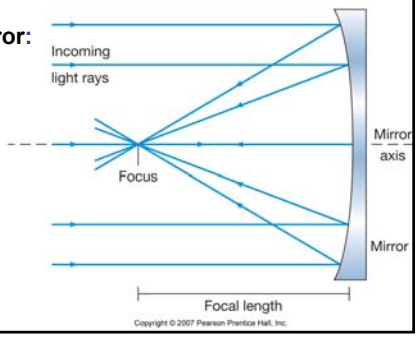
Chapter 3
Telescopes

Units of Chapter 3

3.1 Optical Telescopes

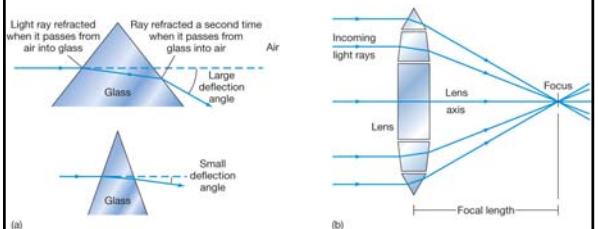
Images can be formed through **reflection** or **refraction**

Reflecting **mirror**:



3.1 Optical Telescopes

Refracting **lens**:



3.1 Optical Telescopes

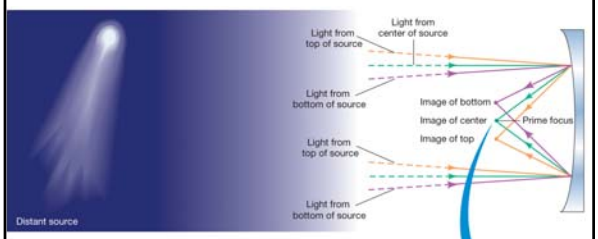
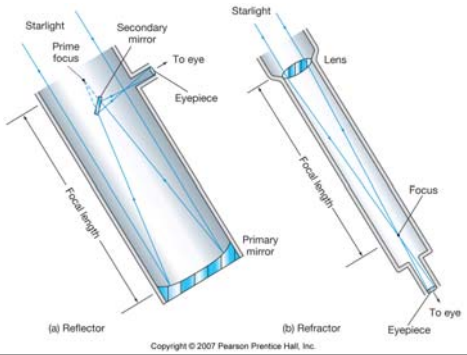


Image formation:

3.1 Optical Telescopes

Reflecting and refracting **telescopes**:



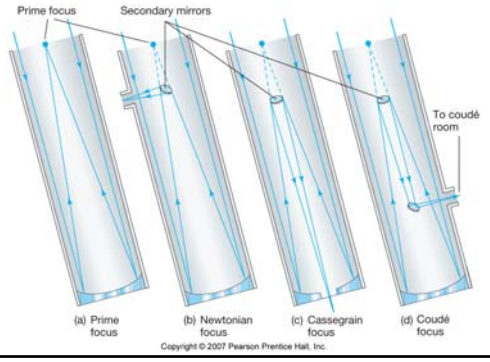
3.1 Optical Telescopes

Modern telescopes are all **reflectors**:

- Light traveling through lens is **refracted differently** depending on wavelength
- Some light traveling through lens is **absorbed**
- Large lens can be very **heavy**, and can only be supported at edge
- Lens needs **two** optically acceptable surfaces, mirror only needs one

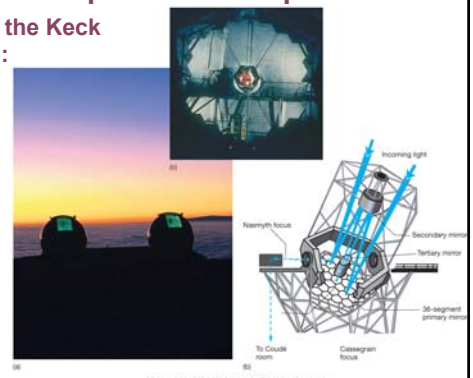
3.1 Optical Telescopes

Types of **reflecting telescopes**:



3.1 Optical Telescopes

Details of the Keck telescope:



3.1 Optical Telescopes

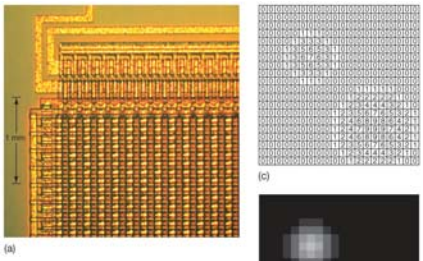
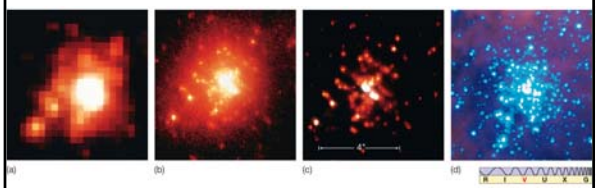


Image acquisition: charge coupled devices (**CCDs**) are electronic devices, can be quickly read out and reset

3.1 Optical Telescopes

Image processing by computers can sharpen images:



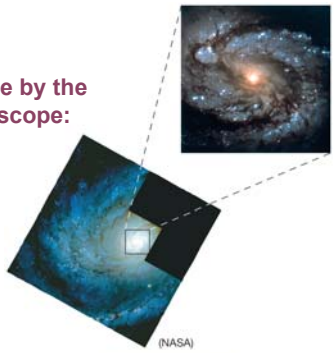
Discovery 3-1: The Hubble Space Telescope

The **Hubble Space Telescope** has several instruments:

(NASA)

Discovery 3-1: The Hubble Space Telescope

Resolution achievable by the Hubble Space Telescope:



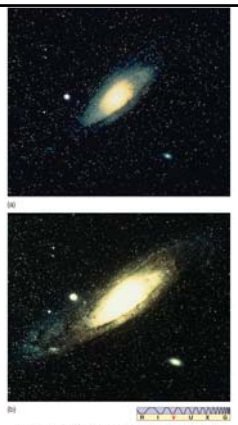
3.2 Telescope Size

Light gathering power:

Improves detail

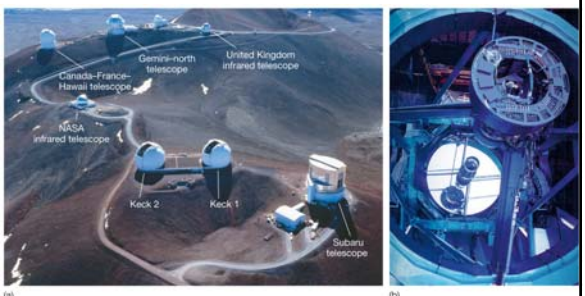
Brightness proportional to square of radius of mirror

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



3.2 Telescope Size

Multiple telescopes: Mauna Kea



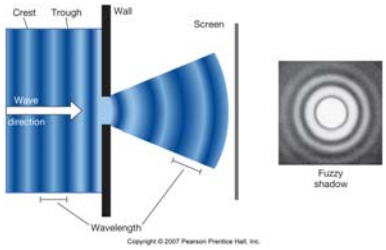
3.2 Telescope Size

The VLT (Very Large Telescope), Atacama, 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



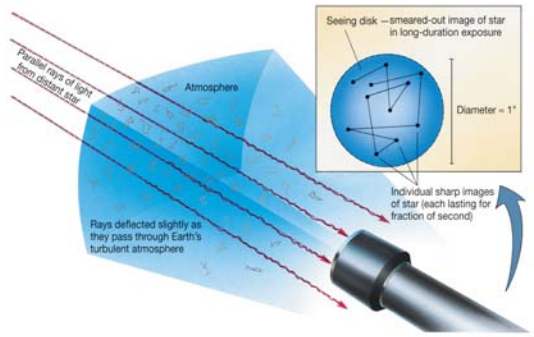
3.2 Telescope Size

Effect of improving resolution:

(a) 10′; (b) 1′; (c) 5″; (d) 1″

3.3 High-Resolution Astronomy

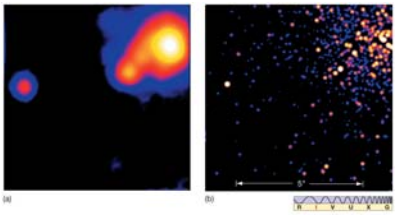
Atmospheric blurring: due to air movements



3.3 High-Resolution Astronomy

Solutions:

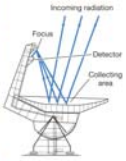
- Put telescopes on mountaintops, especially in deserts
- Put telescopes in space
- **Active optics** – control mirrors based on temperature and orientation



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

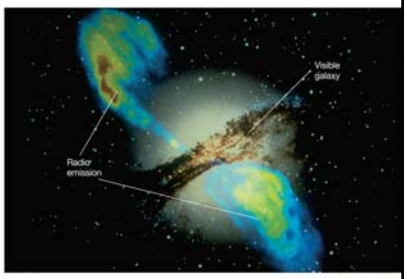
Largest radio telescope: 300-m dish at Arecibo

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



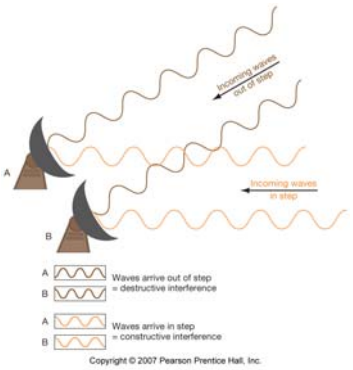
3.4 Radio Astronomy

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

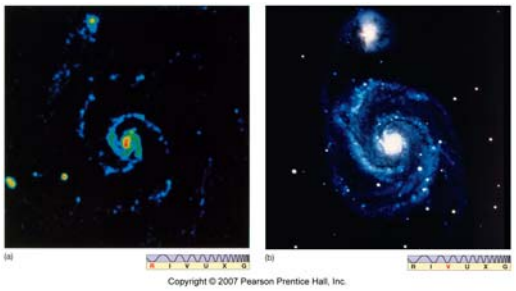
3.4 Radio Astronomy



Interferometry requires preserving the phase relationship between waves over the distance between individual telescopes

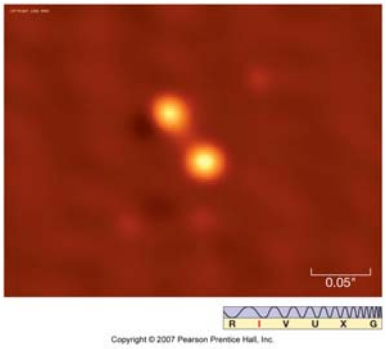
3.4 Radio Astronomy

Can get **radio images** whose **resolution** is close to optical:



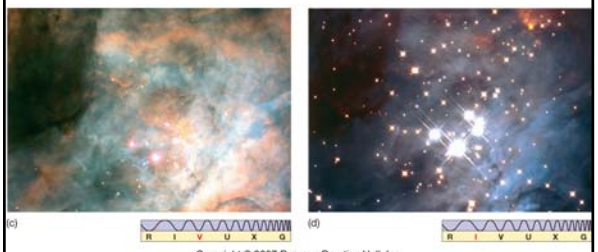
3.4 Radio Astronomy

Interferometry can also be done with visible light, but much harder due to shorter wavelengths:



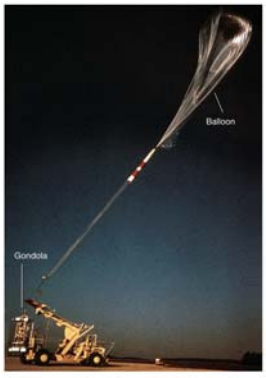
3.5 Other Astronomies

Infrared radiation can image where visible radiation is blocked; generally can use optical telescope mirrors and lenses



3.5 Other Astronomies

Infrared telescopes can also be in space or flown on balloons:

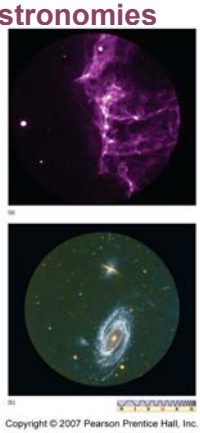


3.5 Other Astronomies

Ultraviolet images.

(a)The Cygnus loop supernova remnant

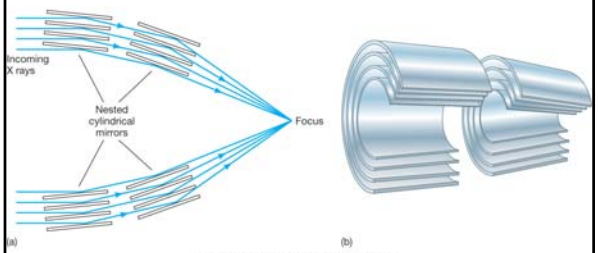
(b) M81



3.5 Other Astronomies

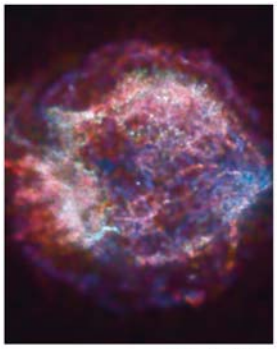
X-rays and **gamma rays** will not reflect off mirrors as other wavelengths do; need new techniques

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



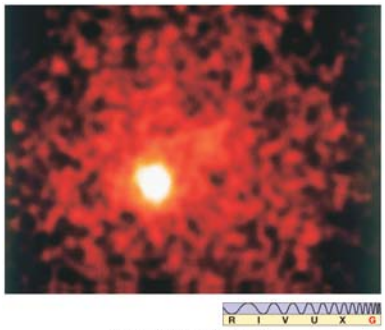
3.5 Other Astronomies

X-ray image of supernova remnant Cassiopeia A:

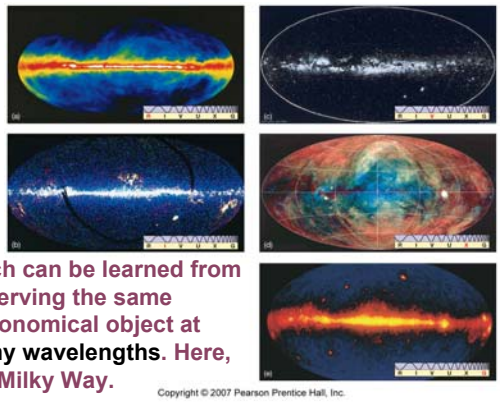


3.5 Other Astronomies

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