CHAPTER 6
TELESCOPES: PORTALS OF DISCOVERY

6.1 Eyes and Cameras: Everyday Light Sensors

Our goals for learning:

- How does your eye form an image?
- How do we record images?

Refraction

- Refraction is the bending of light when it passes from one substance into another
- Your eye uses refraction to focus light

Focusing Light

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

Image Formation

- The focal plane is where light from different directions comes into focus
- The image behind a single (convex) lens is actually upside-down!

Focusing Light

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

What have we learned?

- How does your eye form an image?
  - It uses refraction to bend parallel light rays so that they form an image.
  - The image is in focus if the focal plane is at the retina.
- How do we record images?
  - Cameras focus light like your eye and record the image with a detector.
  - The detectors (CCDs) in digital cameras are like those used on modern telescopes

6.2 Telescopes: Giant Eyes

Our goals for learning:

- What are the two most important properties of a telescope?
- What are the two basic designs of telescopes?
- What do astronomers do with telescopes?

What are the two most important properties of a telescope?

1. **Light-collecting area:** Telescopes with a larger collecting area can gather a greater amount of light in a shorter time.
2. **Angular resolution:** Telescopes that are larger are capable of taking images with greater detail.

Angular Resolution

- The *minimum* angular separation that the telescope can distinguish.
- Ultimate limit to resolution comes from interference of light waves within a telescope.
- Larger telescopes are capable of greater resolution because there's less interference

Interactive Figure

Angular Resolution

- The rings in this image of a star come from interference of light wave.
- This limit on angular resolution is known as the **diffraction limit**

Close-up of a star from the Hubble Space Telescope

What are the two basic designs of telescopes?

- **Refracting telescope:** Focuses light with lenses
- **Reflecting telescope:** Focuses light with mirrors

Refracting Telescope

- Refracting telescopes need to be very long, with large, heavy lenses

Reflecting Telescope

- Reflecting telescopes can have much greater diameters
- Most modern telescopes are reflectors

What do astronomers do with telescopes?

- **Imaging:** Taking pictures of the sky
- **Spectroscopy:** Breaking light into spectra
- **Timing:** Measuring how light output varies with time

Imaging

- Astronomical detectors generally record only one color of light at a time
- Several images must be combined to make full-color pictures

Imaging

- Astronomical detectors can record forms of light our eyes can't see
- Color is sometimes used to represent different energies of nonvisible light

Interactive Figure

Spectroscopy

- A spectrograph separates the different wavelengths of light before they hit the detector

Spectroscopy

- Graphing relative brightness of light at each wavelength shows the details in a spectrum

Timing

- A light curve represents a series of brightness measurements made over a period of time

Want to buy your own telescope?

- Buy binoculars first (e.g. 7x35) - you get much more for the same money.
- Ignore magnification (sales pitch!)
- Notice: aperture size, optical quality, portability.
- Consumer research: Astronomy, Sky & Tel, Mercury. Astronomy clubs.

What have we learned?

- What are the two most important properties of a telescope?
  - Collecting area determines how much light a telescope can gather
  - Angular resolution is the minimum angular separation a telescope can distinguish
- What are the two basic designs of telescopes?
  - Refracting telescopes focus light with lenses
  - Reflecting telescopes focus light with mirrors
  - The vast majority of professional telescopes are reflectors

What have we learned?

- What do astronomers do with telescopes?
  - Imaging
  - Spectroscopy
  - Timing

6.3 Telescopes and the Atmosphere

Our goals for learning:

- How does Earth's atmosphere affect ground-based observations?
- Why do we put telescopes into space?

How does Earth's atmosphere affect ground-based observations?

- The best ground-based sites for astronomical observing are
  - Calm (not too windy)
  - High (less atmosphere to see through)
  - Dark (far from city lights)
  - Dry (few cloudy nights)

Twinkling and Turbulence

Turbulent air flow in Earth's atmosphere distorts our view, causing stars to appear to twinkle

What have learned?

- How does Earth's atmosphere affect ground-based observations?
  - Telescope sites are chosen to minimize the problems of light pollution, atmospheric turbulence, and bad weather.
- Why do we put telescopes into space?
  - Forms of light other than radio and visible do not pass through Earth's atmosphere.
  - Also, much sharper images are possible because there is no turbulence.

6.4 Eyes and Cameras: Everyday Light Sensors

Our goals for learning:

- How can we observe nonvisible light?
- How can multiple telescopes work together?

Radio Telescopes

- A radio telescope is like a giant mirror that reflects radio waves to a focus

X-Ray Telescopes

- Focusing of X-rays requires special mirrors
- Mirrors are arranged to focus X-ray photons through grazing bounces off the surface

Gamma Ray Telescopes

- Gamma ray telescopes also need to be in space
- Focusing gamma rays is extremely difficult

Compton Observatory

Interferometry

- Interferometery is a technique for linking two or more telescopes so that they have the angular resolution of a single large one