 meters, $\lambda = 5 \times 10^{-7}$ meters, this limit is **0.05 arcseconds**.

Clicker Question

Which of the following is *not* an advantage of space telescopes?

A. They are closer to the astronomical objects they are observing.
B. They are unaffected by atmospheric turbulence, which affects angular resolution.
C. They are able to detect light that is blocked by the atmosphere.
D. None of the above (all are advantages)

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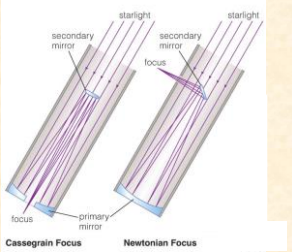
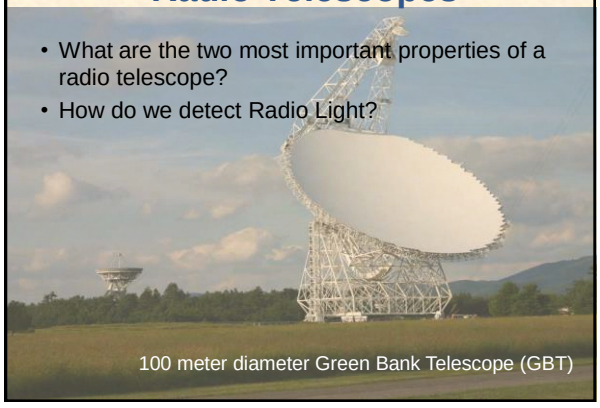
Reflecting Telescope



- Focuses light using mirrors
- Reflecting telescopes can have much greater diameters.
- Most modern telescopes use large mirrors.

Radio Telescopes

- What are the two most important properties of a radio telescope?
- How do we detect Radio Light?



100 meter diameter Green Bank Telescope (GBT)

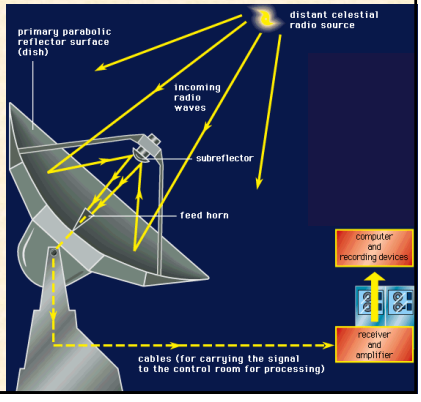
Radio Telescopes: Even bigger Eyes

- Angular Resolution
  - 2.5×10^5 arcsec x **λ / D** λ = wavelength & D = telescope diameter
  - λ = 1 cm & D = 100 meters for the GBT
  - Angular resolution = 25 arcseconds
- Collecting Area
  - $A = \pi * (D/2)^2$
  - Area = 7900 m^2
- Compared to Hubble the GBT has:
  - 500 times less angular resolution
  - 1800 times the light collecting area!
- This lets astronomers detect very faint radio emission

How does it work?

Just like an visible light reflecting telescope a reflecting surface (dish) focuses light.

How we detect light is a different story.



Detecting Radio Light

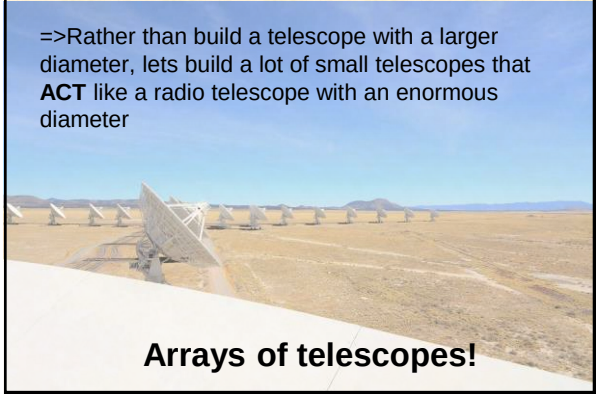
- To detect radio light we typically use the wave nature of light
  - Radio waves carry energy and can move electrons back and forth in an antenna (just like your car radio)
  - The movement of electrons in the antenna is the radio signal that we measure.
  - We can measure the **Amplitude** (how much signal) and the **Frequency** (the frequency/wavelength of light)
- Radio telescopes only have 1 "pixel" but they take a spectrum wherever they look.

How do we improve angular resolution?

- Make it BIGGER!!!
  - GBT is 100 meters in diameter (largest movable structure on land)
  - Arecibo Radio Telescope is built in a crater (300 meters in diameter)
  - Chinese are building a 500 meter telescope in a crater
- To make a bigger telescope costs go as the $(\text{diameter})^3$

Wave nature of light to the rescue!!

=>Rather than build a telescope with a larger diameter, lets build a lot of small telescopes that **ACT** like a radio telescope with an enormous diameter



Arrays of telescopes!

Building Giant Arrays

- Using the wave properties of light it is possible to collect radio light with individual small telescopes and combine the signals to simulate a telescope that is the size of the array.
- This is how the VLA and ALMA work.