Chapter 3
Telescopes

Units of Chapter 3

Optical Telescopes

Telescope Size

High-Resolution Astronomy

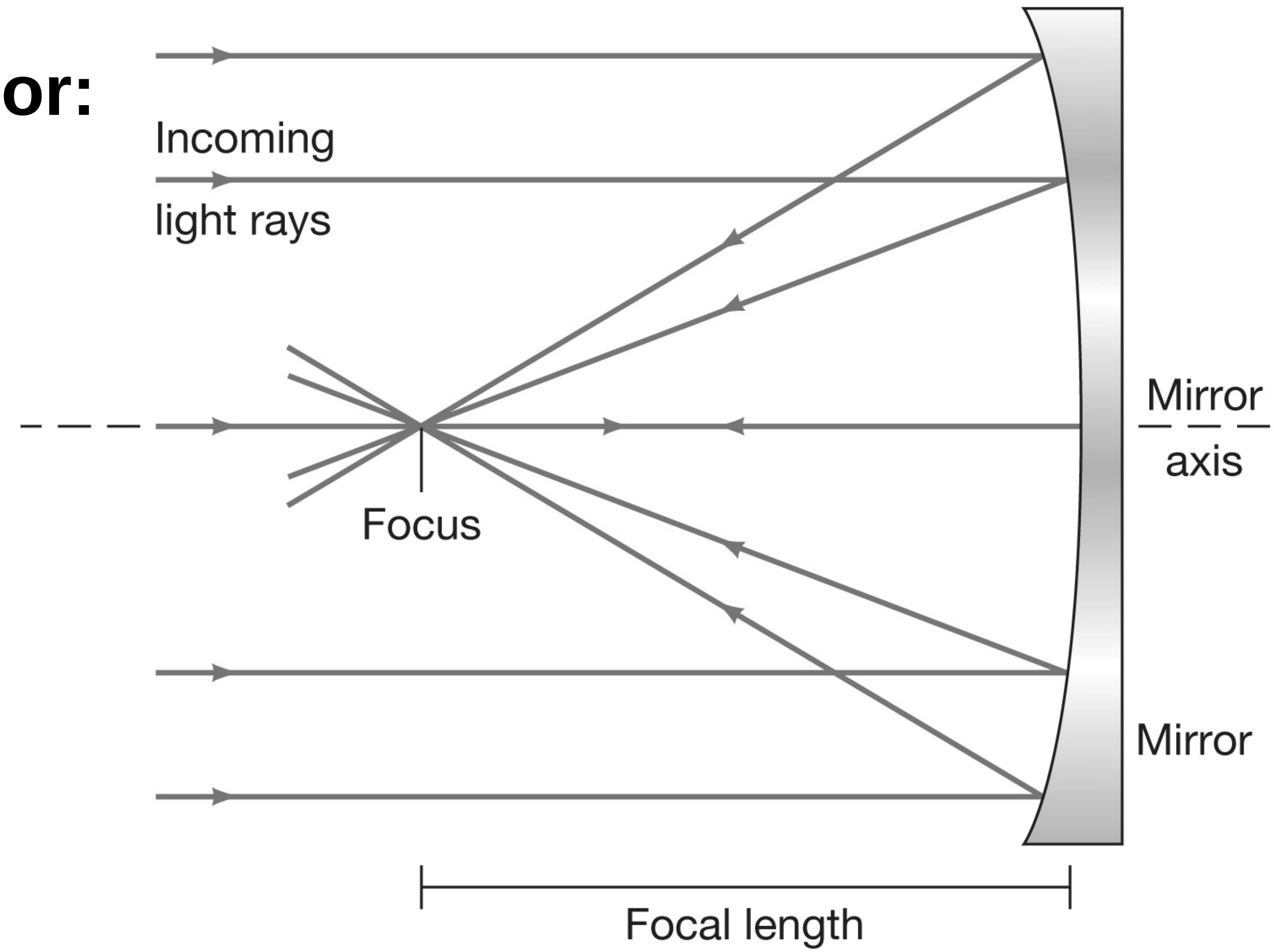
Radio Astronomy

Other Astronomies

3.1 Optical Telescopes

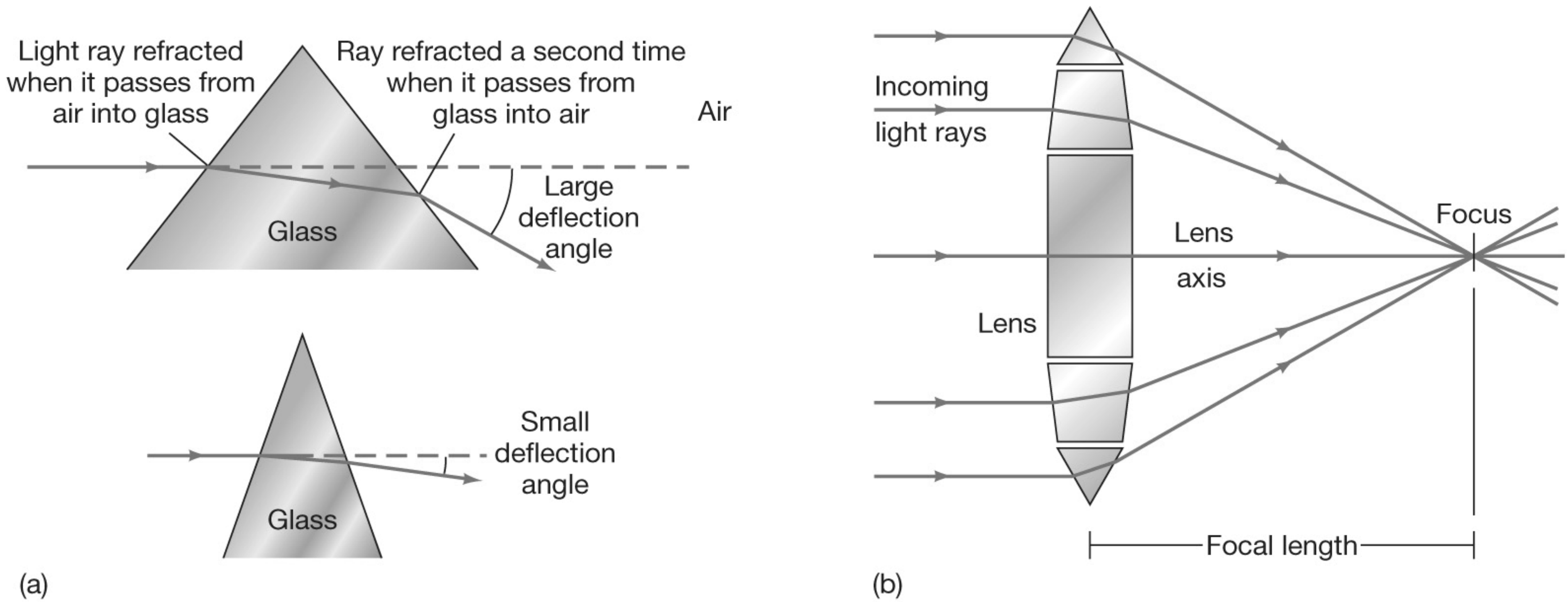
Images can be formed through reflection or refraction

Reflecting mirror:



3.1 Optical Telescopes

Refracting lens:



3.1 Optical Telescopes

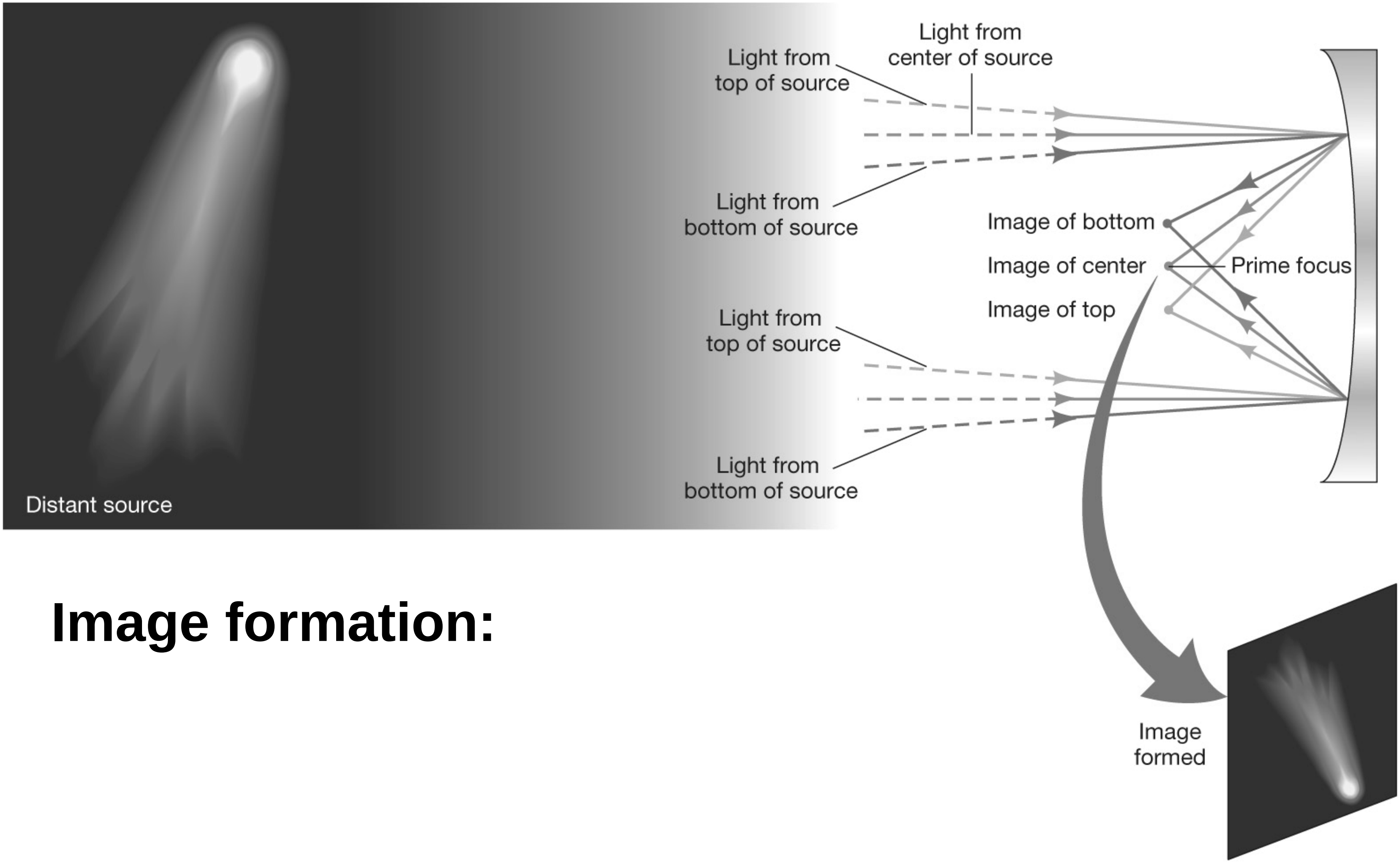
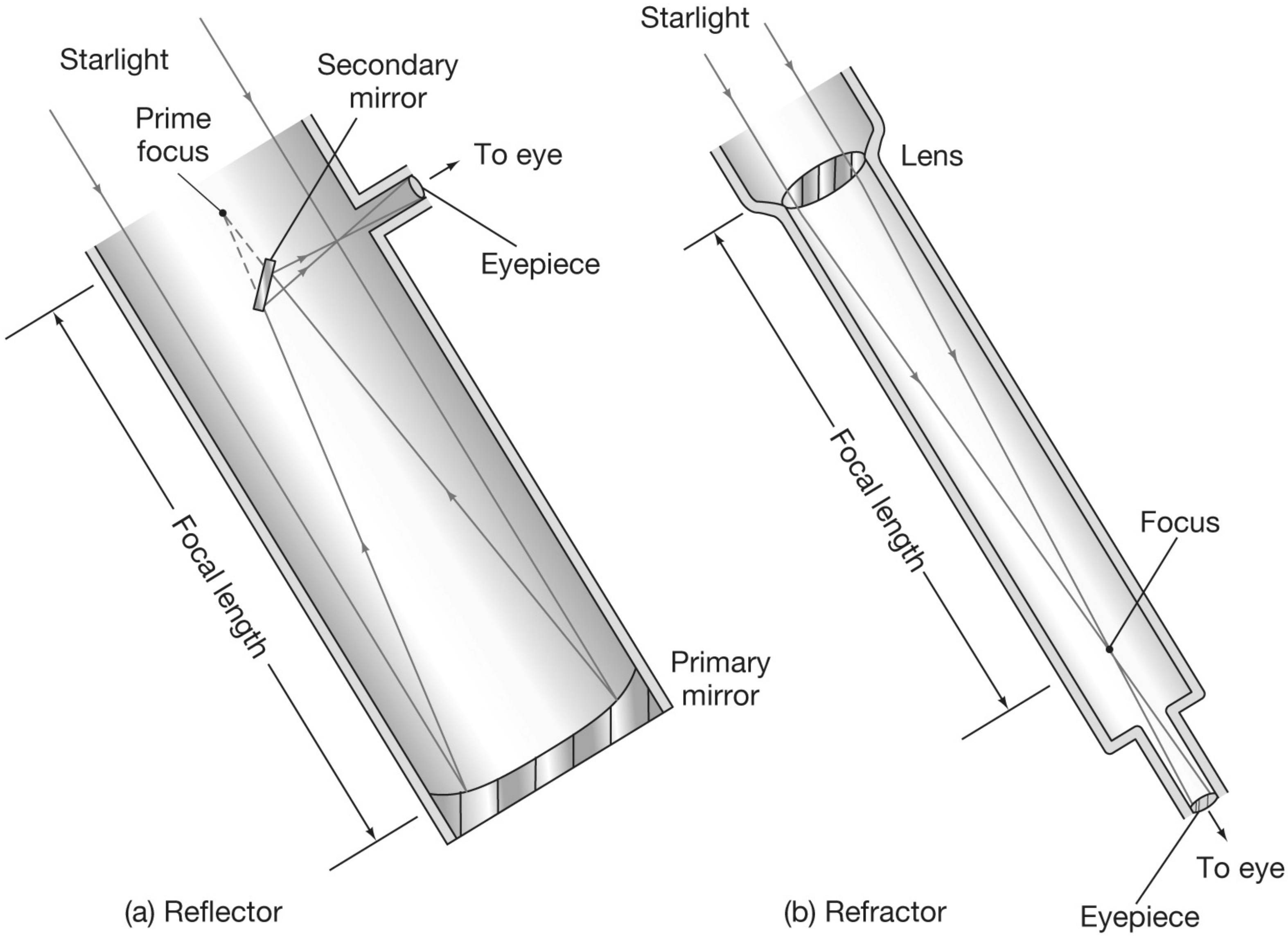


Image formation:

3.1 Optical Telescopes

Reflecting and refracting telescopes:



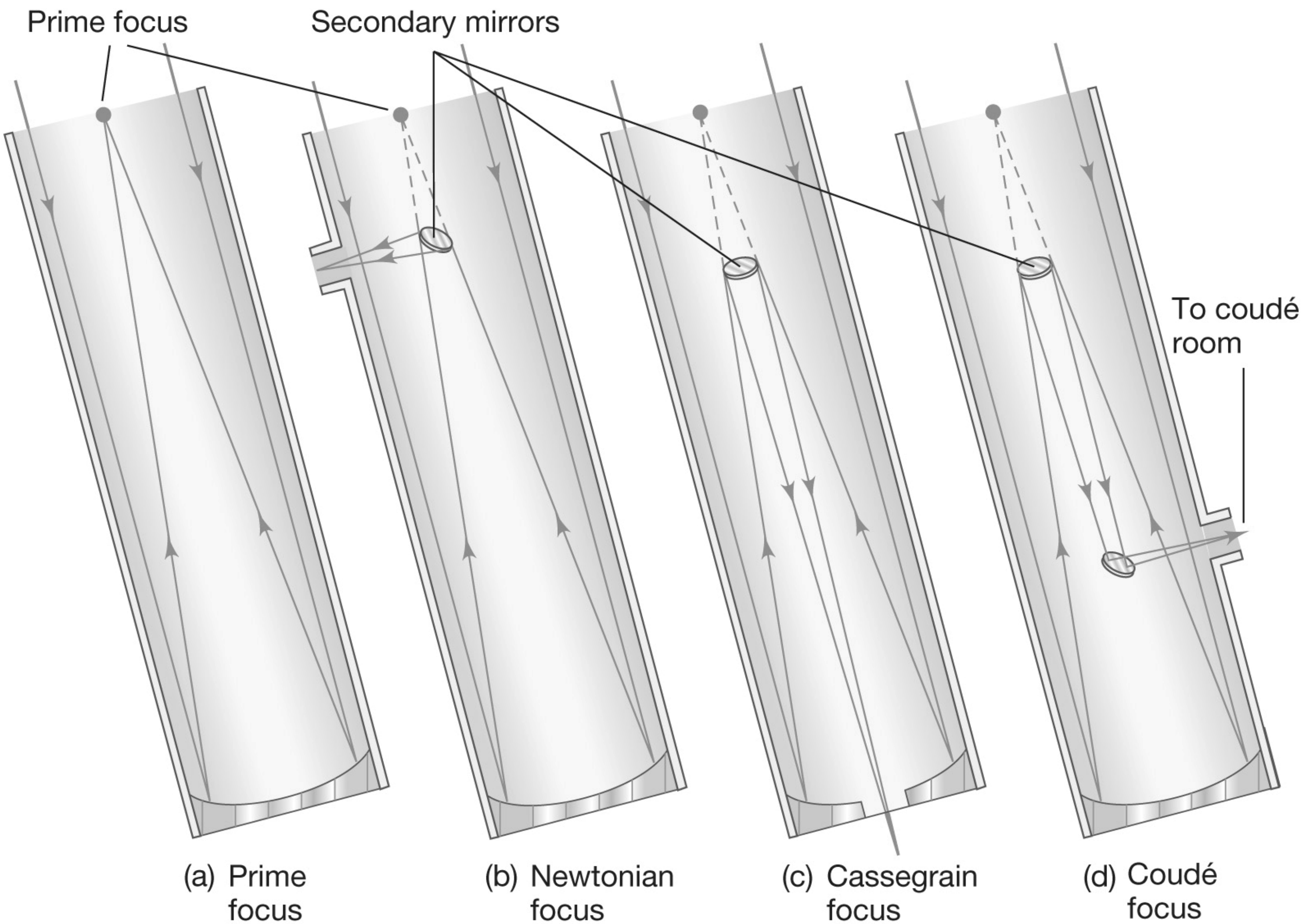
3.1 Optical Telescopes

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**

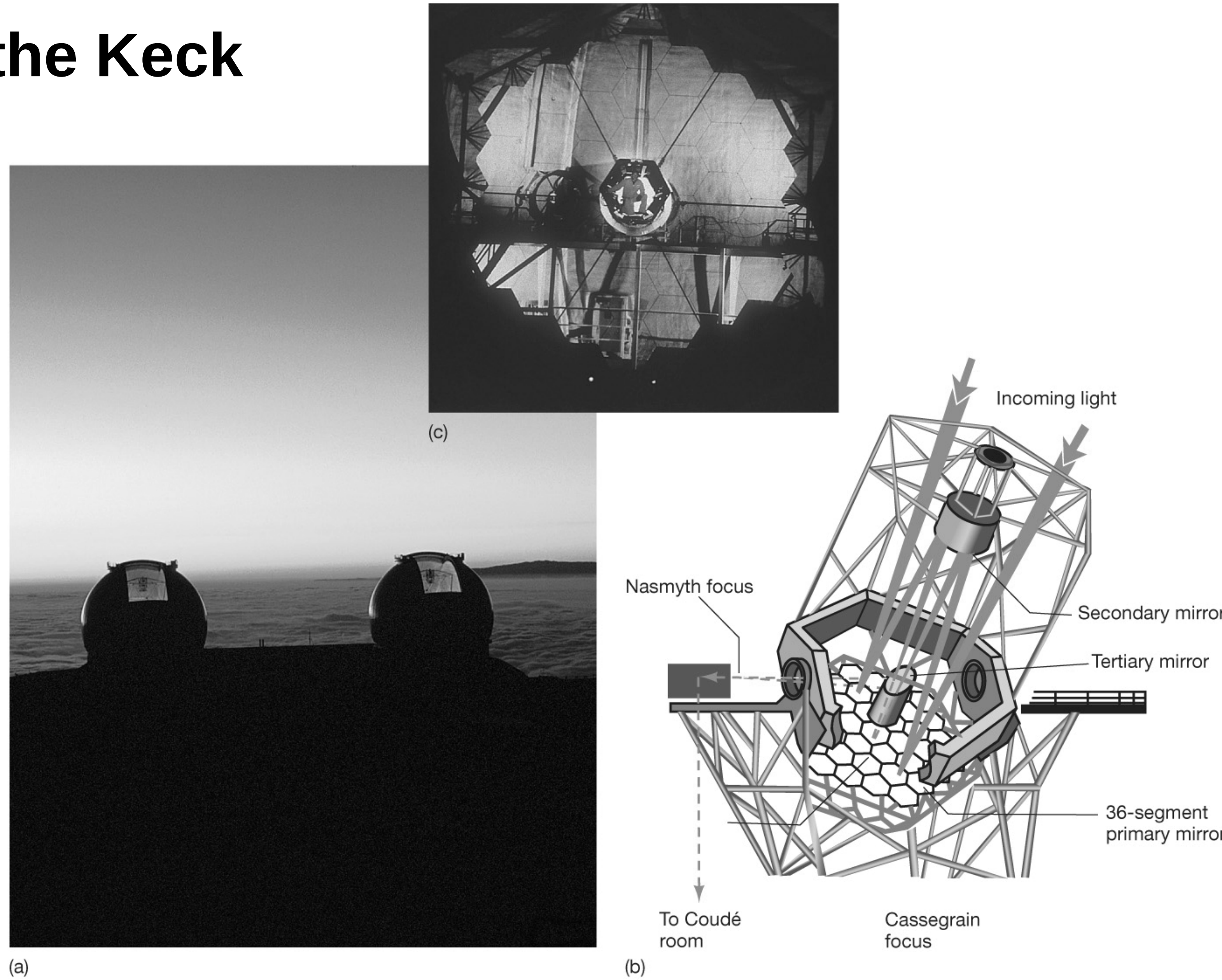
3.1 Optical Telescopes

Types of reflecting telescopes:

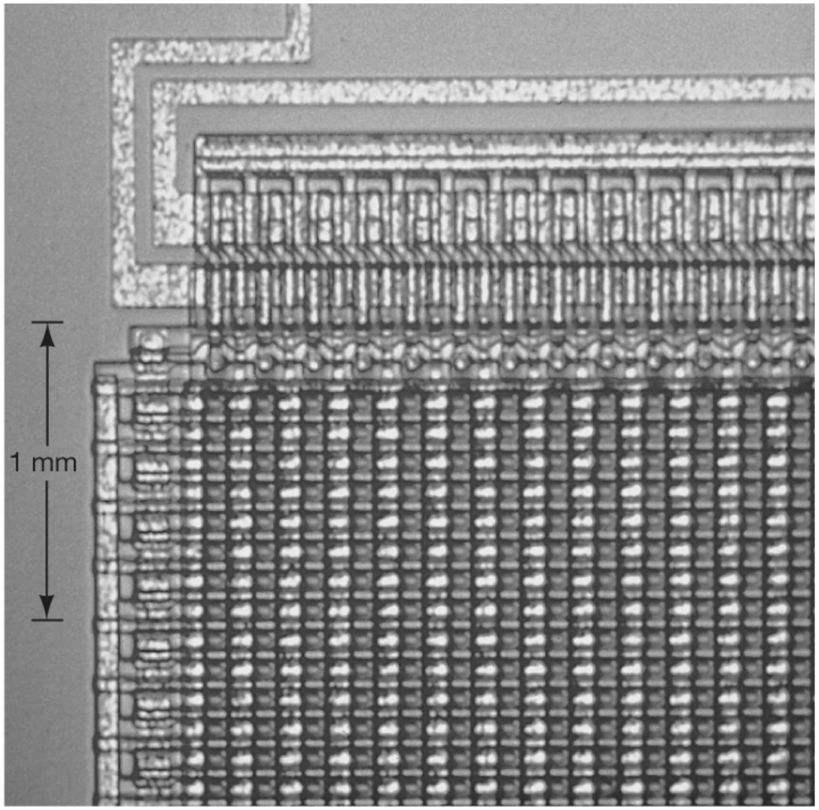


3.1 Optical Telescopes

Details of the Keck telescope:



3.1 Optical Telescopes



(a)

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	3	3	3	1	0	0	0	0	0	0	0	0	0	0	0
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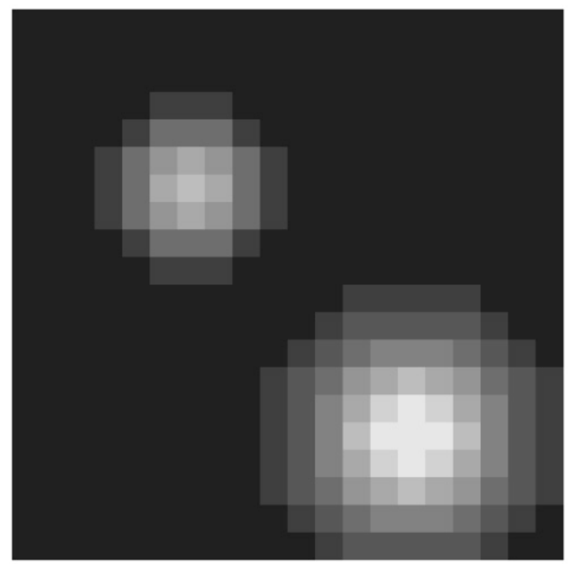
0	0	0	0	0	0	0	0	0	1	2	3	5	6	7	6	5	3	2	1
0	0	0	0	0	0	0	0	0	0	1	2	3	4	4	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	2	1	0	0

(c)

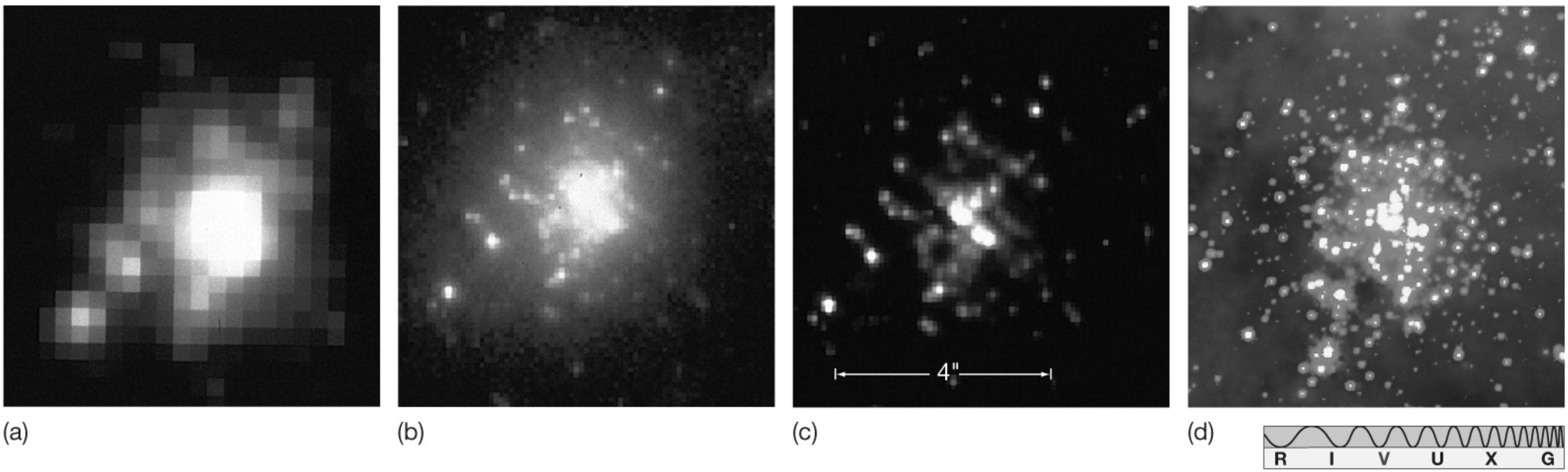


(d)

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

3.1 Optical Telescopes

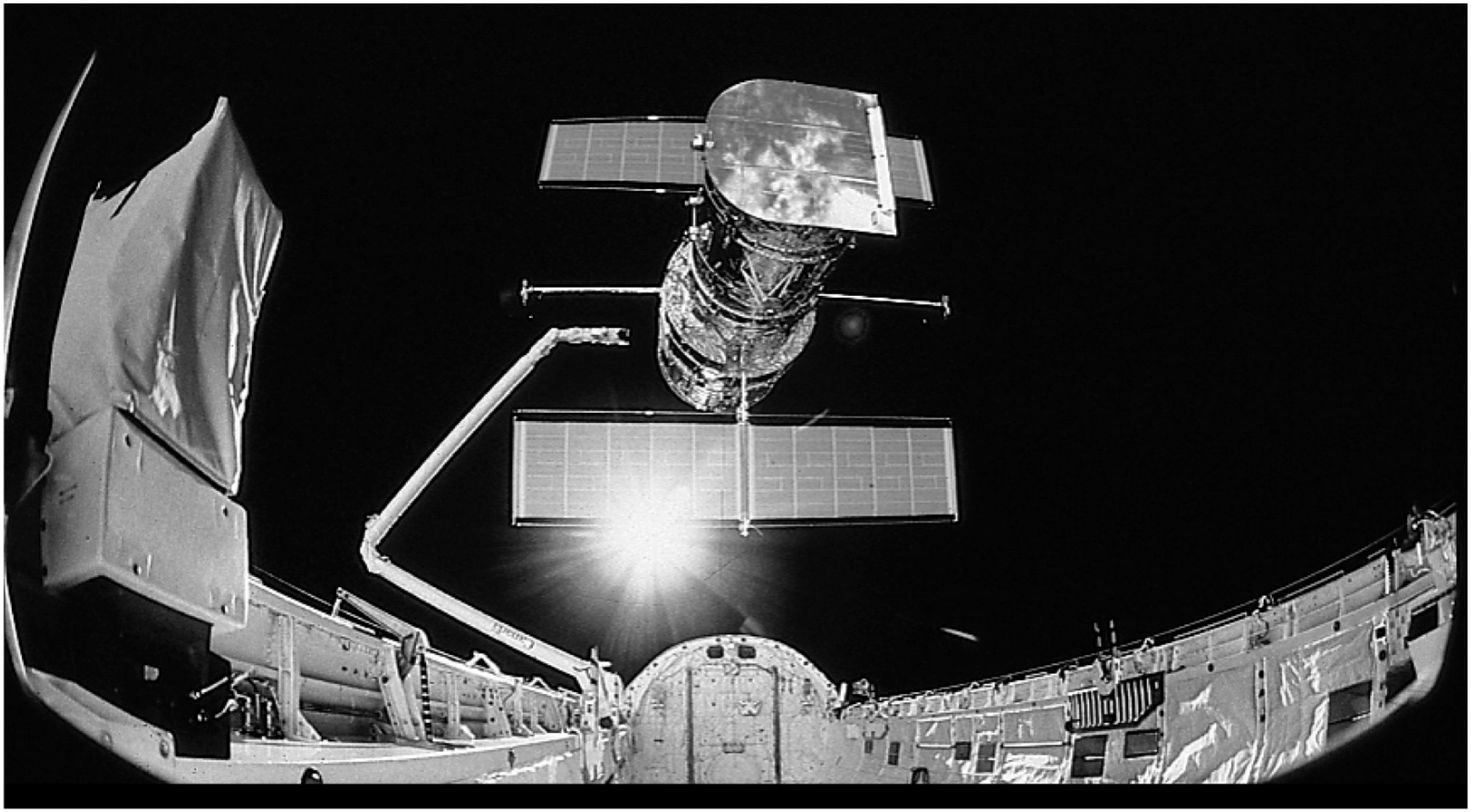
Image processing by computers can sharpen images:



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

Discovery 3-1: The Hubble Space Telescope

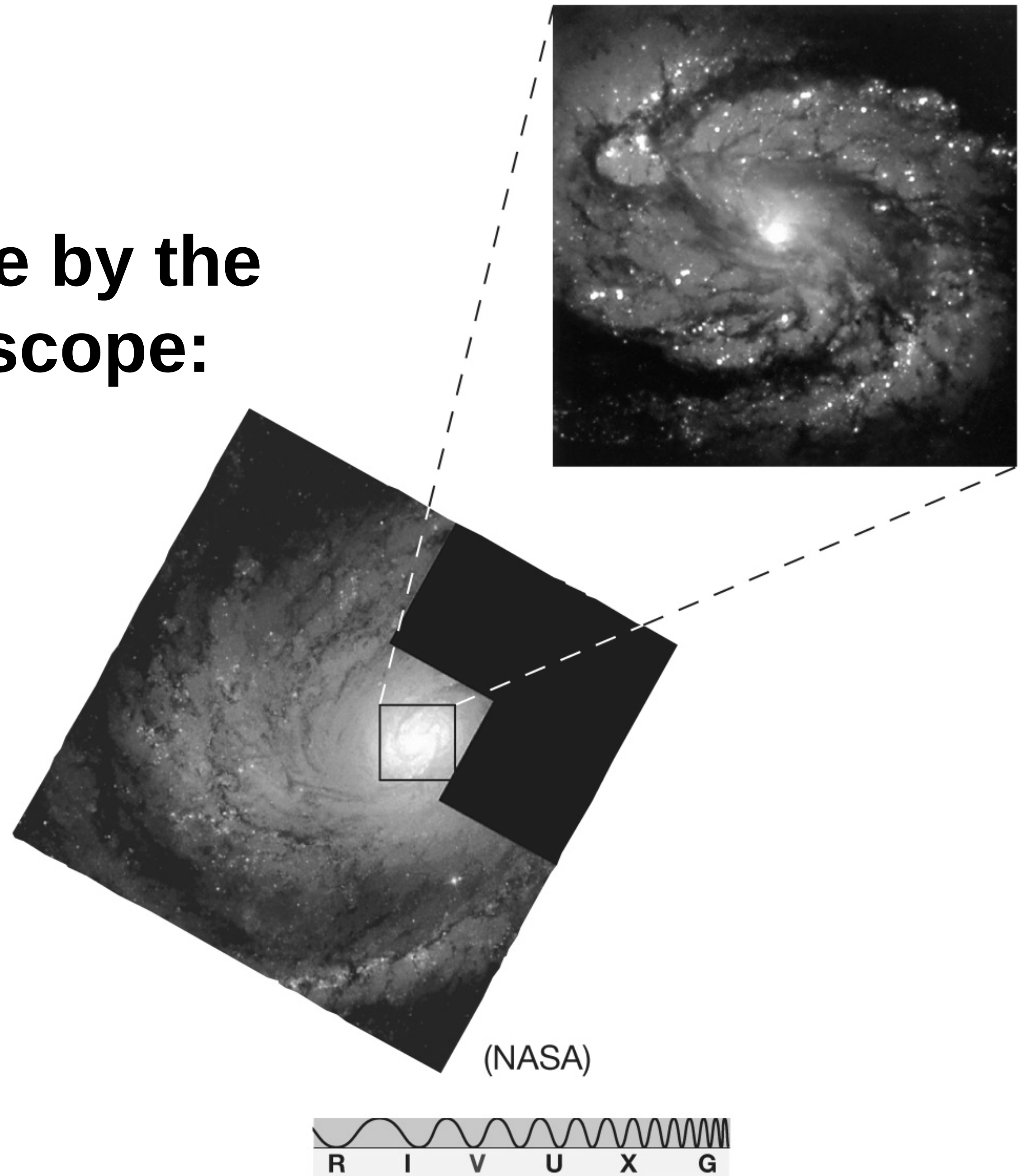
The Hubble Space Telescope has several instruments:



(NASA)

Discovery 3-1: The Hubble Space Telescope

Resolution achievable by the Hubble Space Telescope:



(NASA)

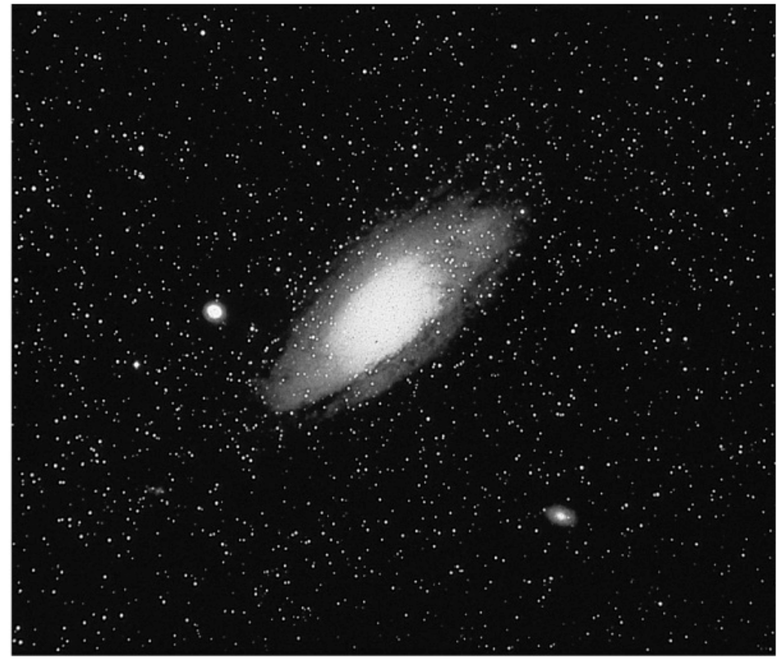
3.2 Telescope Size

Light-gathering power:

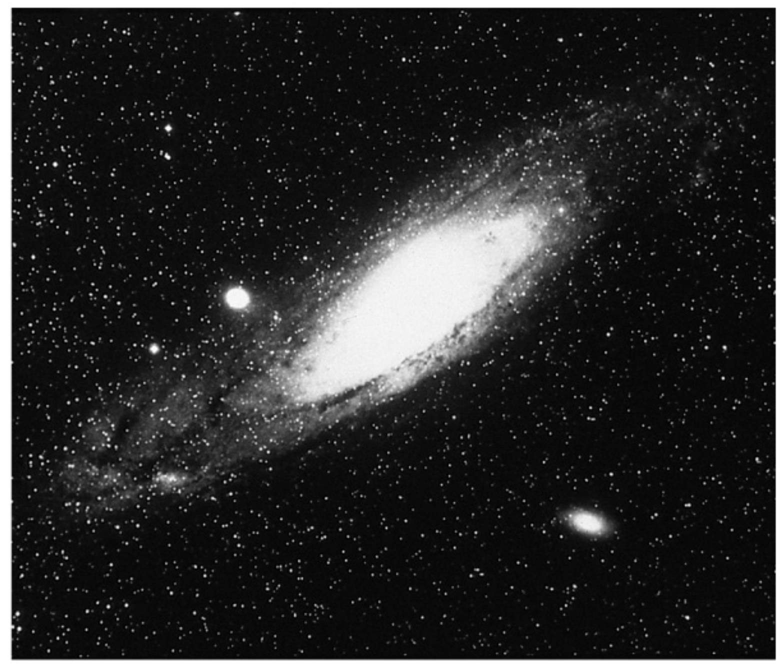
Improves detail

Brightness proportional to square of radius of mirror

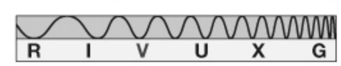
Right: (b) was taken with a telescope twice the size of (a)



(a)

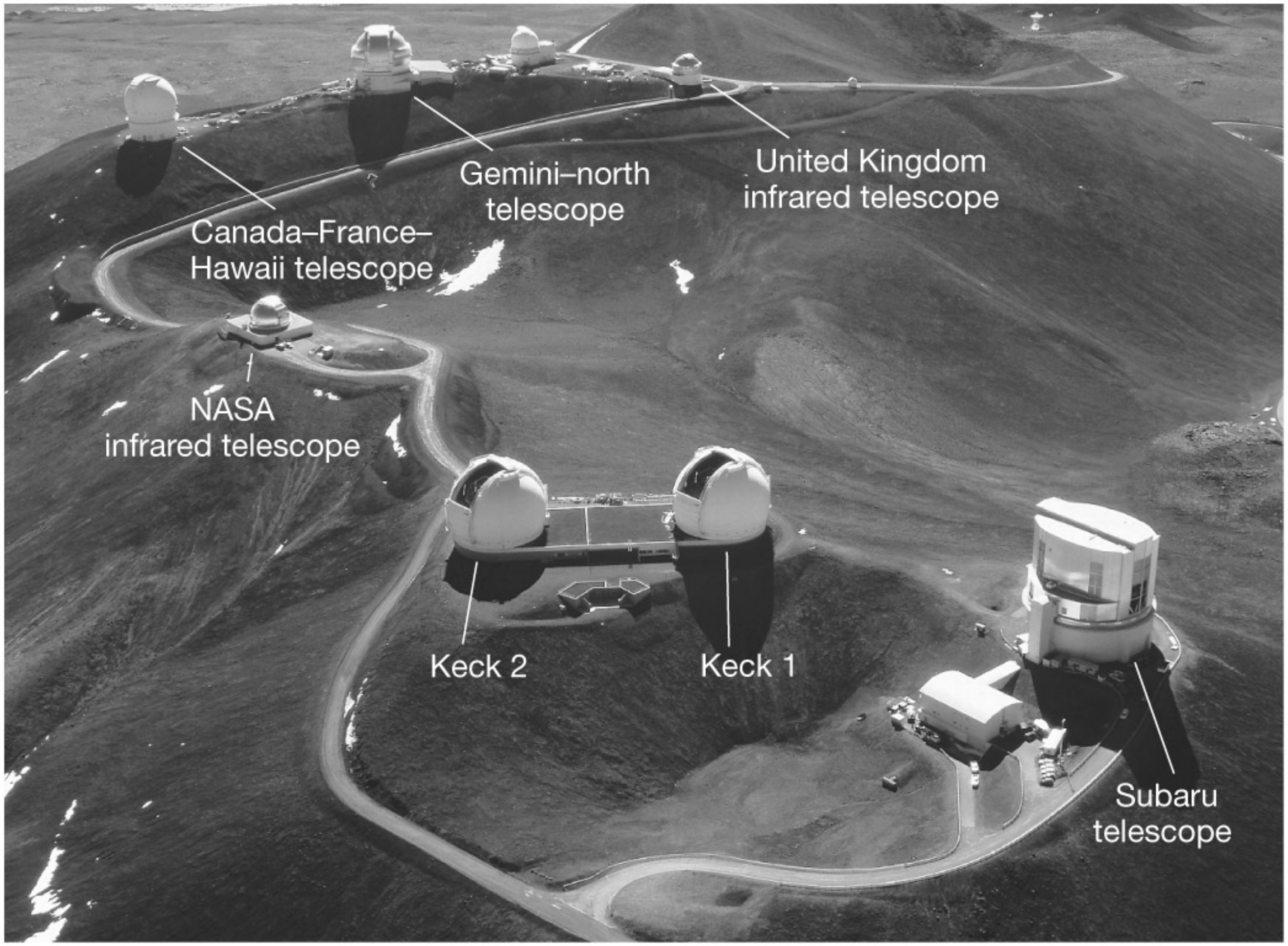


(b)

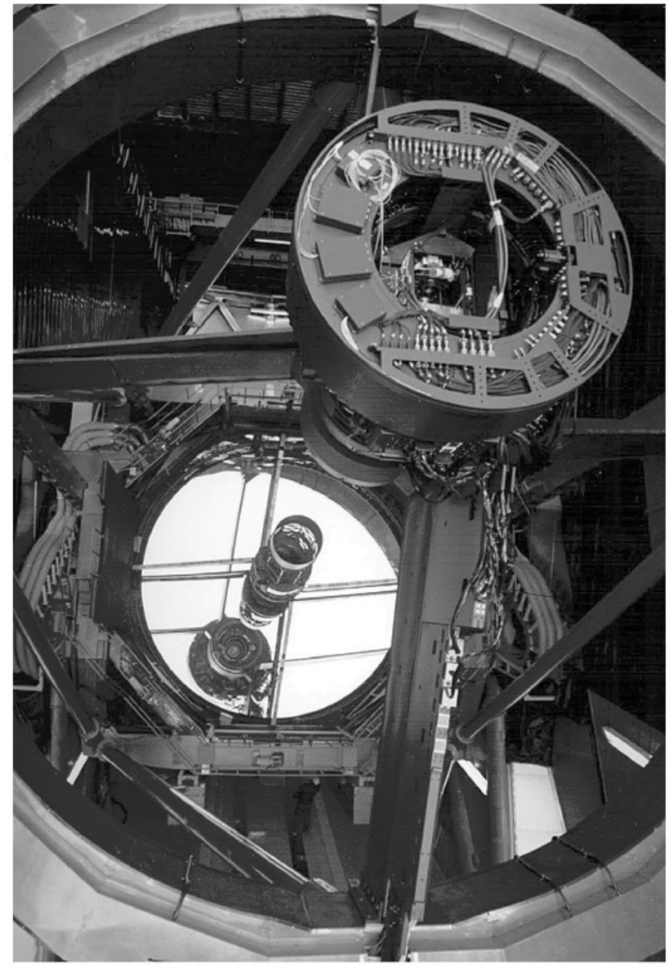


3.2 Telescope Size

Multiple telescopes: Mauna Kea



(a)



(b)

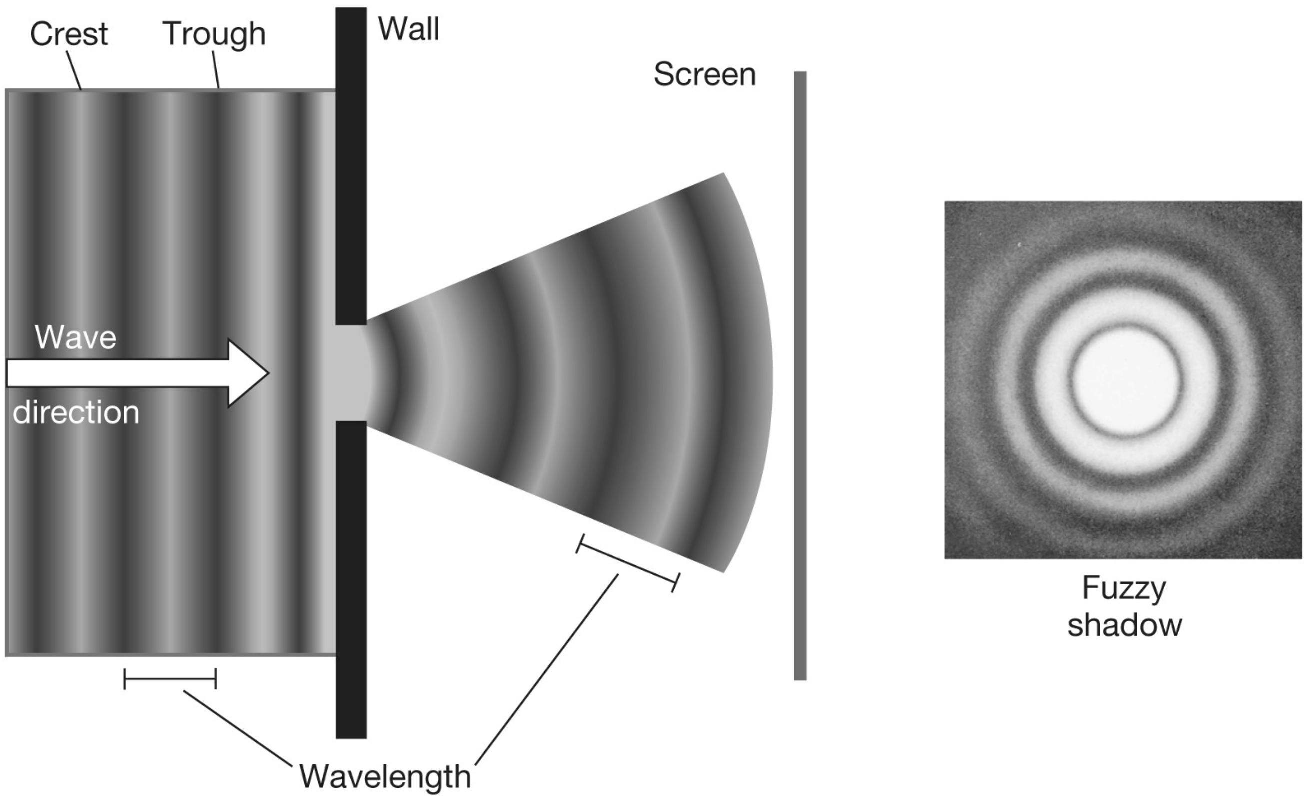
3.2 Telescope Size

The VLT (Very Large Telescope), Chile

3.2 Telescope Size

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

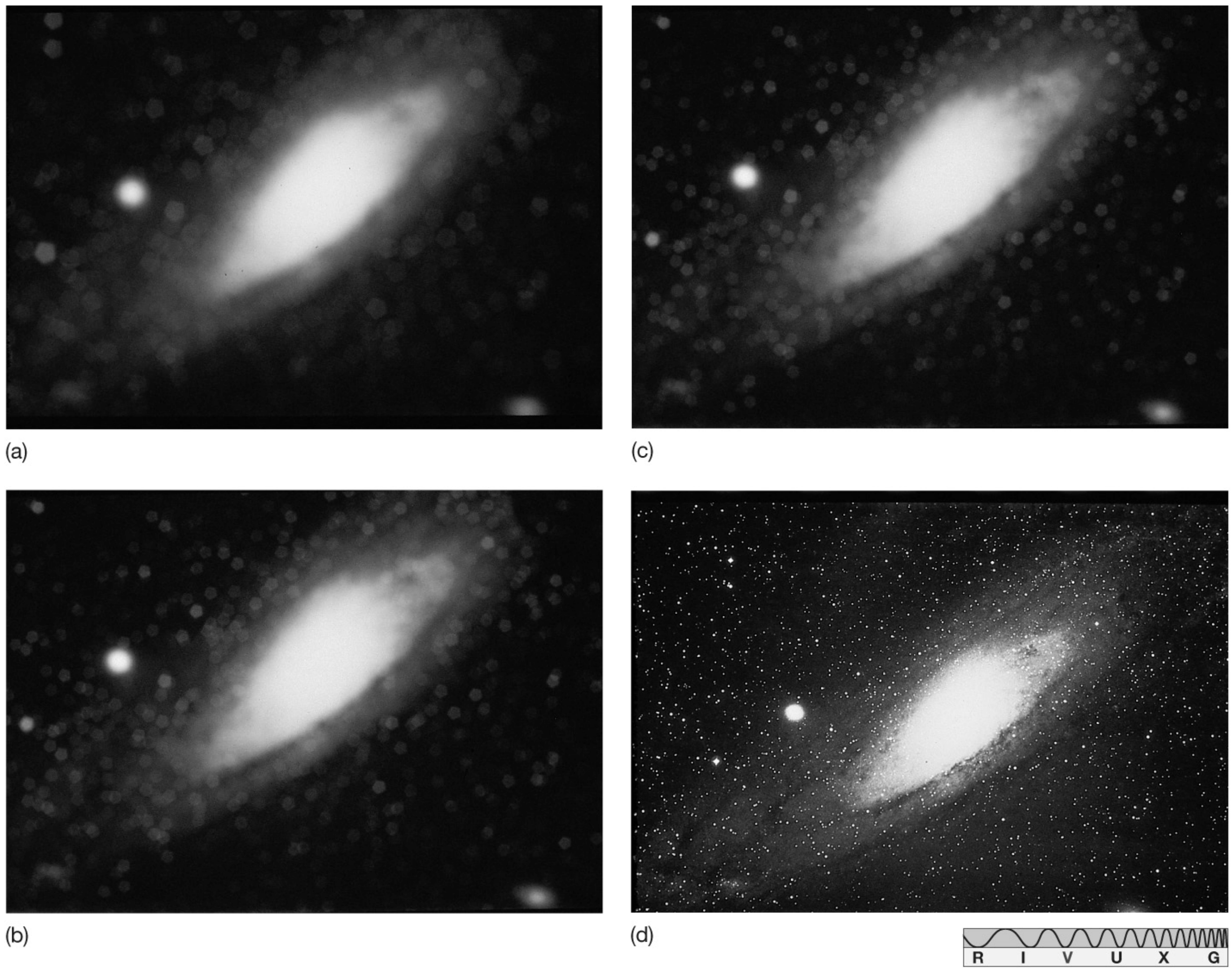
Resolution is proportional to wavelength and inversely proportional to telescope size



3.2 Telescope Size

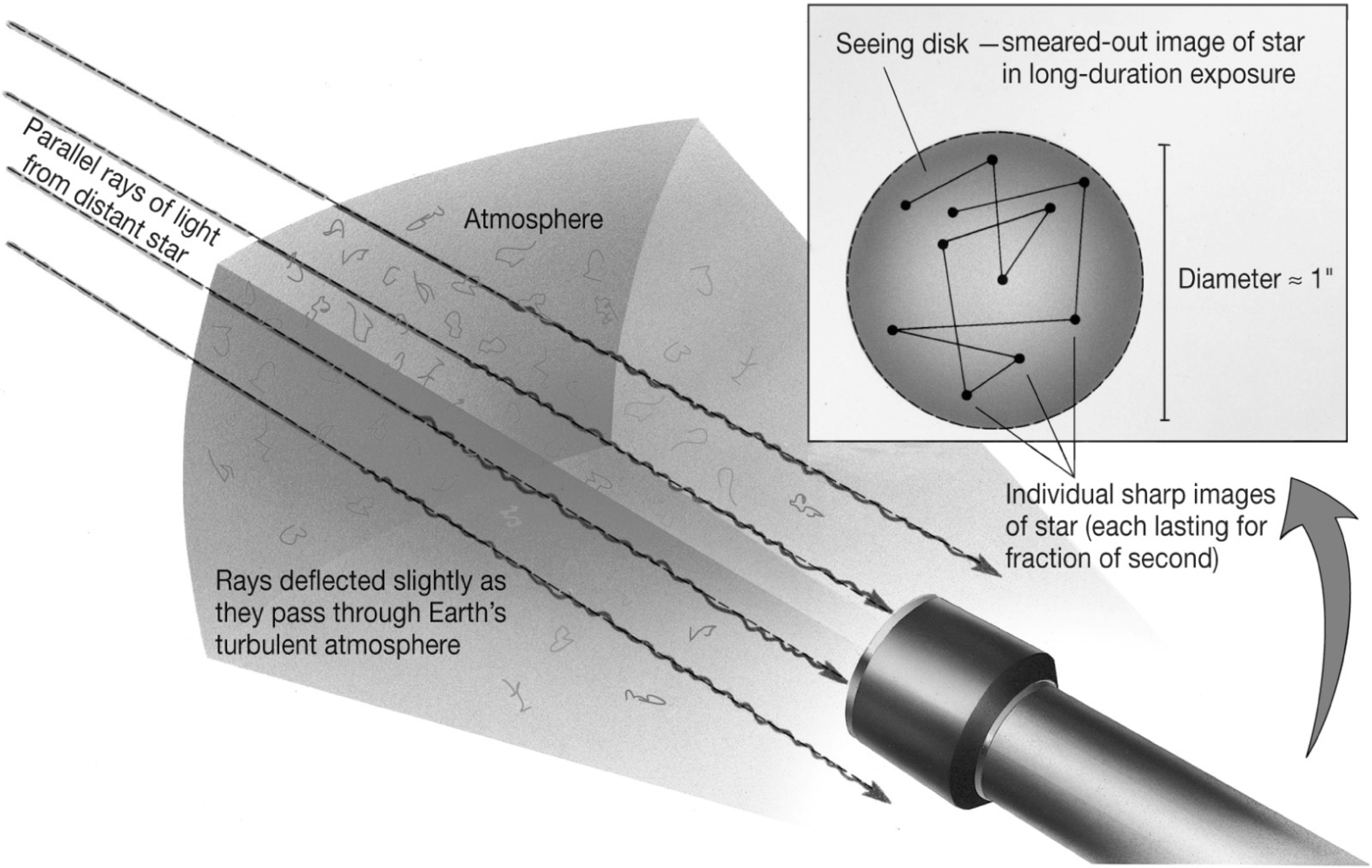
Effect of improving resolution:

(a) 10′; (b) 1′; (c) 5″; (d) 1″



3.3 High-Resolution Astronomy

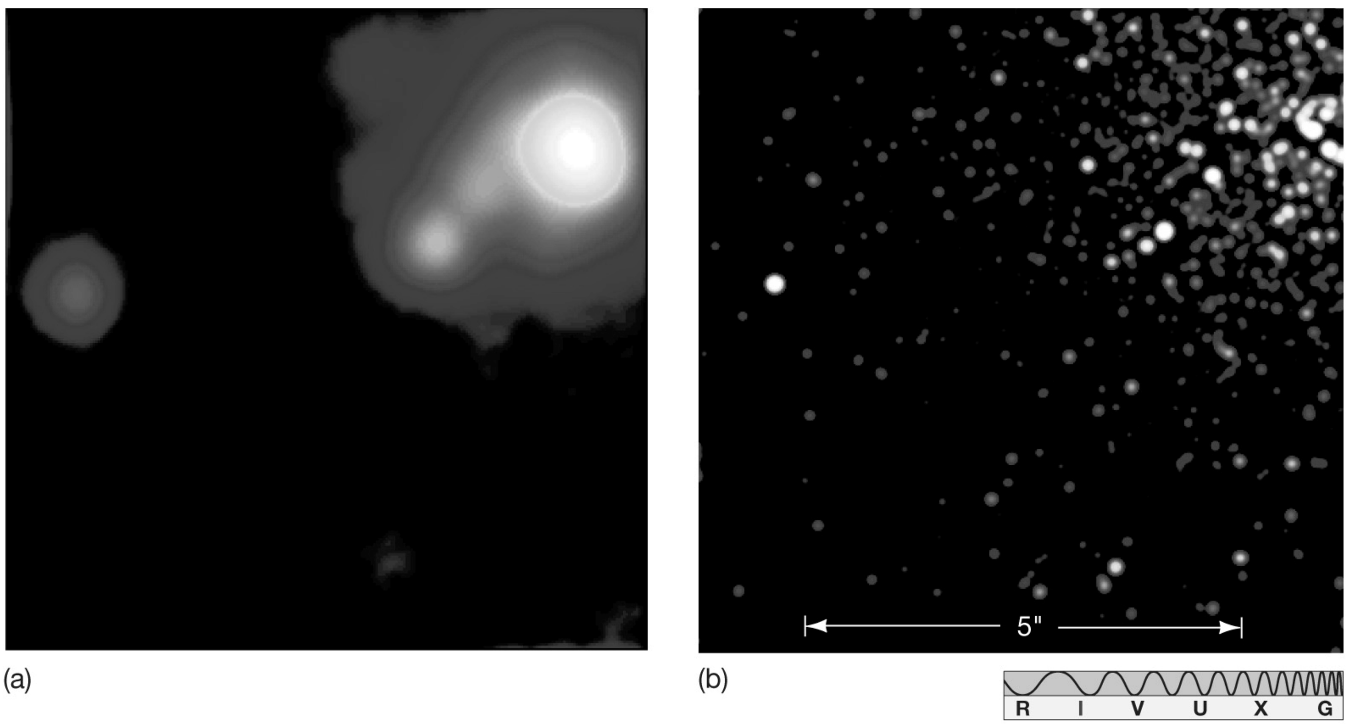
Atmospheric blurring: due to air movements



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**

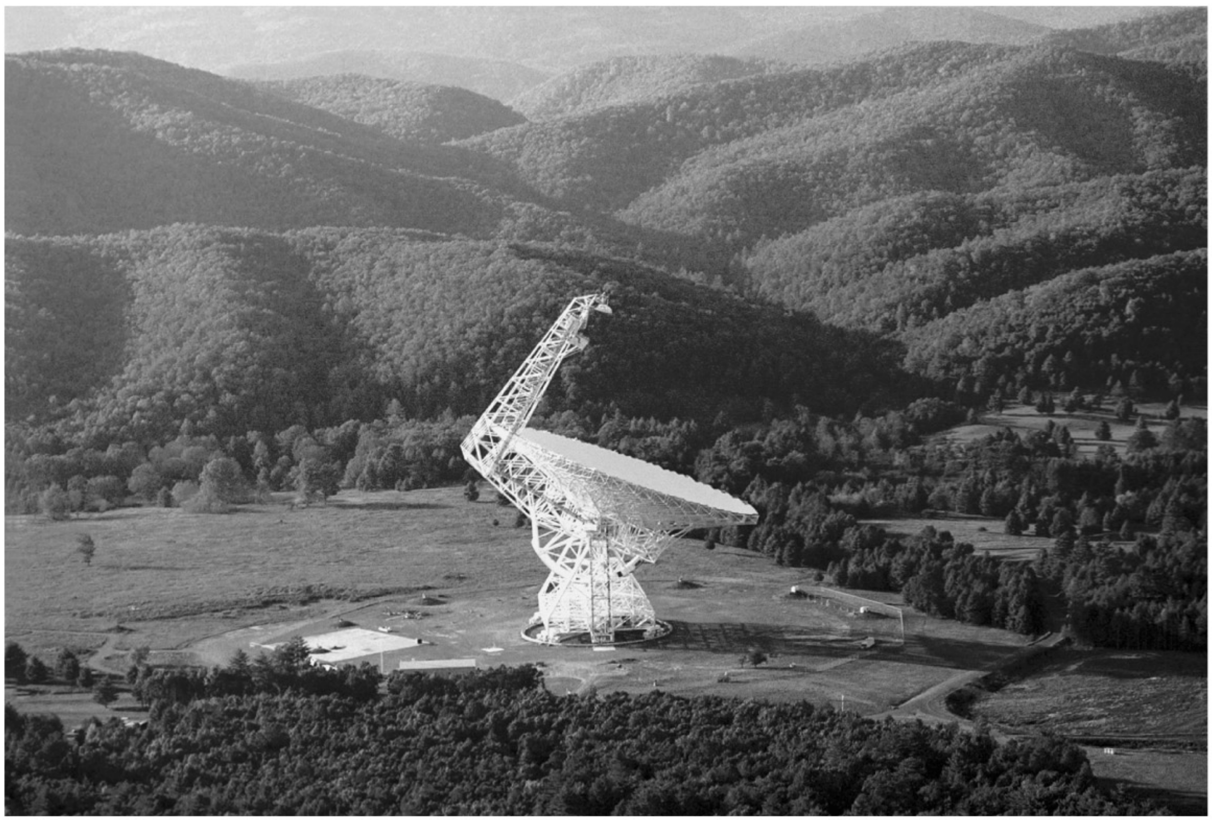


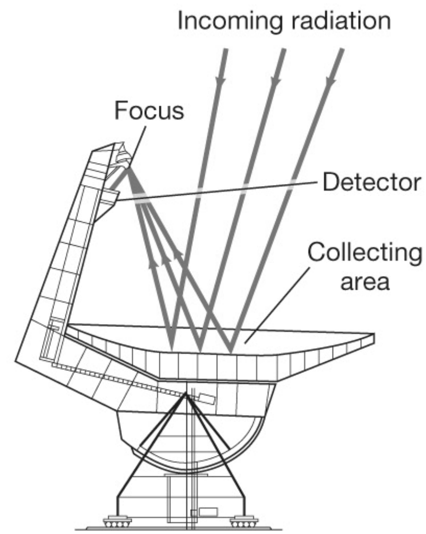
(a) (b)

3.4 Radio Astronomy

Radio telescopes:

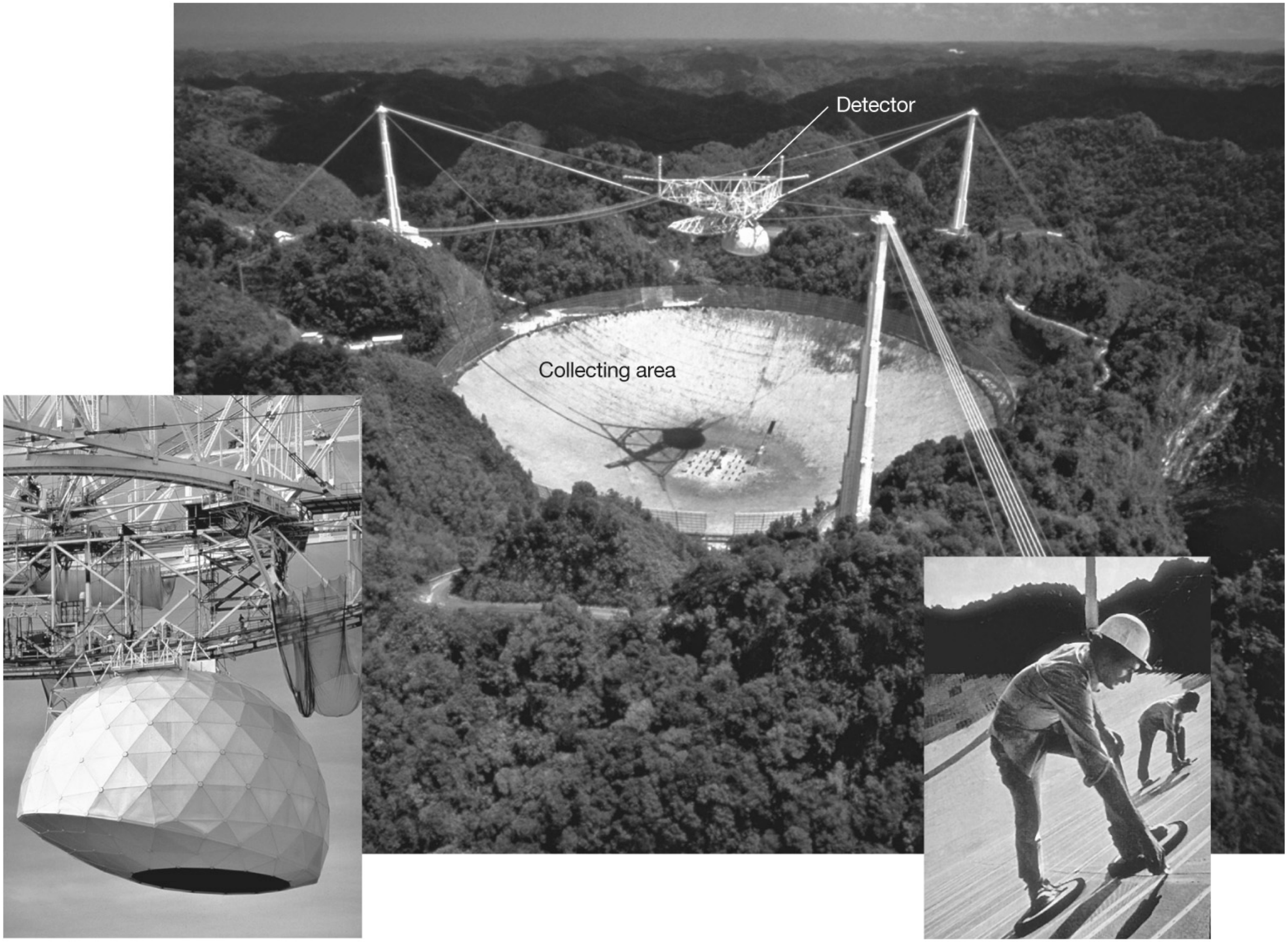
- **Similar to optical reflecting telescopes**
- **Prime focus**
- **Less sensitive to imperfections (due to longer wavelength); can be made very large**





3.4 Radio Astronomy

Largest radio telescope: 300-m dish at Arecibo

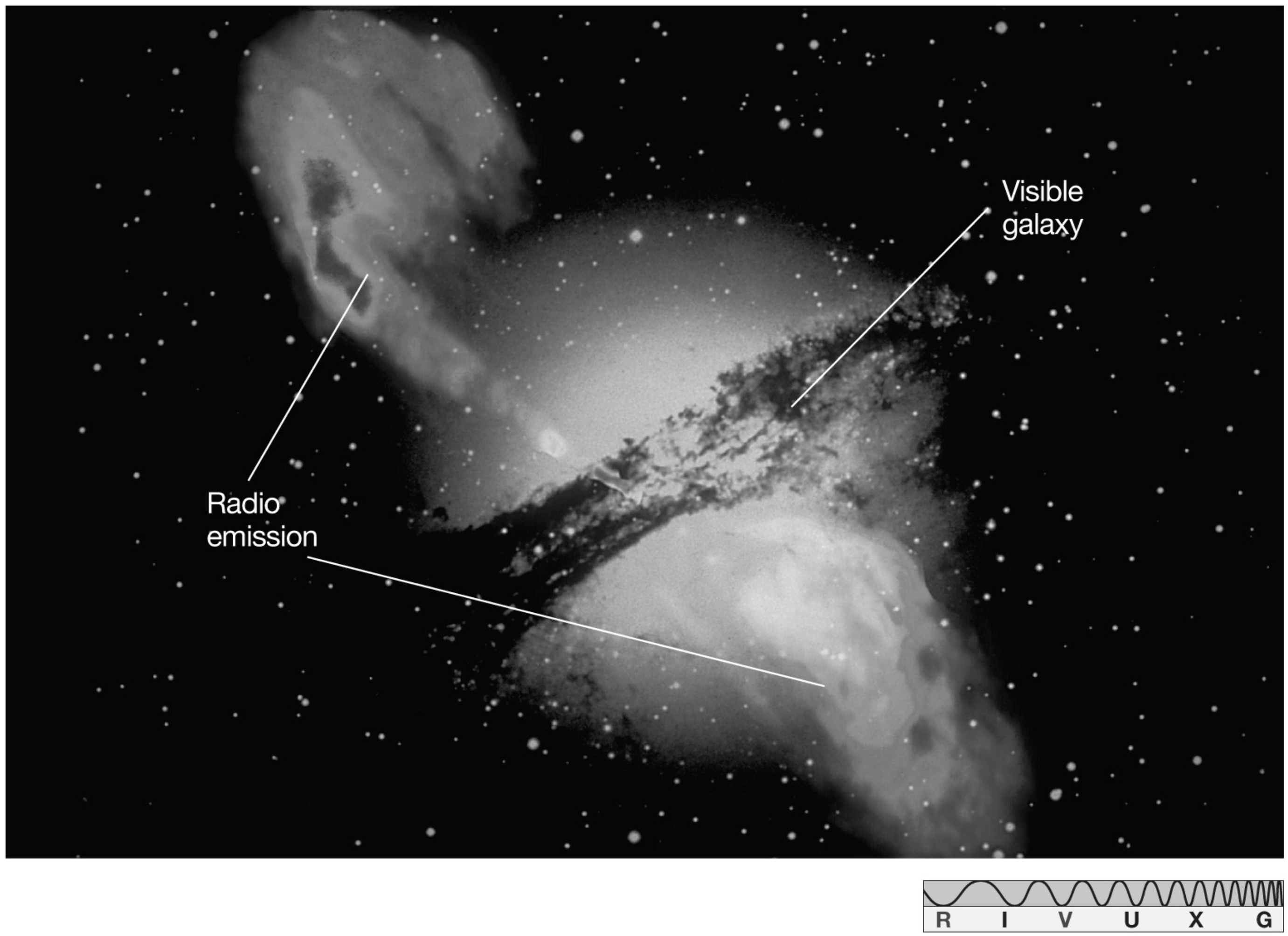


3.4 Radio Astronomy

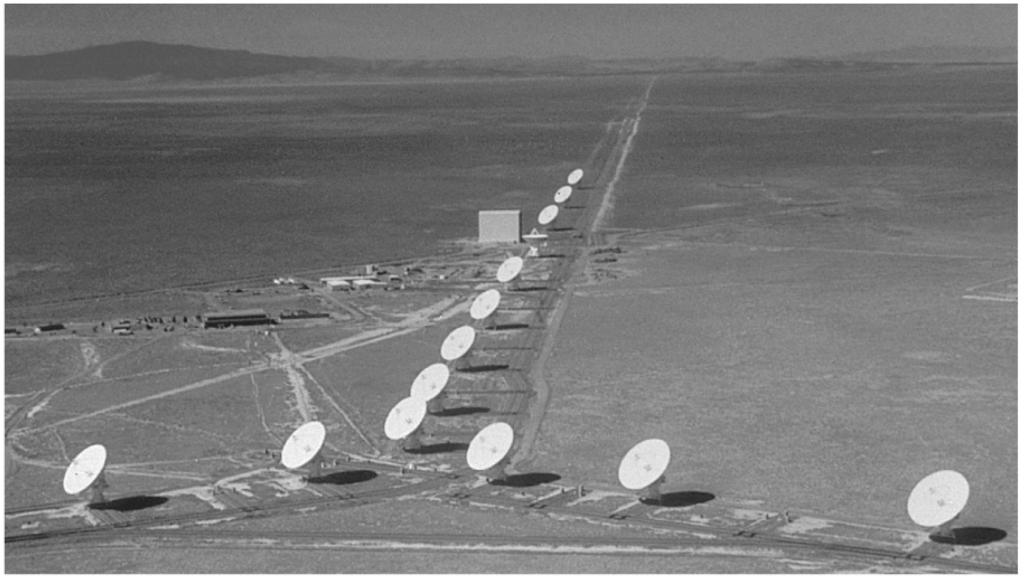
Longer wavelength means poor angular resolution

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



(a)

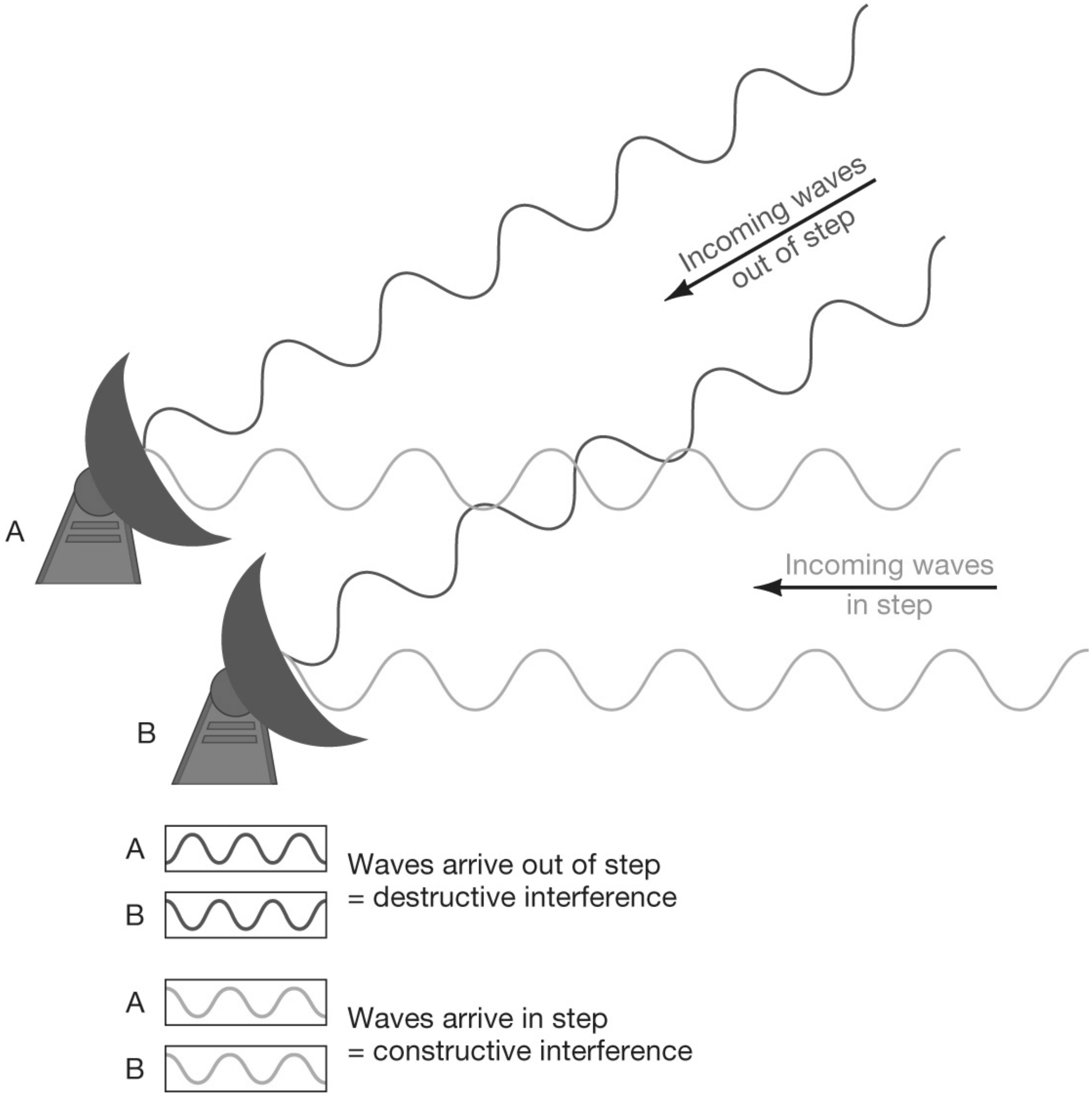
Interferometry:

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

(b)

- Resolution will be that of dish whose diameter = largest separation between dishes

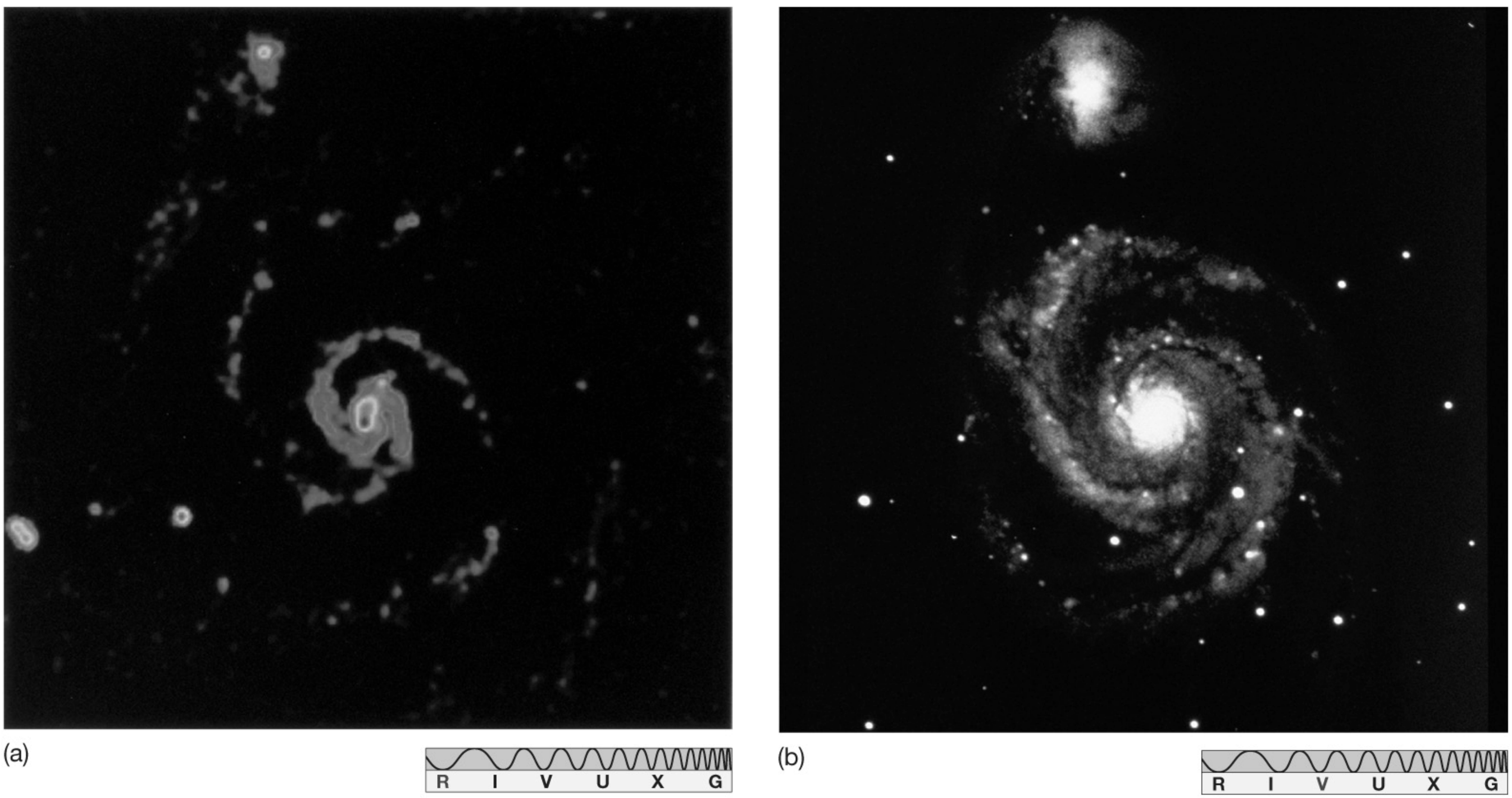
3.4 Radio Astronomy



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

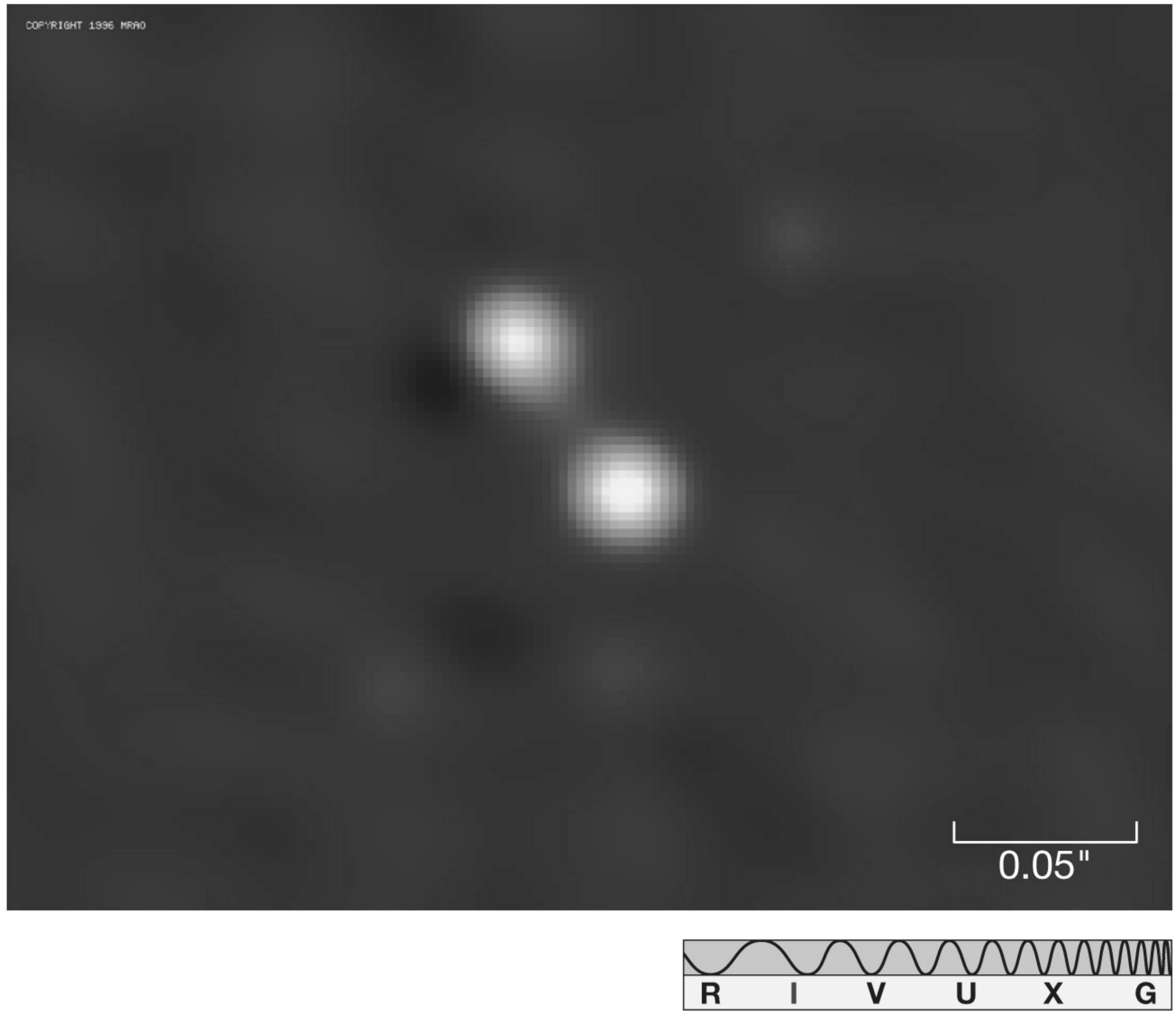
3.4 Radio Astronomy

Can get radio images whose resolution is close to optical:



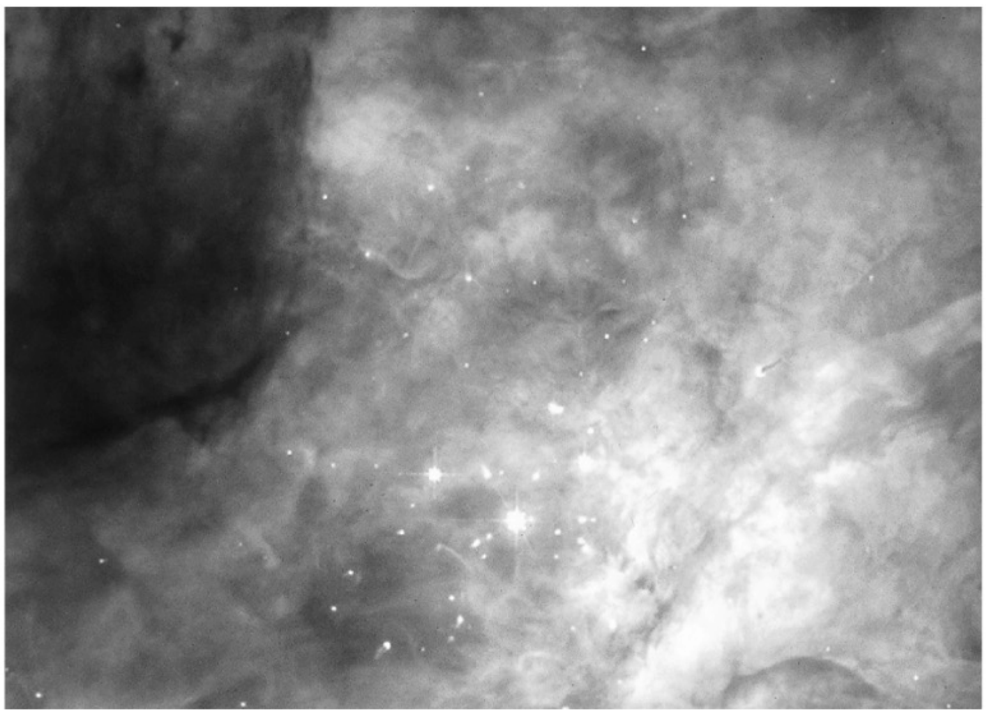
3.4 Radio Astronomy

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

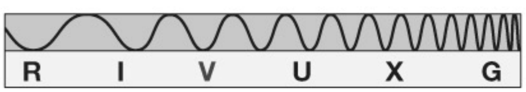


3.5 Other Astronomies

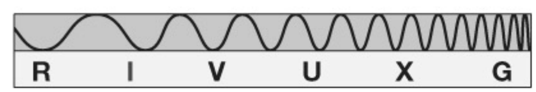
Infrared radiation can image where visible radiation is blocked; generally can use optical telescope mirrors and lenses



(c)

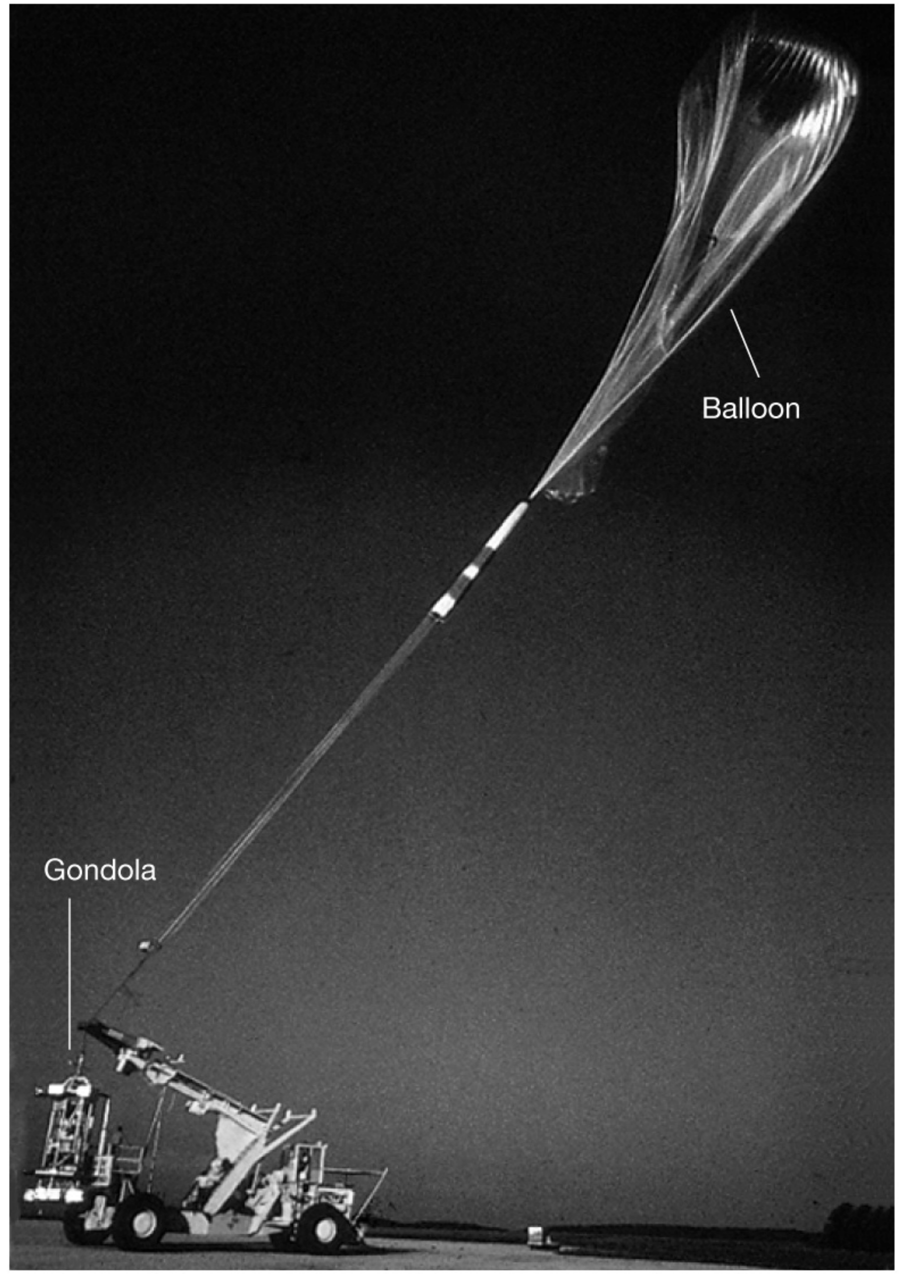


(d)



3.5 Other Astronomies

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

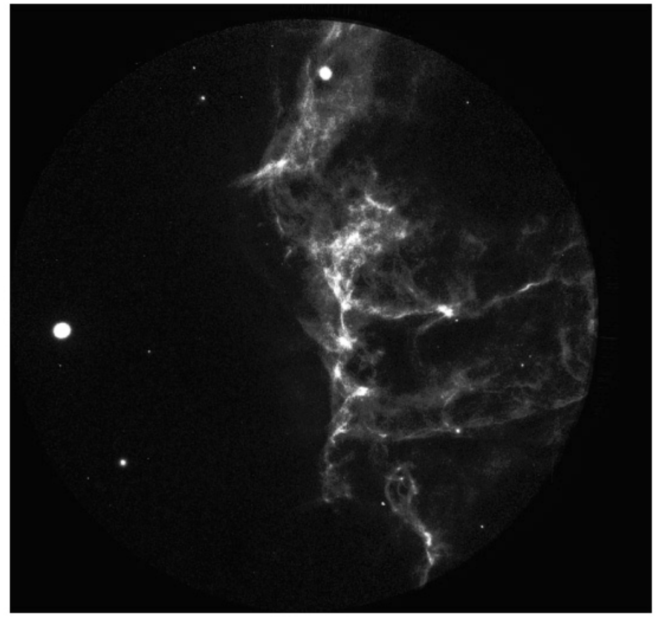


3.5 Other Astronomies

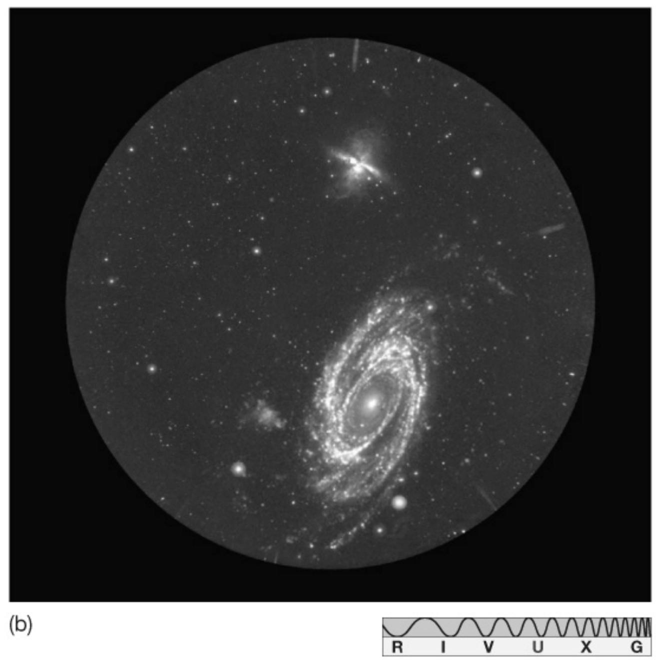
Ultraviolet images.

(a)The Cygnus loop supernova remnant

(b) M81



(a)

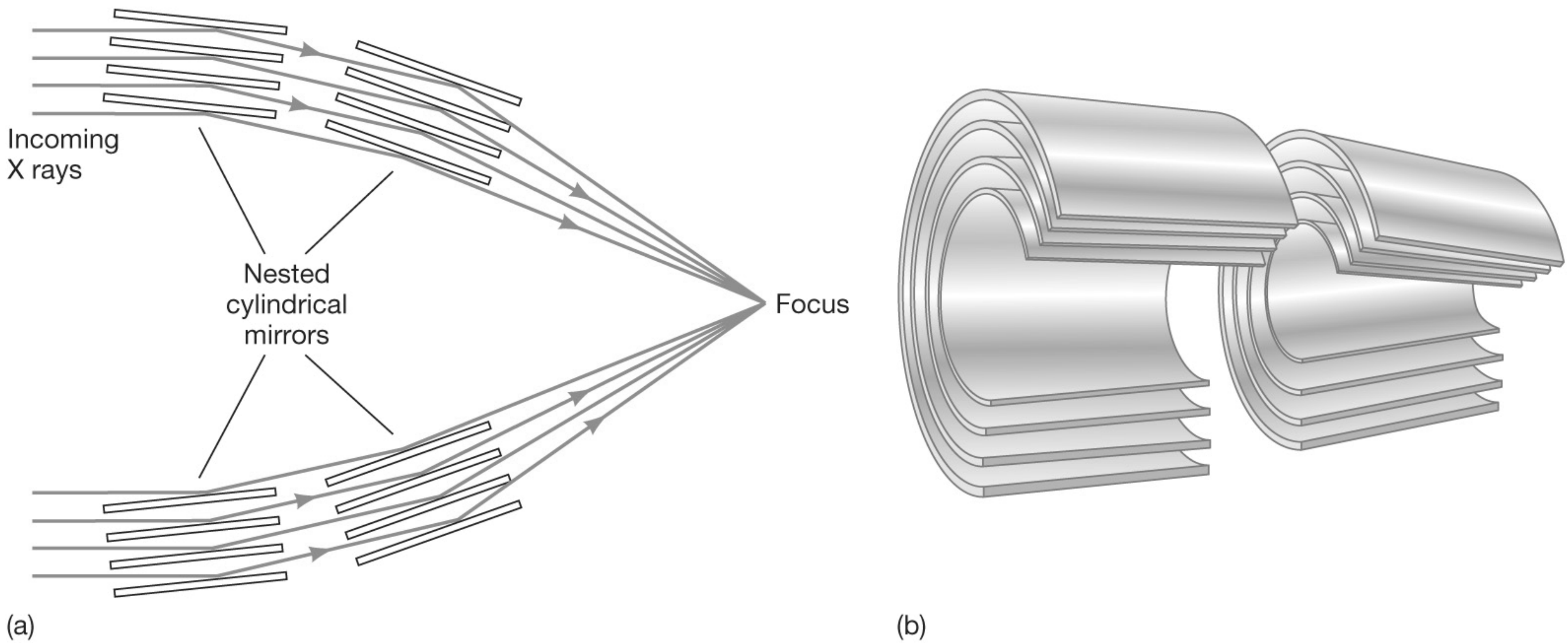


(b)

3.5 Other Astronomies

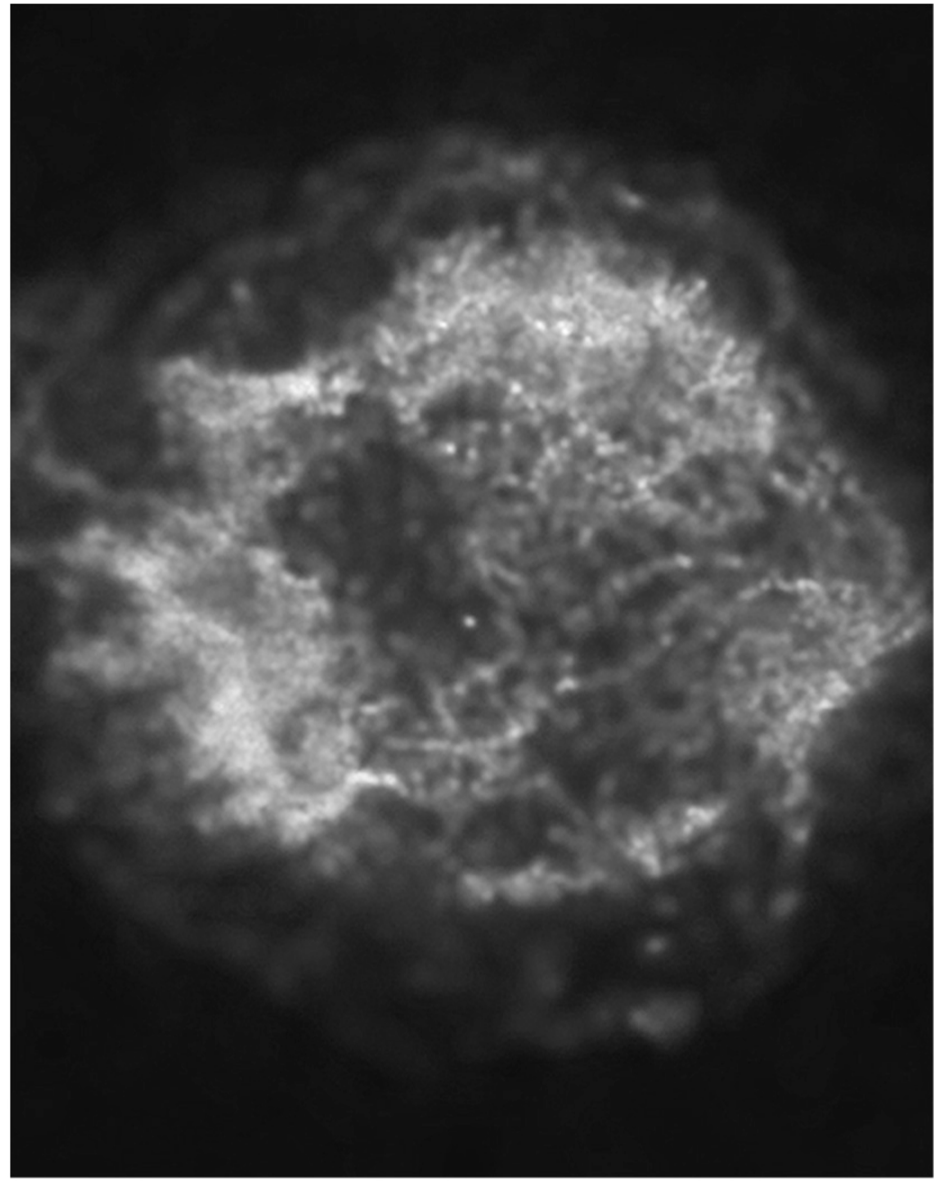
X-rays and gamma rays will not reflect off mirrors as other wavelengths do; need new techniques

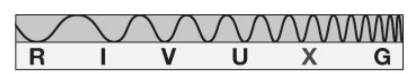
X-rays will reflect at a very shallow angle, and can therefore be focused:



3.5 Other Astronomies

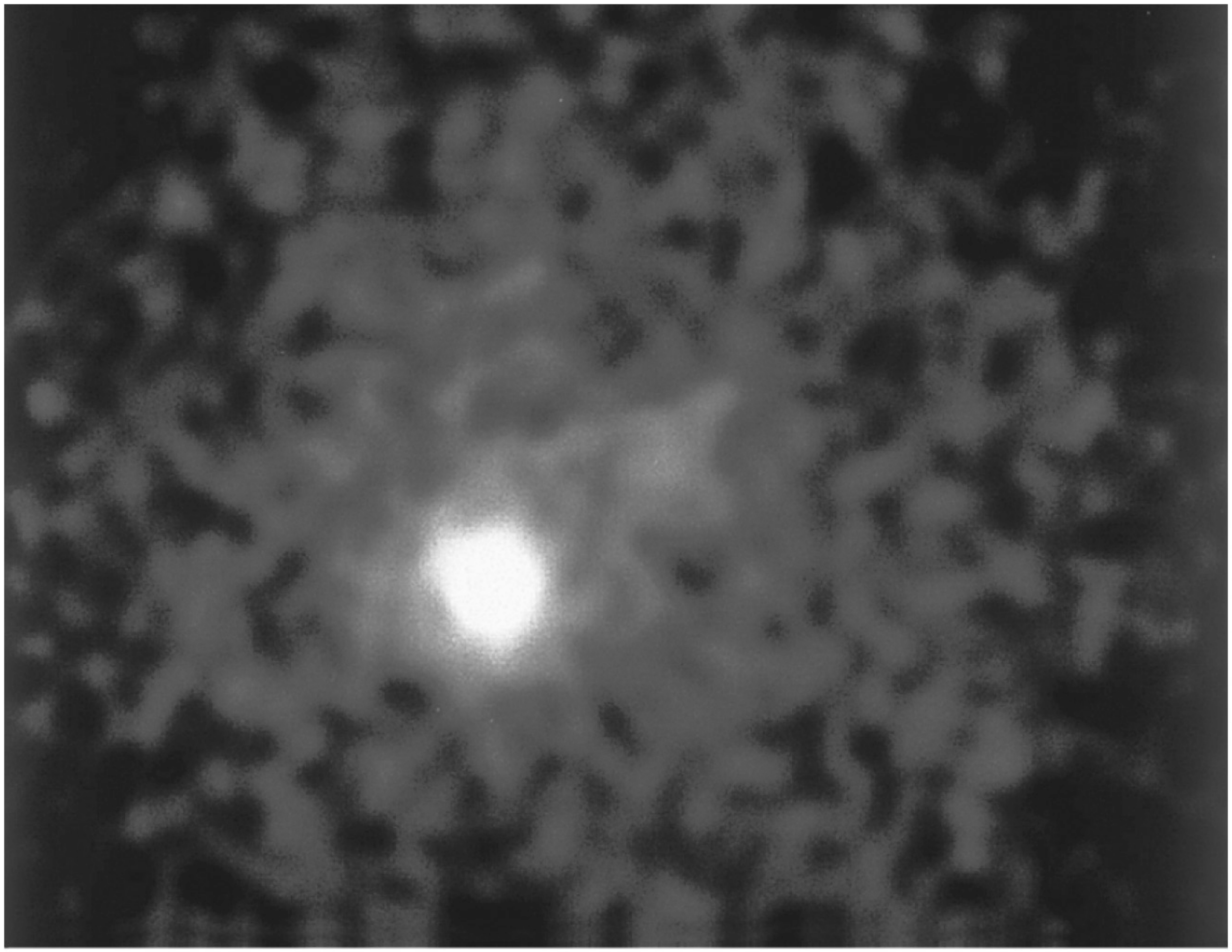
X-ray image of supernova remnant Cassiopeia A:

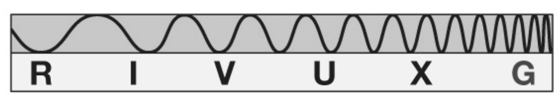




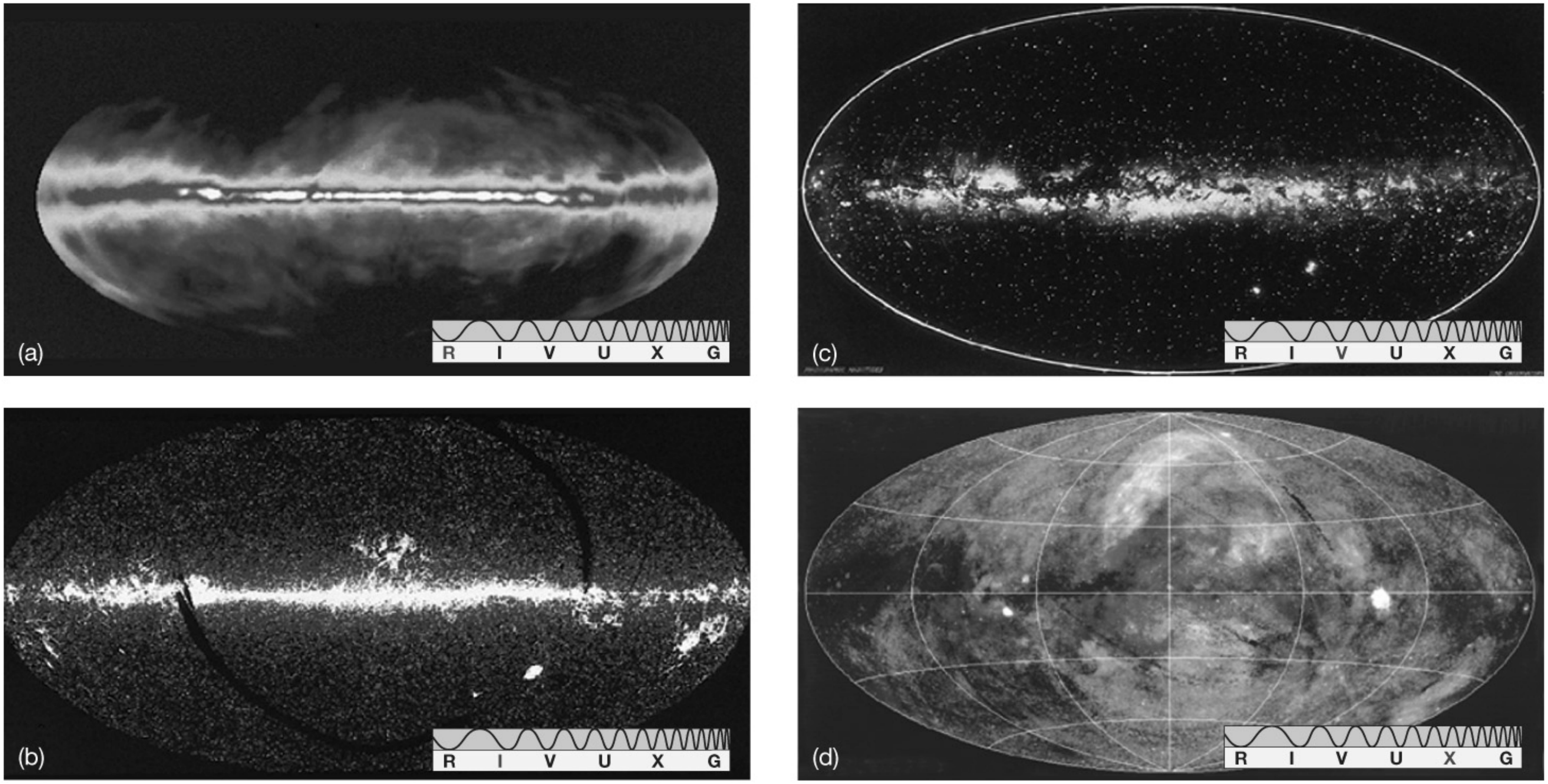
3.5 Other Astronomies

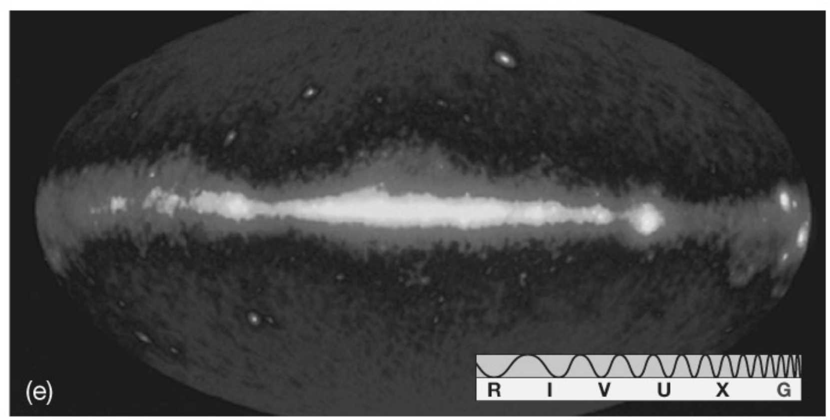
Gamma rays cannot be focused at all; images are therefore coarse:





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