Chapter 6
Telescopes: Portals of Discovery

How does your eye form an image?

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!

How do we record images?

- 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.

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

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.

Light Collecting Area

- A telescope’s diameter tells us its light-collecting area: \( \text{Area} = \pi (\text{diameter}/2)^2 \)
- The largest telescopes currently in use have a diameter of about 10 meters.
Thought 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.

Angular Resolution
• The minimum angular separation that the telescope can distinguish.

Thought 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.

Angular Resolution
• Ultimate limit to resolution comes from interference of light waves within a telescope.
• Larger telescopes are capable of greater resolution (smaller angles) because there’s less interference.
What are the two basic designs of telescopes?

- **Refracting telescope**: Primary collector of light is a lens
- **Reflecting telescope**: Primary collector of light is a mirror

**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

**Designs for Reflecting Telescopes**

- Cassegrain Focus
- Newtonian Focus
- Nasmyth/Coudé Focus
Mirrors in Reflecting Telescopes

Twin Keck telescopes on Mauna Kea in Hawaii

Segmented 10-meter mirror of a Keck telescope

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

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.

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**Timing**

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

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**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.

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**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)
Light Pollution

- Scattering of human-made light in the atmosphere is a growing problem for astronomy

Twinkling and Turbulence

Turbulent air flow in Earth’s atmosphere distorts our view, causing stars to appear to twinkle. Without correction, resolution is limited to $> 1$" (same for 200-inch and 9-inch telescopes).

Adaptive Optics

Rapidly changing the shape of a telescope’s mirror compensates for turbulence
Calm, High, Dark, Dry

- The best observing sites are atop remote mountains

Summit of Mauna Kea, Hawaii

Why do we put telescopes into space?

Transmission in Atmosphere

- Only radio and visible light pass easily through Earth’s atmosphere
- We need telescopes in space to observe other forms

How can we observe nonvisible light?

- A standard satellite dish is essentially a telescope for observing radio waves
Radio Telescopes

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

IR & UV Telescopes

- Infrared and ultraviolet-light telescopes operate like visible-light telescopes but need to be above atmosphere to see all IR and UV wavelengths.

X-Ray Telescopes

- X-ray telescopes also need to be above the atmosphere.

Gamma Ray Telescopes

- Gamma ray telescopes also need to be in space.
  - Focusing gamma rays is extremely difficult.
How can multiple telescopes work together?

Interferometry

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

Interferometry

• Easiest to do with radio telescopes
• Now becoming possible with infrared and visible-light telescopes

Very Large Array (VLA)

Georgia State University’s Center for High Angular Resolution Astronomy

Mt. Wilson, California
First Science Paper from CHARA: Size and Shape of a Blue Star - Regulus