Lecture 12: Optical Telescopes

Launching the Hubble Space Telescope

Telescopes

- Telescopes gather photons like a "light bucket"
- The larger the telescope, the more light it collects
- More light allows us to study fainter objects and obtain more detail
- Optical telescopes focus visible light

Telescopes

- Reflecting telescopes use mirrors to focus light and form an image
- Refracting telescopes use lenses to focus the light
Reflecting Telescopes

- Reflecting telescopes use mirrors to focus light and form an image.
- Light that enters from stars is parallel to the telescopes axis and is focused by the primary mirror.

Formation of image in mirror
Refracting Telescopes

- Refracting telescopes use lenses to focus the light.
- Light entering parallel to the telescope's axis is focused by a primary lens.
- This is the same design used by Galileo for his telescope.
The US Naval Observatory in Washington, DC has an historic 26" Clark Refractor – one of the largest in the world.

World’s largest reflecting telescope – 40" at Yerkes Observatory.

A large research-class reflecting telescope.
Telescopes

- The lens in a refractor works somewhat like a prism, causing a beam of white light to spread out.

- This causes a lens in a refractor to focus red and blue light to different focal points, which is called chromatic aberration.

Chromatic Aberration

- Chromatic aberration blurs color photographs taken using refractor telescopes.

- In a reflector, light is focused to the same point (the focal point) regardless of its color.

- There is no chromatic aberration when a mirror is used.
Reflectors vs. Refractors

- Large lenses are very heavy (a big chunk of solid glass), and they can be supported only from the sides (only the thin edges)

- Mirrors can be supported along the entire back

Reflectors vs. Refractors

- Most large telescopes are reflectors

Equatorial Mounting

- All telescopes mounts need to have two axis of rotation so that they can reach the entire sky
- Equatorial telescope mounts have one axis aligned with the Earth’s rotation axis
Equatorial Mounting

- Using an equatorial mounting, the diurnal motion of objects can be followed by rotating just on the polar axis.
- The declination axis can remain locked during the tracking.
- Most large telescopes have equatorial mounts.
Advantages of Reflectors

• Reflectors are generally better than refractors because
  • It’s difficult to fabricate very large lenses
  • Mirrors only need to be polished on one side
  • Lenses can only be supported on the (thin) edge
  • Mirrors can be supported along the entire back
  • Mirrors have no problem with chromatic aberration

Research Reflectors

• There are several different configurations in use for reflecting large telescopes
  • Prime Focus
  • Newtonian Focus
  • Cassegrain Focus
  • Coude Focus

• Many large telescopes can be set up in multiple modes
Information from Light

- The light received through the telescope can be analyzed in different ways
  - Directly view image using eyepiece
  - Replace eyepiece with photographic plate or CCD camera
  - Use photometer to count all photons
  - Use spectrometer to measure spectrum of radiation
  - Use spectrophotometer to count photons in several wavelength bands

Why Larger Telescopes?

- Large telescopes gather more light, giving brighter images
  - The additional photons give more detail and higher magnification

- The amount of radiation collected by a telescope each second is proportional to its collecting area

\[ Area = \pi \times R^2 \]

- If \( R_2 \) is twice as large as \( R_1 \), then telescope 2 collects 4 times the radiation collected by telescope 1
Resolving Power

- When light enters a telescope, it is bent slightly:
  - The angle of bending limits the resolution of the telescope
  - This depends on the aperture of the telescope, \( D = 2 \times R \)

- The bending angle is given by
  \[
  \Delta (\text{arcsec}) = 0.25 \times \frac{A(\mu m)}{D(m)}
  \]

- Here, the wavelength is measured in micrometers and the aperture is measured in meters
- This angle is the theoretical limit of resolution for the telescope