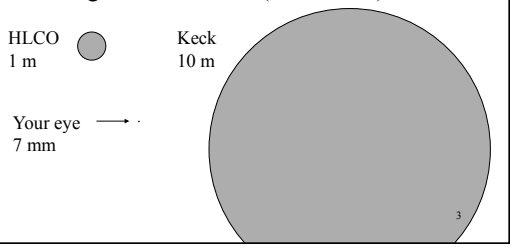
Chapter 6
Telescopes: Portals of Discovery

What are the 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.
3. **Magnification:** How much larger the image appears in the telescope versus the sky.

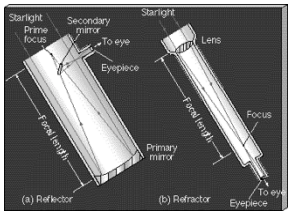
Light Collecting Area

- A telescope's diameter tells us its light-collecting area: Area = π (diameter/2)^2

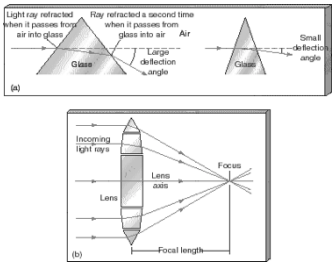


What are the two basic designs of telescopes?

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

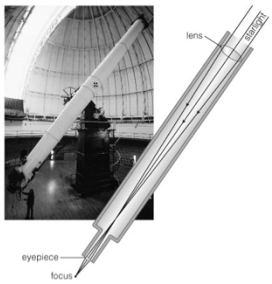


Refracting Telescope



- Refract (bend) light like prisms
- Focal length = distance from lens to focus
- Add eyepiece lens to magnify image

Refracting Telescope



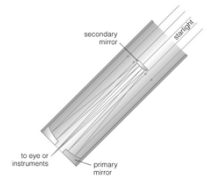
- Focal ratio = focal length / lens diameter
- Magnification = FL(telescope)/FL(eyepiece)
- Example: FL(telescope) = 100 cm and FL(eyepiece) = 2cm. Mag = 100/2 = 50x
- Binoculars: "7x50" means Mag = 7x, lens is 50 mm in diameter

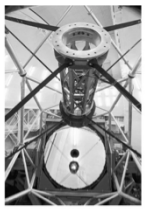
Refracting Telescope Problems

- Glass heavy – sags!
- Glass absorbs some colors
- Two surfaces to polish
- Chromatic aberration – different colors focus at different distances
- Better solution: use mirrors!

7

Reflecting Telescope

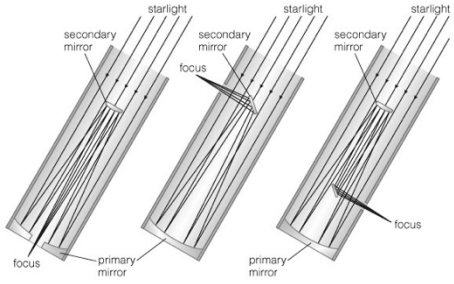




- Only one surface to grind and polish
- Support mirror in back so can make larger
- No chromatic aberration
- Need second mirror to reflect light out of tube

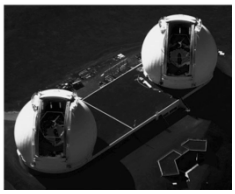
8

Designs for Reflecting Telescopes

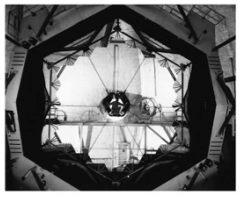


9

Mirrors in Reflecting Telescopes



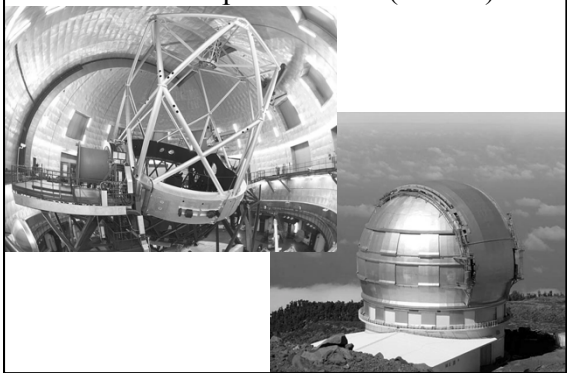
Twin Keck telescopes on Mauna Kea in Hawaii



Segmented 10-meter mirror of a Keck telescope

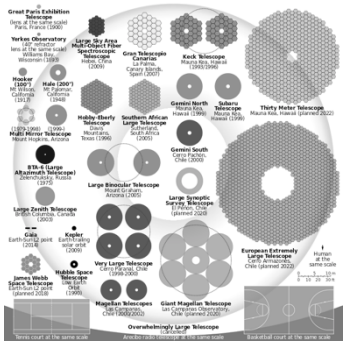
10

Gran Telescopio Canarias (10.4 m)

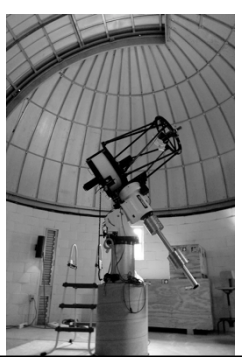


Very Large Telescope (4x8 m)

12



GSU Hard Labor Creek Obs.



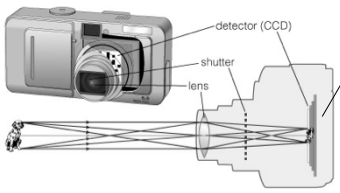
Want to buy your own telescope?

- Buy binoculars first (e.g. 7x50)
- Notice:
  aperture size (> 60 mm)
  optical quality
  mount stability
  portability
- http://www.skyandtelescope.com/astronomy-news/types-of-telescopes/

What do astronomers do with telescopes?

- **Imaging:** Taking pictures of the sky
- **Spectroscopy:** Breaking light into spectra

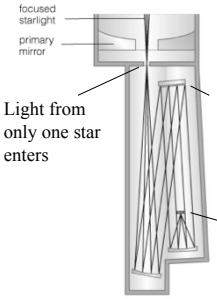
Focusing Light for Images



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 (better than film)

Spectroscopy



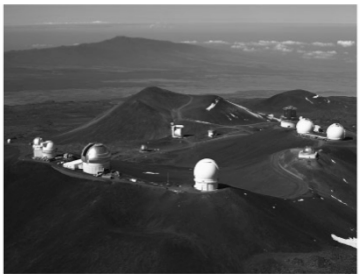
- A spectrograph separates the different wavelengths of light before they hit the detector

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)
- Often atop remote mountains

19

Calm, High, Dark, Dry



Summit of Mauna Kea, Hawaii

20

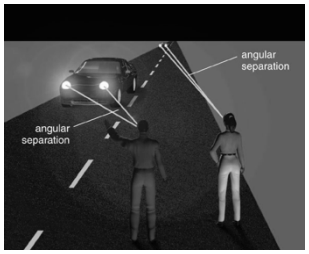
Light Pollution

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

21

Angular Resolution

- The *minimum* angular separation that the telescope can distinguish (amount of detail)
- Smaller (better) with larger telescope diameter and smaller wavelength of light



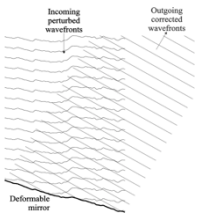
22

Atmospheric Turbulence

- Stars appear as twinkling dots
- Blur size typically about 1 arcsecond

23

Adaptive Optics



OFF ON

24

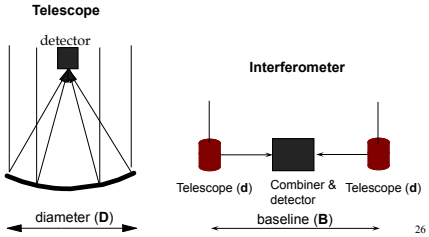
Center for High Angular Resolution Astronomy (CHARA)

- Long term program at GSU to study tiny details in the sky ("high resolution")
- Limited by diameter of telescope
- GSU developed novel approach using multiple-telescopes: **Long baseline interferometry**
- CHARA Array: best of its kind!

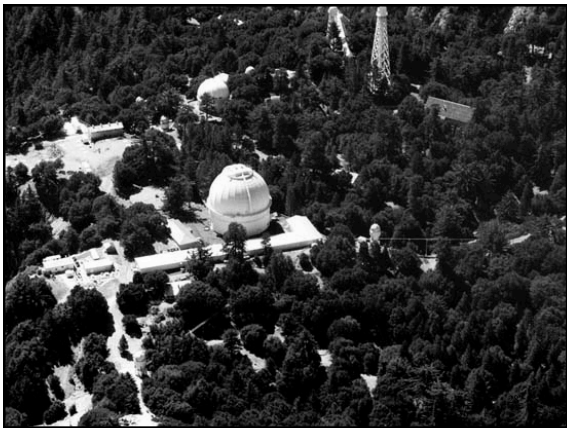
25

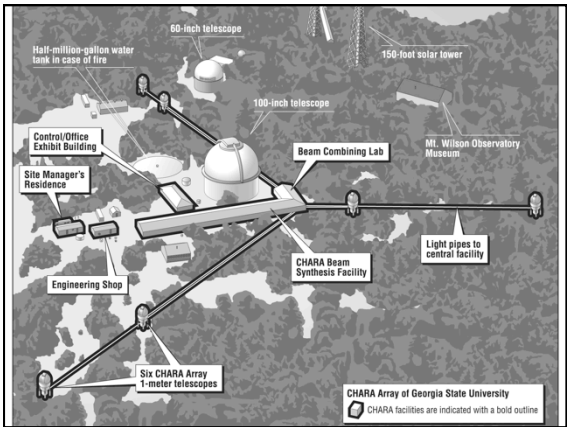
Interferometry

- An interferometer combines the light from several small telescopes to yield the power of a much larger telescope
- The larger the separation, the better the results

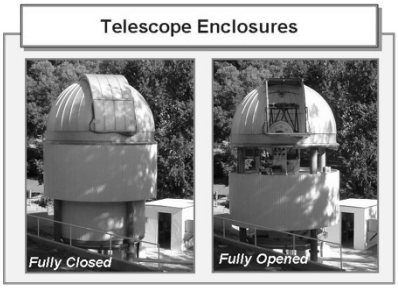


26





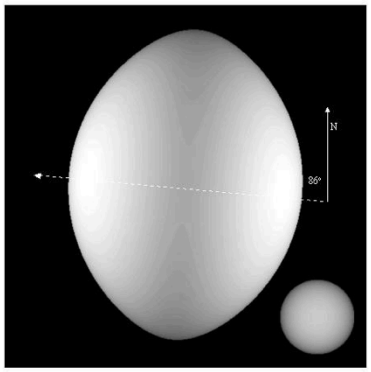
Six Telescopes, Largest Baseline of 330 m



30

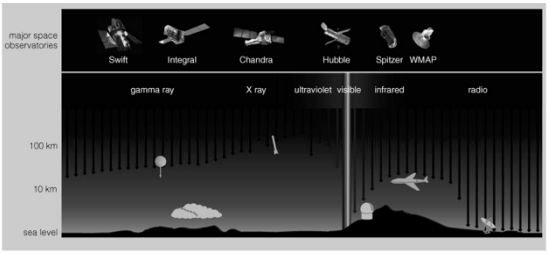
Resolve objects the size of a dime in LA as viewed from Atlanta

Rapidly spinning star Regulus



31

Transmission in Atmosphere



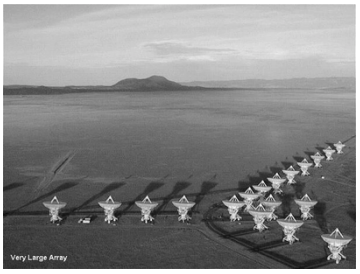
- Only radio and visible light pass easily through Earth's atmosphere
- We need telescopes in space to observe other forms

Radio Telescopes

- A radio telescope is like a giant mirror that reflects radio waves to a focus
- Arecibo, Puerto Rico; 205 m dish

33

Radio Telescopes



- Observe interstellar clouds invisible in optical
- Interferometry easier in radio; Very Large Array (VLA), New Mexico

34

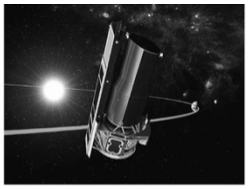
Radio Telescopes

- Atacama Large Millimeter Array 64 radiotelescope interferometer in the foothills of Andes Mountains in Chile
- Detailed images of cool gas and dust in universe

35

Infrared Telescopes

SOFIA

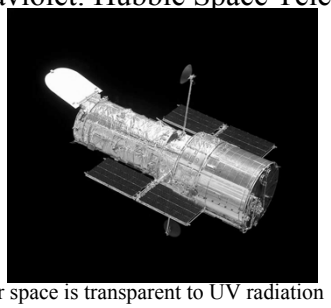


Spitzer

- Infrared telescopes operate like visible-light telescopes but need to be above atmosphere
- View cool, dusty objects in space

36

Ultraviolet: Hubble Space Telescope



- Outer space is transparent to UV radiation
- Sky is very dark, no atmospheric turbulence
- Observe very hot and faint objects

37

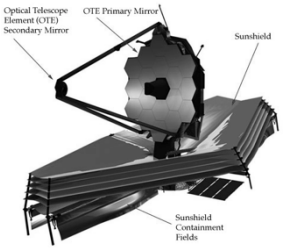
X-Ray Telescopes

Chandra

- X-ray telescopes also need to be above the atmosphere
- Observe very hot gas (millions of degrees)

38

Future Telescope



- James Webb Space Telescope is a large (6.5 m), infrared-optimized space telescope, scheduled for launch in 2018
- Will observe redshifted light from distant galaxies

39

Next time:

- Chapter 7:
  Solar System
  please read pages 191 – 209 in text.