###### Chapter 5 – Telescopes Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

###### **Tools of the Trade: Telescopes**

* Stars and other celestial objects are too far away to test directly
  + Astronomers passively collect radiation emitted from distant objects
  + Extremely faint objects make collection of radiation difficult
* Specialized Instruments Required
  + Need to measure brightness, spectra, and positions with high precision
  + Astronomers use mirrored telescopes and observatories
* Modern Astronomers are rarely at the eyepiece, more often they are at a computer terminal!

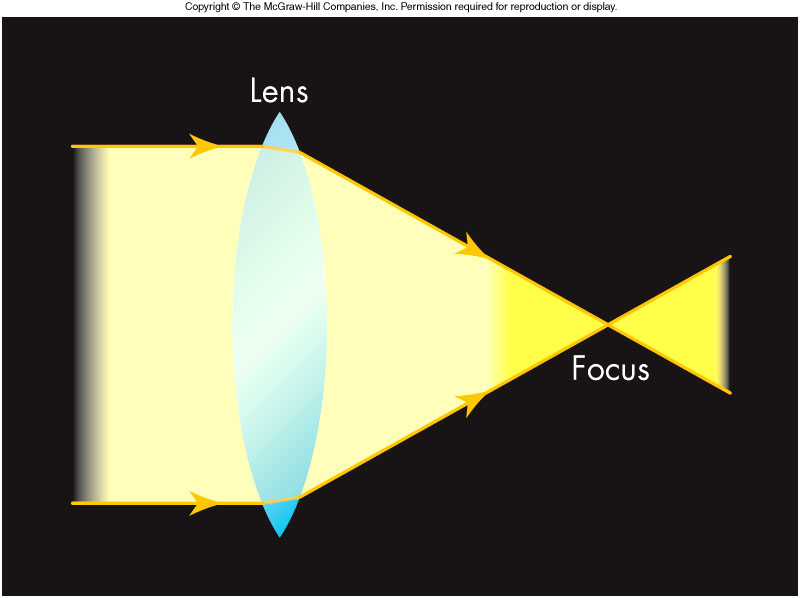
**The Powers of a Telescope**

* *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
  + *Bigger telescope, more light collected!*
* *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
  + *Use mirrors or lenses to bend the path of light rays to create images*
* *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
  + *Picking out the details in an image*

**Light Gathering Power**



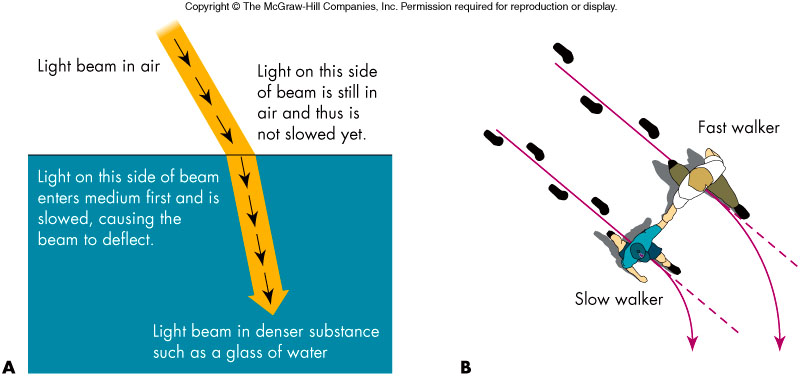
* + Light collected proportional to “collector”\_\_\_\_\_\_\_\_\_\_
  + Pupil for the eye
  + Mirror or lens for a telescope
  + Telescope “\_\_\_\_\_\_\_\_\_” light to our eyes for a brighter image
  + Small changes in “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_” radius give large change in number of photons caught

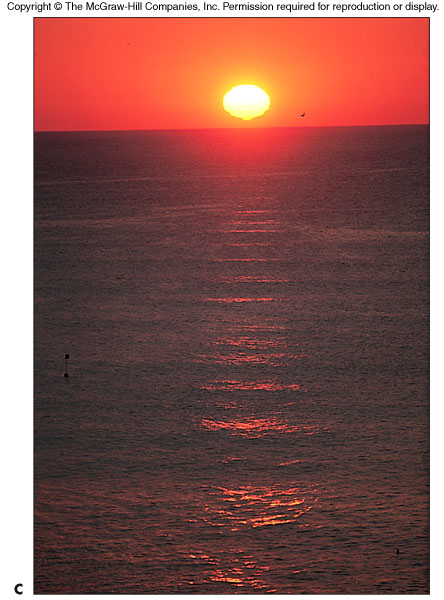


**Focusing Power**

* Refraction
  + Light moving at an angle from one material to another will bend due to a process called ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***
  + Refraction occurs because the \_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is different in different materials

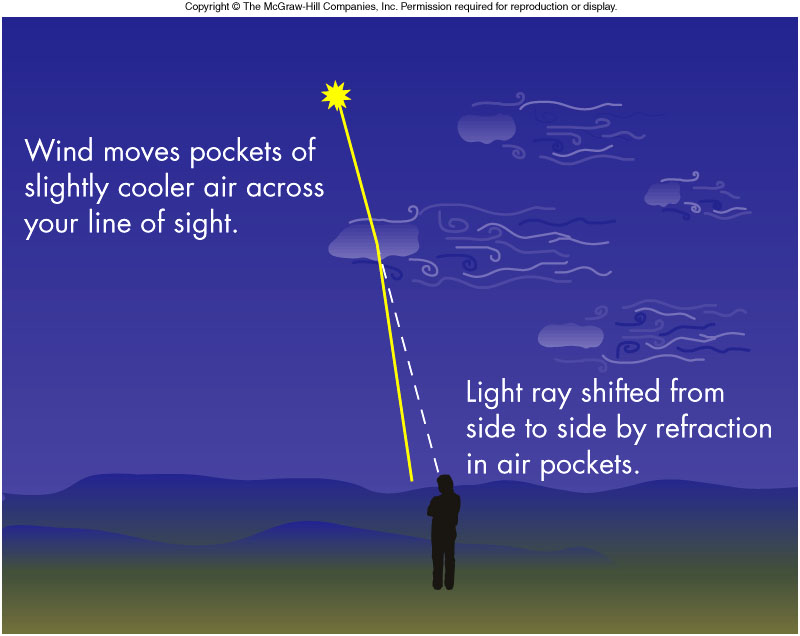
**Refraction**





***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***causes different colors to travel at different speeds through the same material

Refraction is responsible for the distortion of the Sun near the horizon, but not the ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***

* Refraction is also responsible for ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***
  + Twinkling of stars
  + AKA***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***
* Temperature and density differences in pockets of air shift the image of the star.

**Refracting Telescopes**

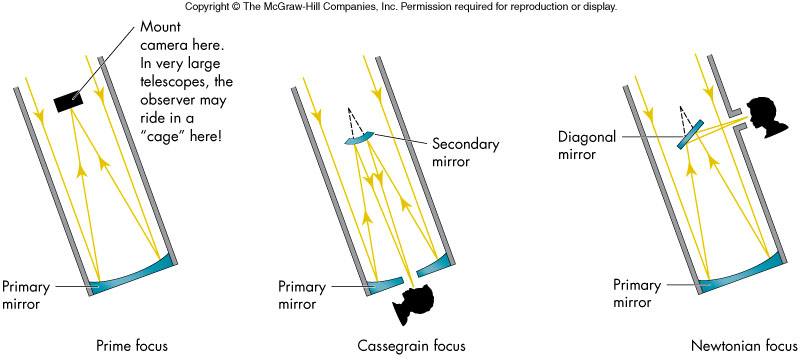
* A lens employs refraction to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Telescopes that employ lenses to collect and focus light are called ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***

Disadvantages to Refractors

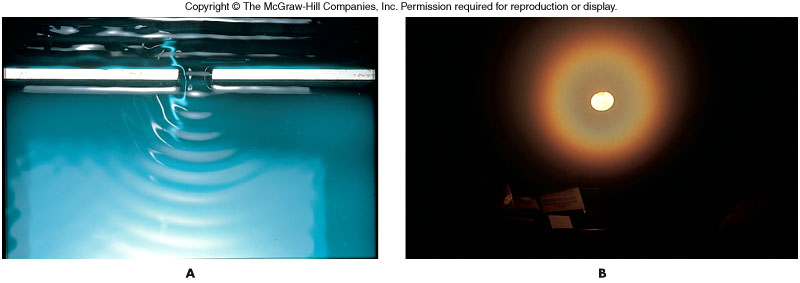
* Lenses have many disadvantages in large telescopes!
  + Large lenses are extremely \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to fabricate
  + A large lens will \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_in the center since it can only be supported on the edges
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ causes images to have colored fringes
  + Many lens materials \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ light

**Reflecting Telescopes**

* Reflectors
  + Used almost exclusively by astronomers today
  + Twin Keck telescopes, located on the 14,000 foot volcanic peak Mauna Kea in Hawaii, have \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ collector mirrors!
  + Light is focused in front of the mirror
* A ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_*** may be used to deflect the light to the side or through a hole in the ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***
* ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*** and ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*** are two modern approaches to dealing with large pieces of glass in a telescope system



**Resolving Power**

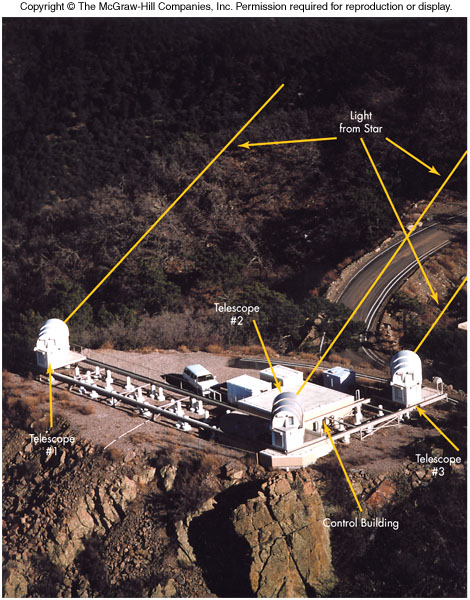


* A telescope’s ability to discern detail is referred to as its ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_***
* Resolving power is limited by the wave nature of light through a phenomenon called ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***
* Waves are diffracted as they pass through \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* A diffracted point source of light appears as a point surrounded by \_\_\_\_\_\_\_\_\_\_\_ of light

**Resolving Power and Aperture**

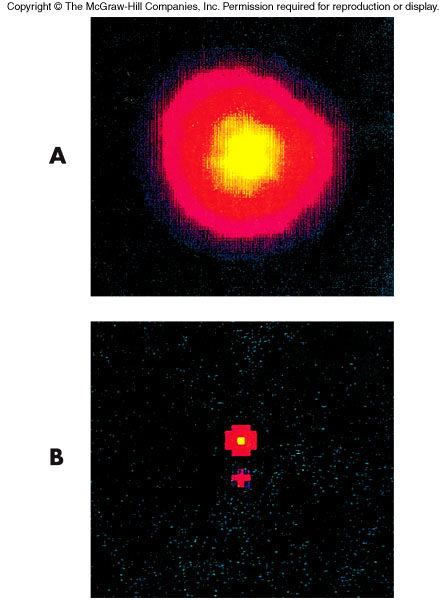
* Two points of light separated by an angle \_\_\_\_\_\_\_\_ (in arcsec) can be seen at a \_\_\_\_\_\_\_\_\_\_\_ (in nm) only if the telescope diameter D (in cm) satisfies:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Increasing Resolving Power: Interferometers

For a given wavelength, **\_\_\_\_\_\_\_\_\_\_\_\_\_** is increased for a larger telescope diameter

An *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* accomplishes this by simultaneously combining observations from two or more widely-spaced telescopes.



The resolution is determined by the individual telescope \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and not the individual diameters of the telescopes themselves

Key to the process is the \_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_and the electronic processing of the waves from the various telescopes

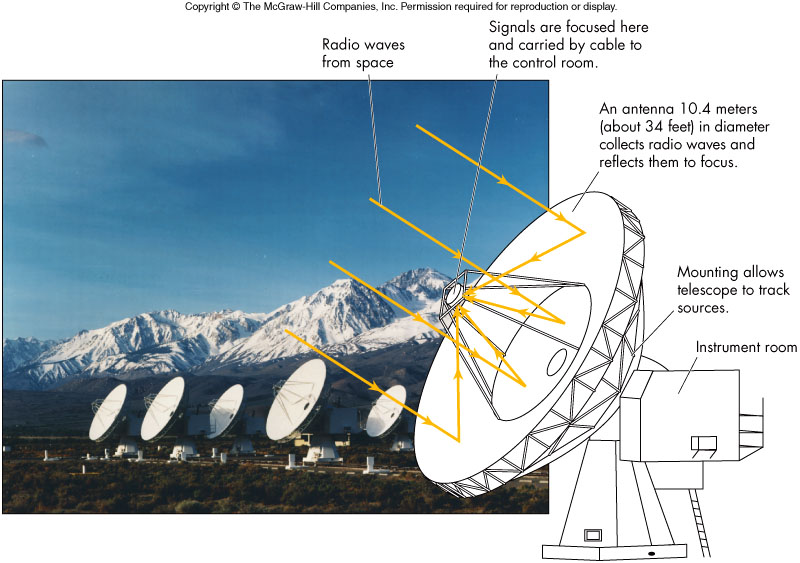
**Detecting the Light**

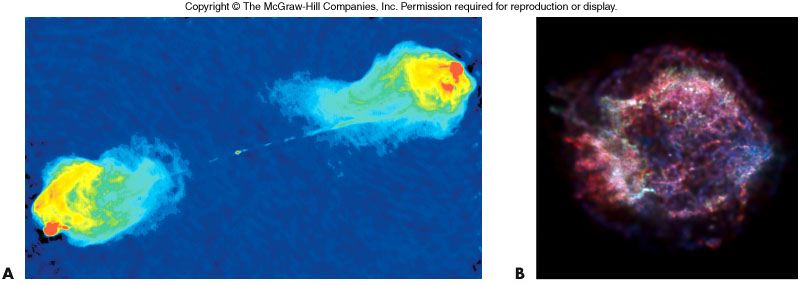
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Once used with a telescope to record observations or make sketches
  + Not good at detecting faint light, even with the 10-meter Keck telescopes
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Chemically stores data to increase sensitivity to dim light
  + Very inefficient: Only 4% of striking photons recorded on film
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Incoming photons strike an array of semiconductor pixels that are coupled to a computer
  + Efficiencies of 75% possible
  + ***\_\_\_\_\_\_\_\_\_\_\_\_***(Charged-coupled Device) for pictures

**Nonvisible Wavelengths**

* Many astronomical objects radiate in wavelengths other visible
  + Cold gas clouds radiate in the \_\_\_\_\_\_\_\_\_\_\_\_
  + Dust clouds radiate in the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Hot gases around black holes emit \_\_\_\_\_\_\_\_\_\_\_\_

**Radio Observatories**

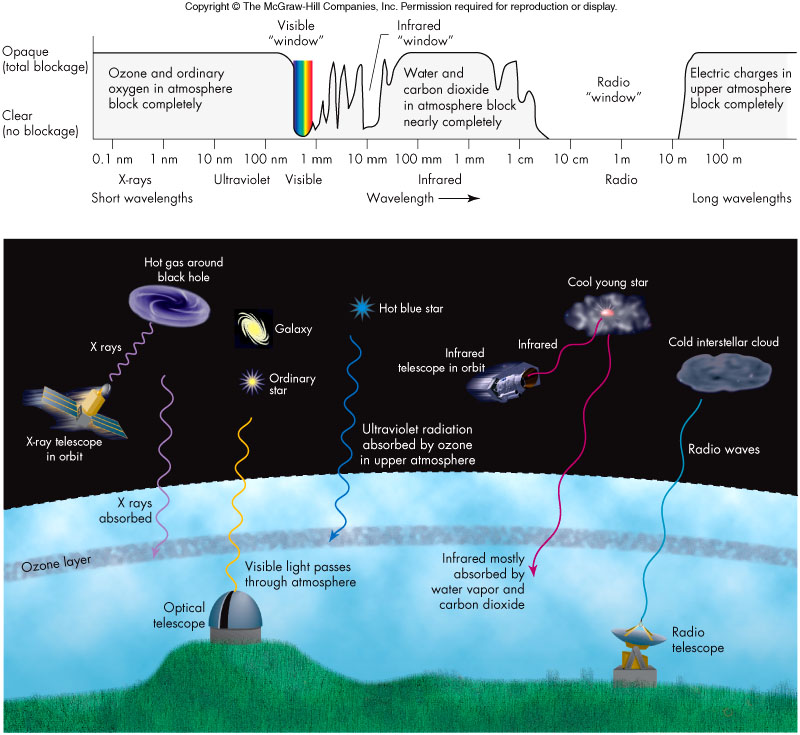




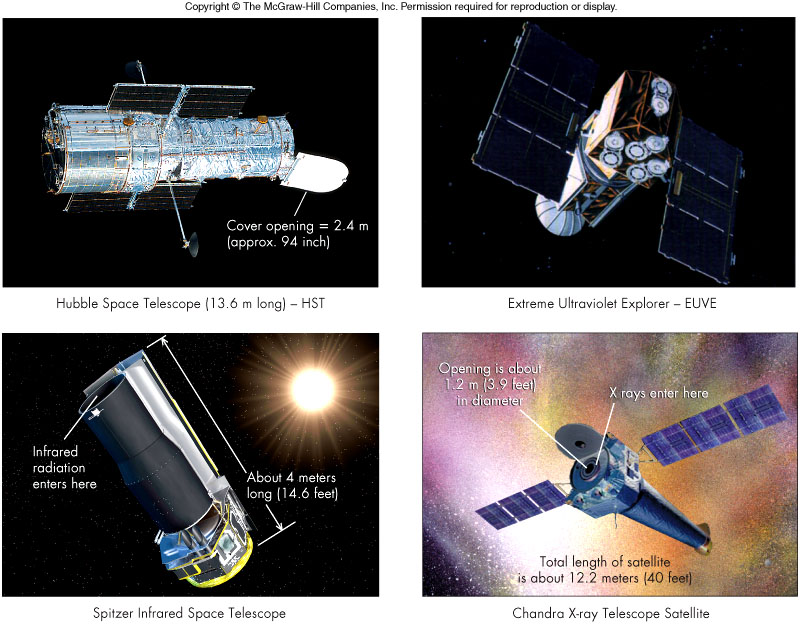
* False color images are typically used to depict wavelength distributions in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ observations

Gamma Rays Bursts

* Exploring New Wavelengths: Gamma Rays
  + Gamma-ray astronomy began in 1965
  + By 1970s, gamma rays found to be coming from familiar objects: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
  + 1967 gamma-ray bursts from space discovered by military satellites watching for Soviet nuclear bomb explosions
  + Source of gamma-ray bursts is likely due to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_!



Major Space Observatories



* Why put them in space?

**Atmospheric Blurring**

* + Twinkling of stars in sky, called ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_,*** is caused by moving atmospheric irregularities refracting star light into a blend of paths to the eye
  + The condition of the sky for viewing is referred to as the ***\_\_\_\_\_\_\_\_\_\_\_***
  + Distorted seeing can be improved by ***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_,*** which employs a powerful laser and correcting mirrors to offset scintillation

**Observatories**

* The immense telescopes and their associated equipment require observatories to facilitate their use and protection from the elements
* Thousands of observatories are scattered throughout the world and are on every continent including Antarctica
* Some observatories:
  + Twin 10-meter Keck telescopes are largest in U.S.
  + The Hobby-Eberly Telescope uses 91 1-meter mirrors set in an 11-meter disk
  + Largest optical telescope, VLT (Very Large Telescope) in Chile, is an array of four 8-meter mirrors

Space vs.Ground-Based Observatories

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Freedom from atmospheric blurring
  + Freedom of atmospheric absorption
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Larger collecting power
  + Equipment easily fixed
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Weather, humidity, and haze
  + Light pollution