Chapter 3
Telescopes
Units of Chapter 3

Optical Telescopes
Telescope Size
High-Resolution Astronomy
Radio Astronomy
Other Astronomies
3.1 Optical Telescopes

Images can be formed through reflection or refraction

Reflecting mirror:
3.1 Optical Telescopes

Refracting lens:

(a) Light ray refracted when it passes from air into glass
    Ray refracted a second time when it passes from glass into air
    Large deflection angle

(b) Lens axis
    Light rays
    Focus
    Focal length

Copyright © 2007 Pearson Prentice Hall, Inc.
3.1 Optical Telescopes

Image formation:
3.1 Optical Telescopes
Reflecting and refracting telescopes:
3.1 Optical Telescopes

Modern telescopes are all reflectors:

• Light traveling through a lens is refracted differently depending on wavelength

• Some light traveling through a lens is absorbed

• Large lenses can be very heavy, and can only be supported at the edge

• A lens needs two optically acceptable surfaces, a mirror only needs one
3.1 Optical Telescopes

Types of reflecting telescopes:

(a) Prime focus
(b) Newtonian focus
(c) Cassegrain focus
(d) Coudé focus

Copyright © 2007 Pearson Prentice Hall, Inc.
3.1 Optical Telescopes

Details of the Keck telescope:
3.1 Optical Telescopes

Image acquisition: charge-coupled devices (CCDs) are electronic devices, can be quickly read out and reset.
3.1 Optical Telescopes

Image processing by computers can sharpen images:

(a)  (b)  (c)  (d)

Copyright © 2007 Pearson Prentice Hall, Inc.
Discovery 3-1: The Hubble Space Telescope

The Hubble Space Telescope has several instruments:
Resolution achievable by the Hubble Space Telescope:
3.2 Telescope Size

Light-gathering power:
Improves detail
Brightness proportional to square of radius of mirror

Right: (b) was taken with a telescope twice the size of (a)
3.2 Telescope Size

Multiple telescopes: Mauna Kea
3.2 Telescope Size
The VLT (Very Large Telescope), Chile
3.2 Telescope Size

Resolving power: When better, can distinguish objects that are closer together.

Resolution is proportional to wavelength and inversely proportional to telescope size.
3.2 Telescope Size

Effect of improving resolution:

(a) 10′; (b) 1′; (c) 5″; (d) 1″
3.3 High-Resolution Astronomy

Atmospheric blurring: due to air movements

Parallel rays of light from distant star

Rays deflected slightly as they pass through Earth's turbulent atmosphere

Seeing disk — smeared-out image of star in long-duration exposure

Diameter ≈ 1"

Individual sharp images of star (each lasting for fraction of second)
3.3 High-Resolution Astronomy

Solutions:
- Put telescopes on mountaintops, especially in deserts
- Put telescopes in space
- Active optics – control mirrors based on temperature and orientation
3.4 Radio Astronomy

Radio telescopes:

- Similar to optical reflecting telescopes
- Prime focus
- Less sensitive to imperfections (due to longer wavelength); can be made very large
3.4 Radio Astronomy

Largest radio telescope: 300-m dish at Arecibo
3.4 Radio Astronomy

Longer wavelength means poor angular resolution

Advantages of radio astronomy:

• Can observe 24 hours a day

• Clouds, rain, and snow don’t interfere

• Observations at an entirely different frequency; get totally different information

![Radio galaxy image with labels: Visible galaxy, Radio emission]
3.4 Radio Astronomy

Interferometry:
• Combine information from several widely-spread radio telescopes as if they came from a single dish

• Resolution will be that of dish whose diameter = largest separation between dishes
3.4 Radio Astronomy

Interferometry requires preserving the phase relationship between waves over the distance between individual telescopes.
3.4 Radio Astronomy

Can get radio images whose resolution is close to optical:
3.4 Radio Astronomy

Interferometry can also be done with visible light, but much harder due to shorter wavelengths:
3.5 Other Astronomies
Infrared radiation can image where visible radiation is blocked; generally can use optical telescope mirrors and lenses
Infrared telescopes can also be in space or flown on balloons:
3.5 Other Astronomies

Ultraviolet images.

(a) The Cygnus loop supernova remnant

(b) M81
3.5 Other Astronomies

X-rays and gamma rays will not reflect off mirrors as other wavelengths do; need new techniques.

X-rays will reflect at a very shallow angle, and can therefore be focused:

(a) Incoming X-rays
(b) Nested cylindrical mirrors

Focus

Copyright © 2007 Pearson Prentice Hall, Inc.
3.5 Other Astronomies

X-ray image of supernova remnant Cassiopeia A:
3.5 Other Astronomies

Gamma rays cannot be focused at all; images are therefore coarse:
3.5 Other Astronomies

Much can be learned from observing the same astronomical object at many wavelengths. Here, the Milky Way.
Summary of Chapter 5

- Refracting telescopes make images with a lens
- Reflecting telescopes with a mirror
- Modern research telescopes are all reflectors
- CCDs are used for data collection
- Data can be formed into image, analyzed spectroscopically, or used to measure intensity
- Large telescopes gather much more light, allowing study of very faint sources
- Large telescopes also have better resolution
Summary of Chapter 5, cont.

• Resolution of ground-based optical telescopes is limited by atmospheric effects

• Resolution of radio or space-based telescopes is limited by diffraction

• Active and adaptive optics can minimize atmospheric effects

• Radio telescopes need large collection area; diffraction limited

• Interferometry can greatly improve resolution
Summary of Chapter 5, cont.

- Infrared and ultraviolet telescopes are similar to optical
- Ultraviolet telescopes must be above atmosphere
- X-rays can be focused, but very differently than visible light
- Gamma rays can be detected but not imaged