"Telescopes are in some ways like time machines. They reveal galaxies so far away that their light has taken billions of years to reach us."

Sir Martin Rees

Second Bonus Assignment

- Astronomically speaking, how was yesterday (September 23rd) special?

Due: October 1, 2007

- For up to 15 bonus points, turn in (2 pages max)
  - Your answer to the above question
  - Describe what makes the day special
    - Draw figures
    - Write brief descriptions
  - Talk about
    - Sun, path in the sky
    - Seasons
    - Length of daylight
    - Customs and traditions around this day
  - Include a picture of sunrise or sunset you take today or tomorrow

Creative alternative

- Write a poem
- Write a story
- Paint a picture
- Build a model

Must be your original work!

What We Will Learn Today

- Why talk about eyes in an astronomy course?
- How do we observe faint, distant objects?
- What are the main attributes of a telescope?
- What are the basic telescope designs?
- Why do we have space telescopes?
- How can multiple telescopes work together?

The Human Eye: The First Detector

- Pupil controls the amount of light entering our eye
- Lens & cornea *refract* light to bring it to a focus
- Retina captures the light
  - Rods interpret brightness, are very sensitive
  - Cones sensitive to colors, need brighter light
- Brain analyzes the image

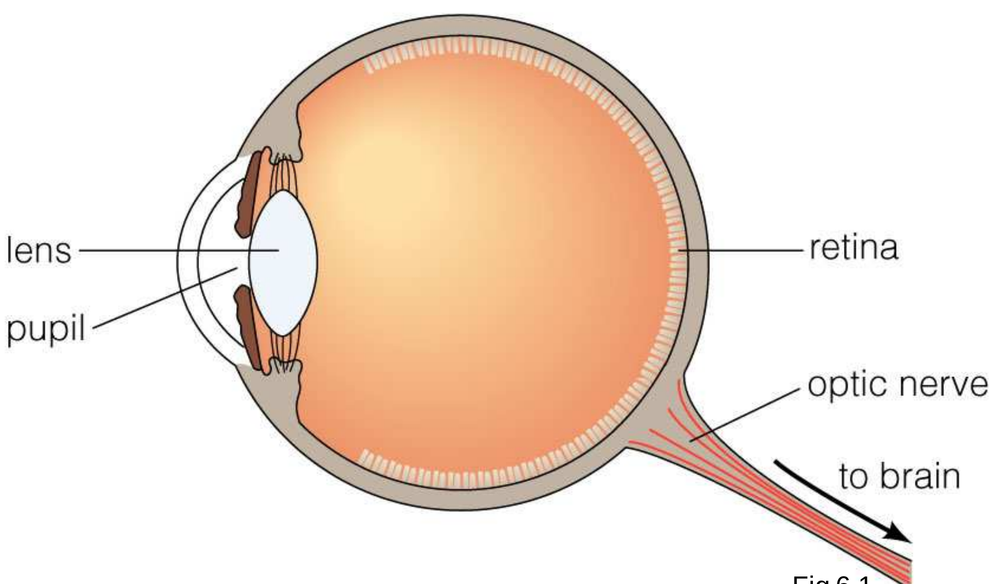


Fig 6.1

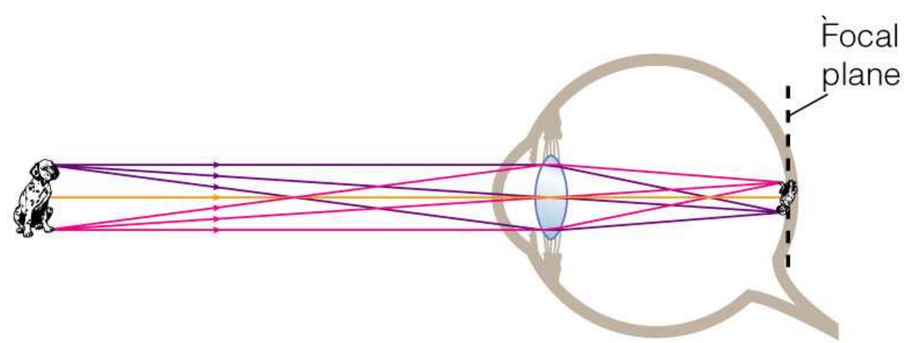


Fig 6.4

Cameras Capture Images

- Cameras can “soak up” light over time
  - Exposure time or Integration time
  - Our eye can not integrate over long durations
- Most of astronomy is **<u>not</u>** done by looking through the eyepiece of the telescope
  - Capture images using cameras and analyze

Long exposure (~15 minutes) picture I took at Kitt Peak, AZ

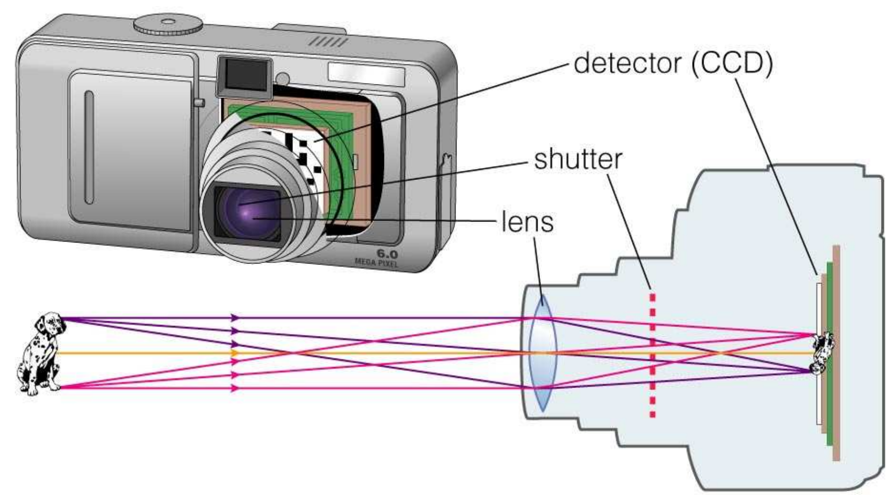


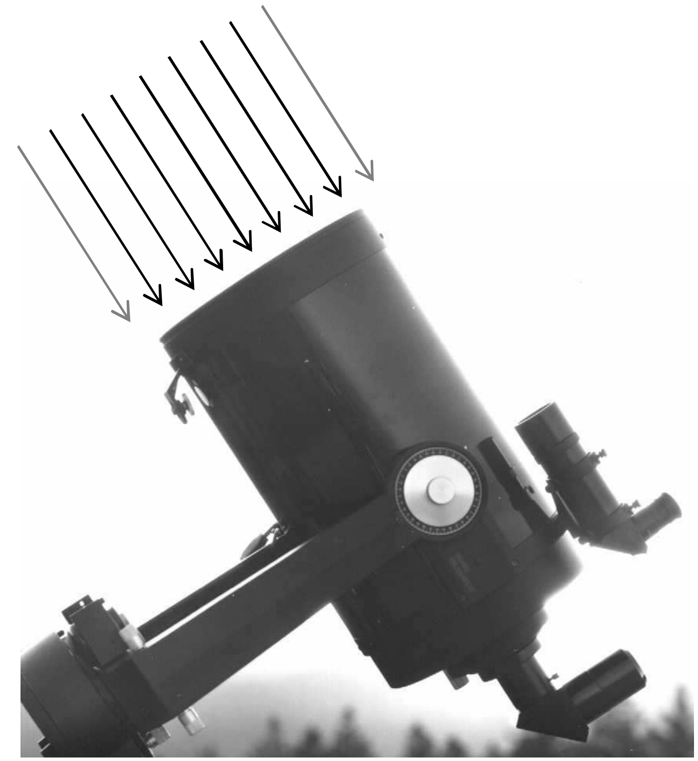
Fig 6.5

Telescopes: Important Attributes

- **<u>Not</u>** magnification!
  - That would be a microscope
- How faint can one see?
  - Faint limit
  - Related to the aperture
- Angular resolution
  - “Fineness” of details seen
  - Also related to aperture
- For telescopes, the larger the light collecting area, the better
  - Can see fainter objects
  - Can see finer detail

Telescopes: Aperture

- How faint can one see?
  - Telescope = Light bucket
  - Longer the exposure time, fainter the objects seen
  - For given exposure time,
    - Larger the light collecting area, fainter the objects seen
    - Area of circle = πR^2
    - Diameter of opening = **<u>Aperture</u>**
    - Double the aperture, 4 times light collected per unit time

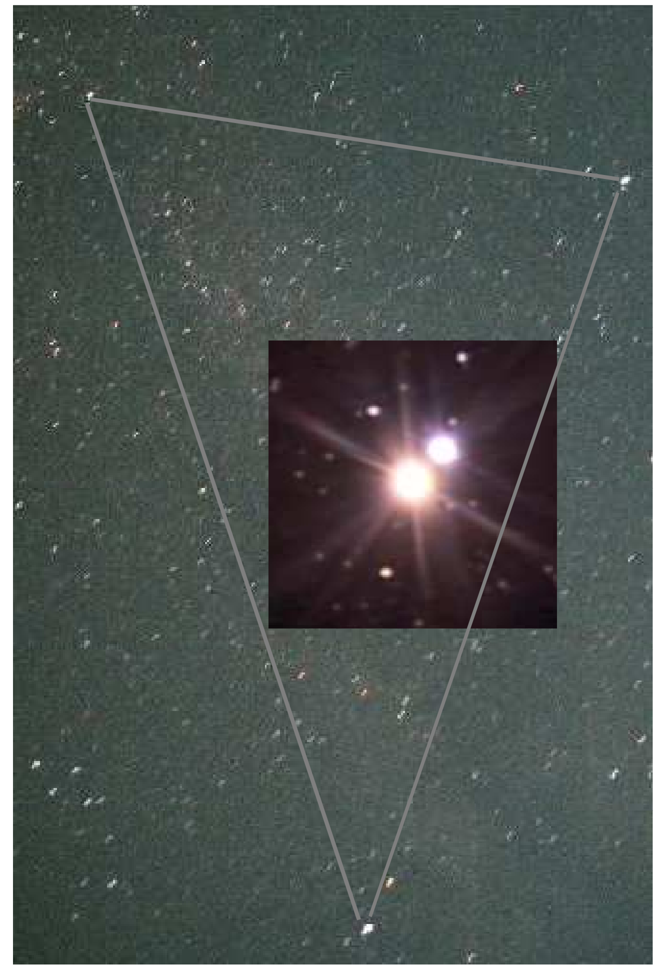


Telescopes: Angular Resolution

- What details can one see?
  - Details = Angular Resolution

$$R_{arc\sec} = 2.5x10^5 \frac{\lambda}{D}$$

  - λ = Wavelength of light observed
  - D = Diameter (aperture) of telescope
  - λ & D in same units of length
- Longer wavelength = Poorer resolution for a given aperture
  - Radio telescopes are very large
- Double the aperture of telescope
  - Half the numerical resolution (R)
  - Double the angular resolution



Albiero in the Summer Triangle
~2 minute exposure picture I took at Mount Wilson, CA

Refracting Telescopes

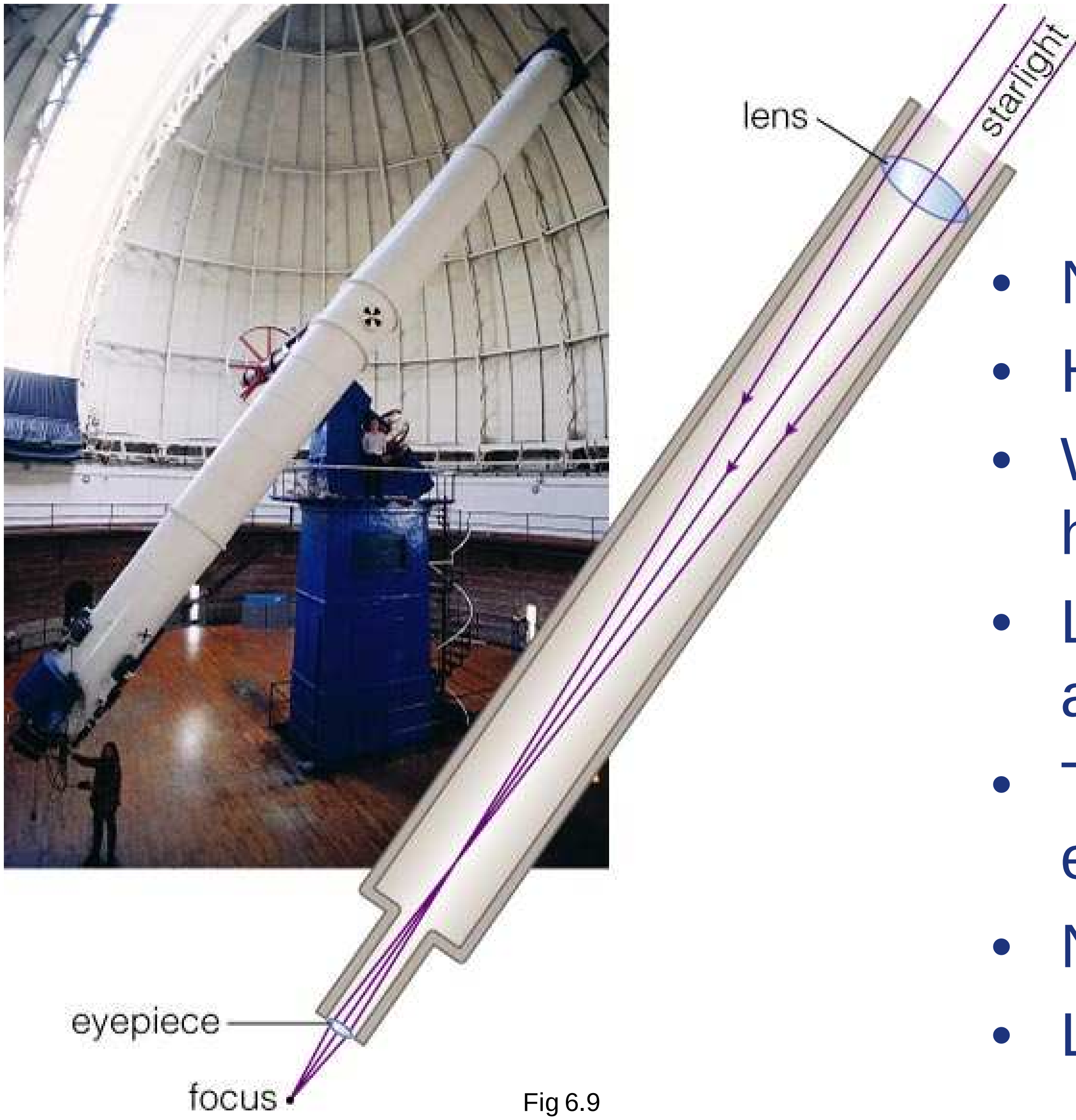


Fig 6.9

- Needs high quality glass
- Heavy
- Weight at the top, so harder to balance
- Leads to chromatic aberration
- Tough to build, more expensive
- Not much in use now
- Largest aperture = 1m

Reflecting Telescopes

- Primary mirror surface precisely shaped
- Reflective coating on mirror surface
- Light does not pass through the glass
- Weight at the bottom
- Easier to build
- Largest single mirror = 8 m aperture
- 30 meter telescopes in design!

3.6 m WIYN Primary, Kitt Peak, AZ

Fig 6.10 b: 8-m Gemini North Telescope

Types of Reflecting Telescopes

- Different ways of getting the light from the mirror to the image capturing device (usually a CCD camera)

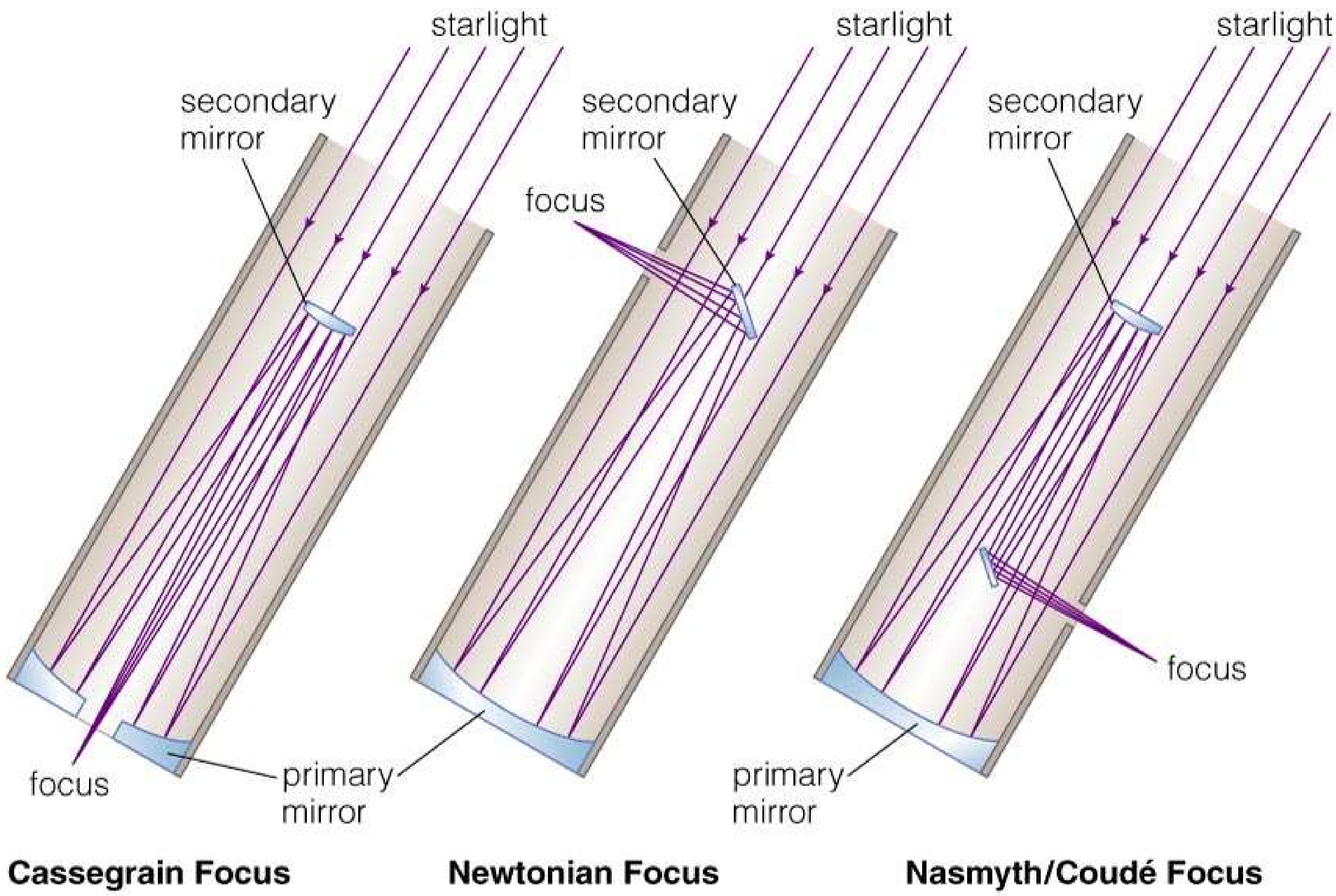


Fig 6.10 a

Ground-Based Observing: Issues

- Can only observe at night
  - Radio waves are an exception
- Need good weather (clear skies)
- Light pollution
  - City lights brighten the night sky
- Atmosphere blurs the image
  - Twinkle, twinkle little star…
  - Ever try to look at trees from under water?
- Most of the EM spectrum does not reach the ground!

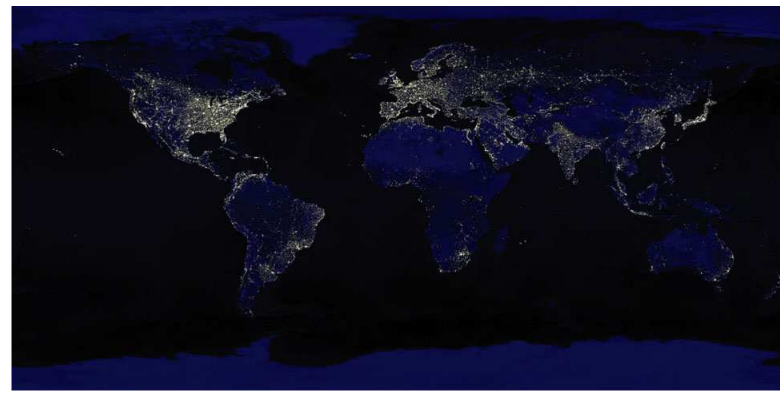


Fig 6.18

Ideal Ground Conditions

- High
  - Leave 30% of atmosphere behind at an altitude of 10,000 ft
- Dry
  - Clear nights, low humidity
- Away from cities
  - Dark skies, no light pollution
- Smooth air flow
  - Less turbulence
- Excellent locations on Earth
  - Hawaii (Mauna Kea)
  - Atacama Desert (Chile)
  - Arizona, California are good locations in Continental US

Our Atmosphere is a Good Filter

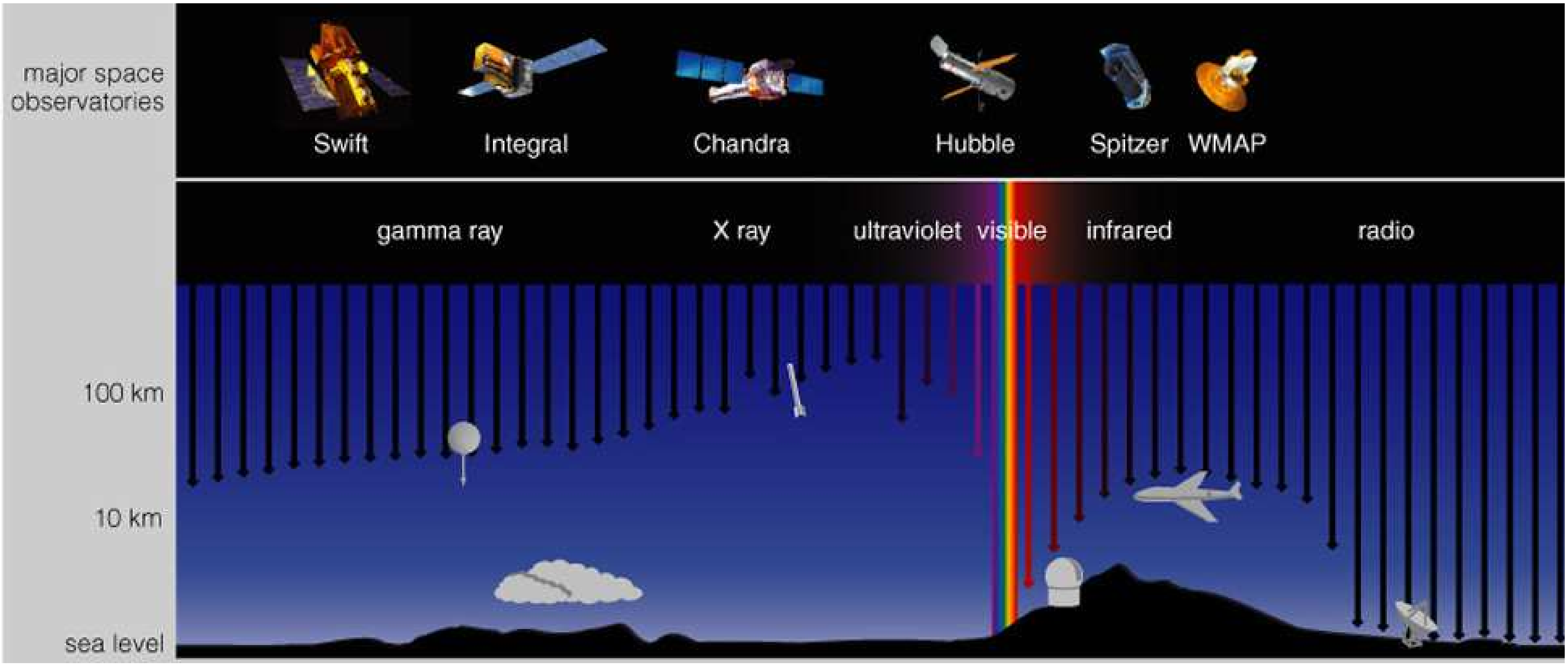


Fig 6.22

- Space based observations are far better in any wavelength
- And, a necessity in most wavelengths

How Do We “See” X-Ray Images

- Same way we see X-ray images from our doctor
  - Actually, these are negatives
- Measure intensity of radiation at various wavelengths
- Depict energy of radiation with different colors
  - Translate invisible to ROYGBIV
- Sometimes, depict intensity by colors

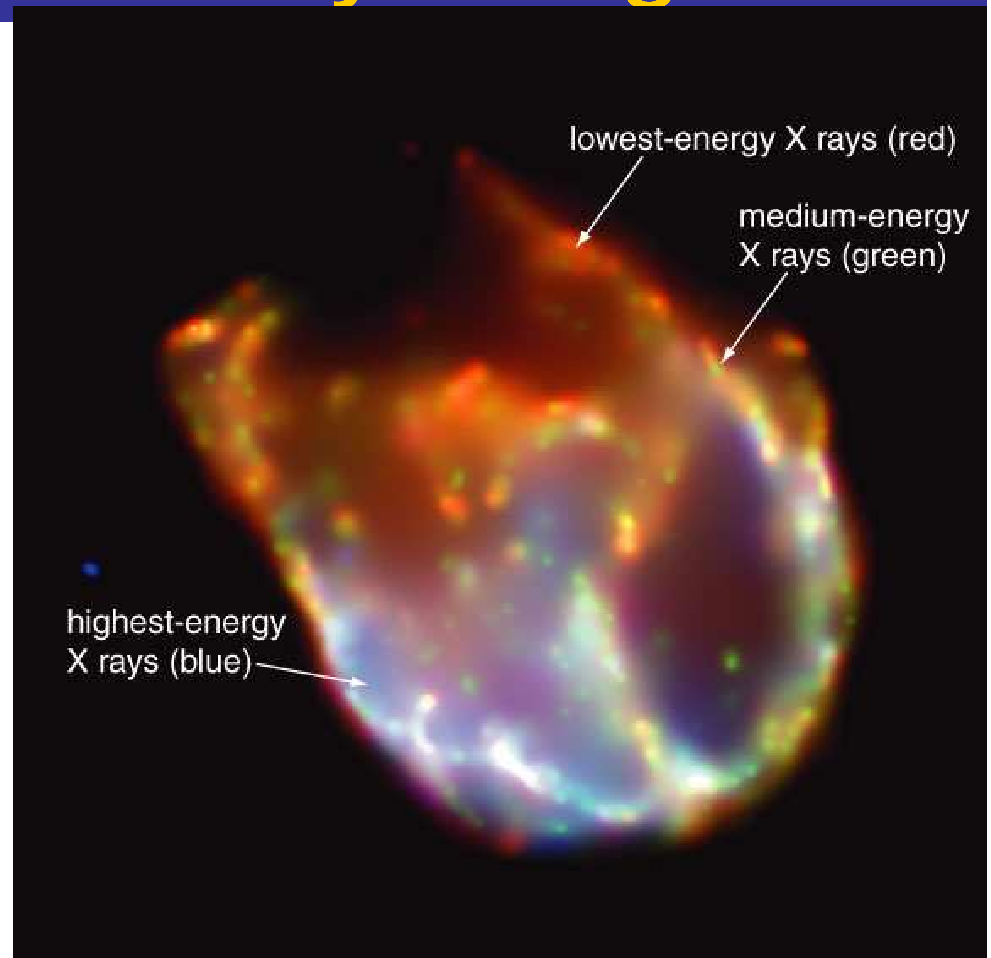


Fig 6.14: Supernova remnant

Interferometry

- Combine light from multiple telescopes to get significantly better angular resolution
- Remember telescope resolution? $R_{arcsec} = 2.5\text{x}10^5 \frac{\lambda}{D}$
- GSU's CHARA Array
  - World's longest baseline optical interferometer
  - 330-m baseline
  - Mount Wilson, CA
  - Very high-tech
  - Moving mirrors with 1 nanometer precision
  - Can read your textbook from over 400 miles away!