Astro 301/ Fall 2006

(50405)

Introduction to Astronomy

http://www.as.utexas.edu/~sj/a301-fa06

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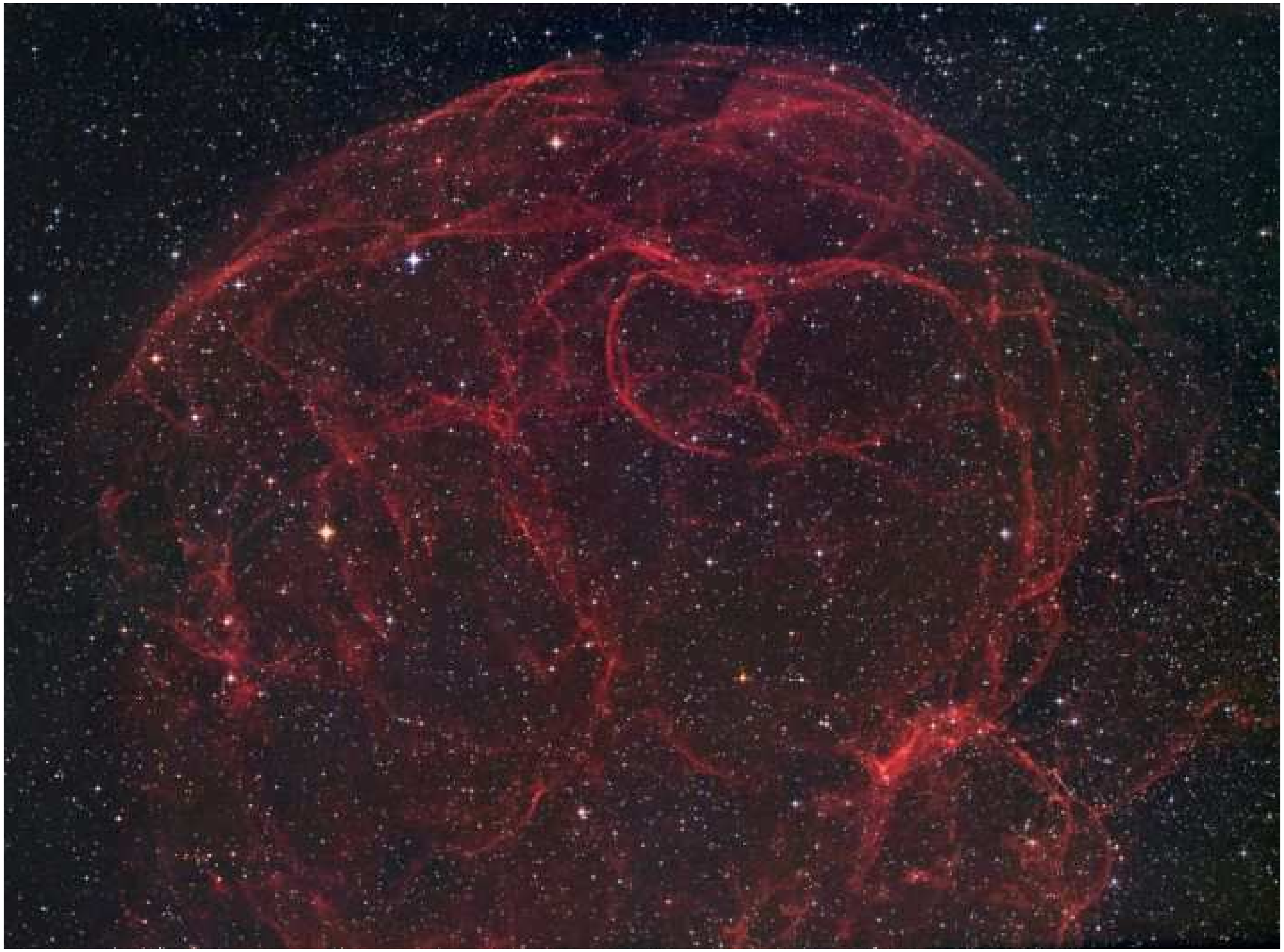
TAs: Biqing For, Candace Gray, Irina Marinova

Lecture 17: Tu Oct 31

Astronomy Picture of the Day



- Simeis 147: Supernova Remnant in Taurus. Covers 3 deg or size of 6 full moons on the sky
- Composite of optical imags shows shocked, glowing gas. After a massive star exploded 100,000 years ago, this gas was blasted out and heated by shock waves.
- It leaves behind the stellar core which has collapsed into a spinning neutron star

Recent and Upcoming topics in class

---Telescopes : Our Eyes on the Universe

-- Important properties of a telescope

1) Collecting Area: Current and Next Generation Largest telescopes. GMT

2) Resolving power

3) Space-based vs ground-based NASA's four Great Observatories

4) Operating Wavelength: Using observations at different wavelengths to unveil the mysteries of the Universe

Lecture 17: Announcements

-- Extra Credit option: if you have not started, you may run out of time check website

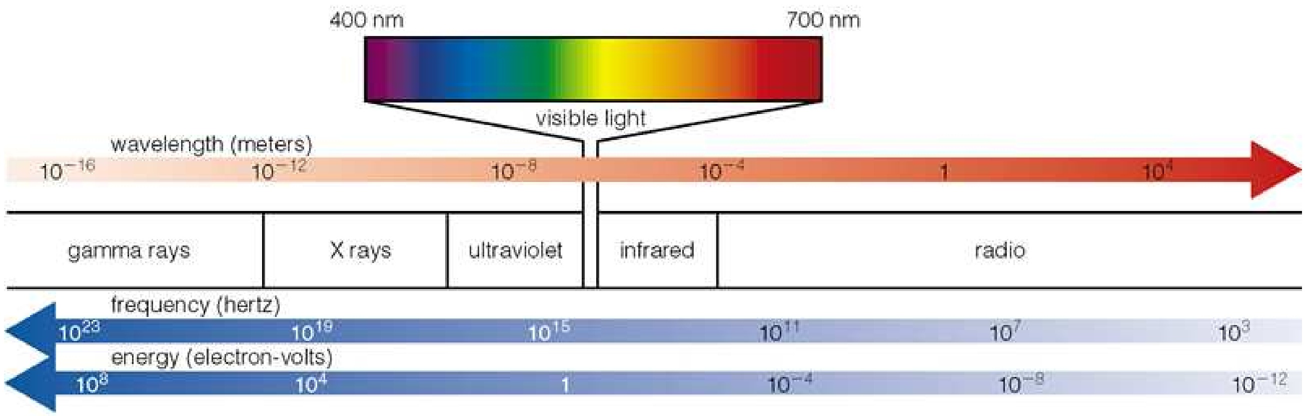
-- Exam 2 : Th Nov 9

Telescopes and Detectors

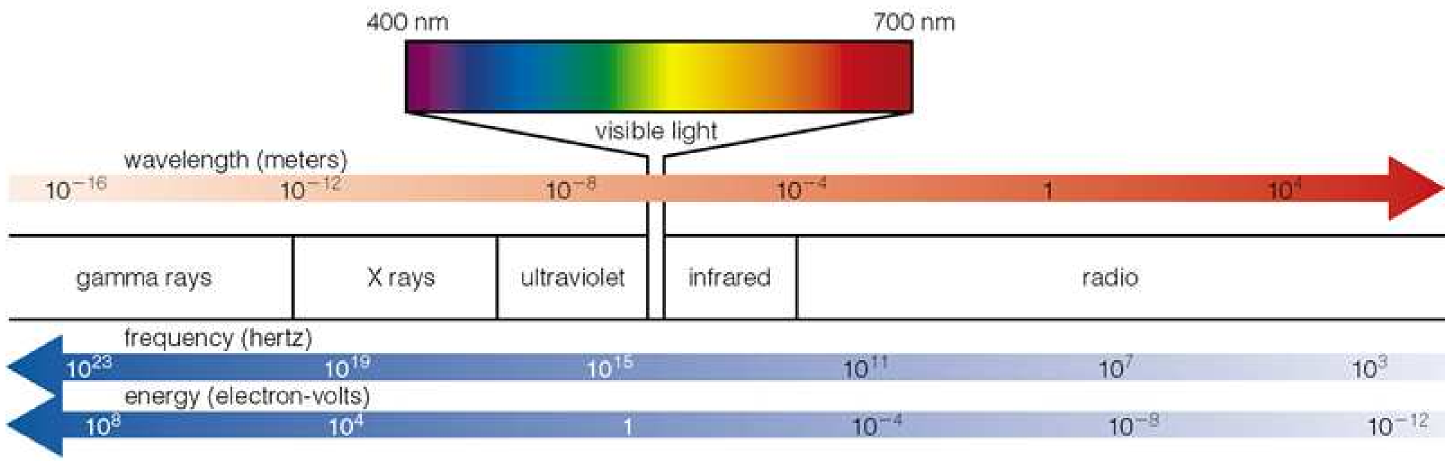
What is a telescope?
A device that collects light from a distant object (star, galaxy, planet) and delivers the light to a detector for detailed study.

Recall: light can be considered as electromagnetic waves of different wavelengths

Gamma rays	10^{-16} m
X rays	10^{-12} m
Ultraviolet	3×10^{-7} m
Optical	4 to 9×10^{-7} m = Violet, blue, green, yellow, orange, red
Infrared	10^{-6} m to 10^{-4} m
Radio	10^{-3} m to 10 m



Telescopes and Detectors



The detector varies depending on the wavelength at which the telescope operates

- Optical light : detector = photographic plate, or a CCD (Charged Coupled Devices)
  How does a CCD work?
- Gamma-ray light : detector = a counting device
- Radio light : detector = radio receiver

Why is the collecting area of a telescope important?

Consider an object of luminosity L at a distance d from Earth

Recall definition of flux or apparent brightness

à The flux f we receive from the object is defined as the energy received per second per m^2

à The value of the flux is directly proportional to the luminosity L and inversely proportional to the square of the distance

f = (Luminosity of object) /(Area of sphere of radius d)

= $L / 4 \pi d^2$ (See in-class figure)

Suppose we collect the flux (light) from the object with a telescope of area A by observing for a time t (called the exposure time).

Total energy collected

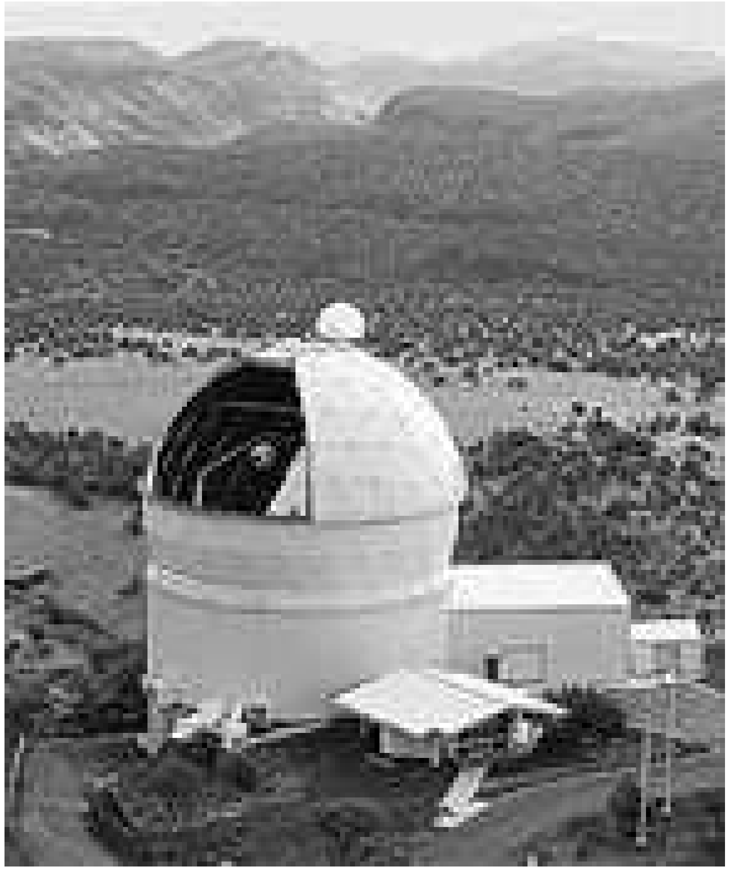
= Energy collected per second per m^2 x Area A in m^2 x time t in s

= flux f of distant object x Area A in m^2 x time t in s

For a given distant object, we can collect more light energy by using a larger telescope or/and a longer exposure time

Largest Optical and Infrared Telescopes

Keck 10-m telescope at 5000 feet on Mauna Kea in Hawaii



9.2m Hobby Eberly Telescope of UT Austin at the McDonald Observatory in West Texas

Largest Optical and Infrared Telescopes

Concrete base, 40 ft diameter, that supports the 9.2m Hobby Eberly Telescope

Next Generation Largest Ground-Based Telescopes

Giant Magellan Telescope (GMT)

- Diameter of combined mirror = 22 m
  (7 mirrors of size 8.4 m)
- Area ~4 times larger than current optical telescopes
- Location = Northern Chile
- First light in 2016

Casting of first mirror completed 27 Oct 2005!

GMT partners include U of Arizona **UT Austin,** Carnegie Observatories, Harvard, MIT Michigan, etc

In the offing
CELT
OWL

Angular resolution of a telescope

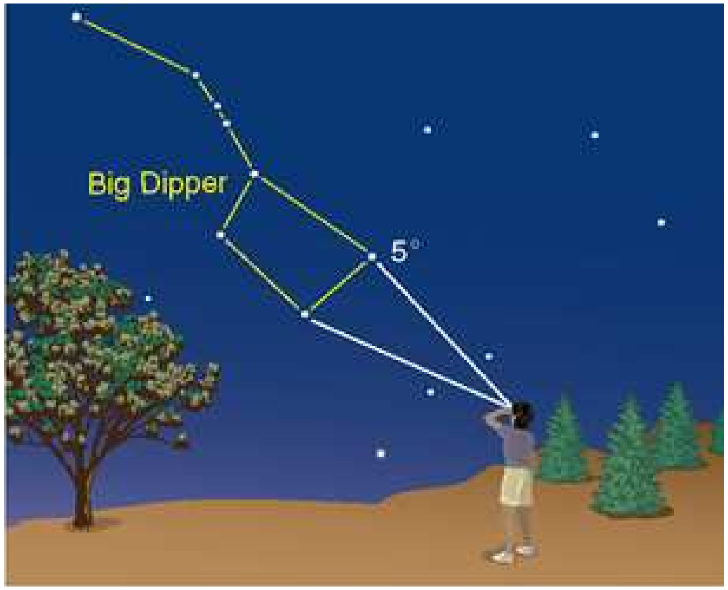
Angular separation

Recall lecture 3

-The linear separation L between 2 objects is the true separation measured in m

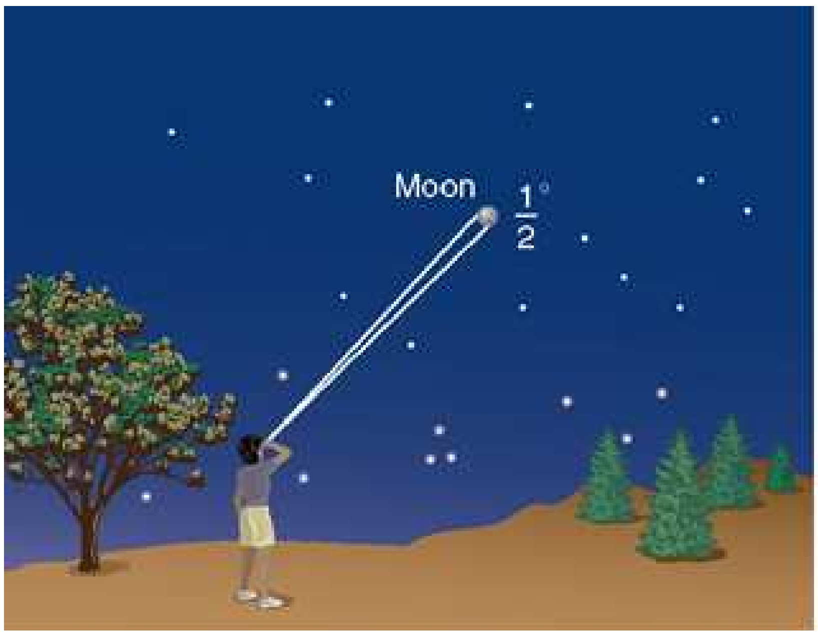
- The angular separation α between 2 object **is the angle which they appear to span in the sky .** It is measured in degrees or arcminutes or arcseconds where

1 degree = 60 arcminutes (60 ') = 3600 arcseconds (3600 ")

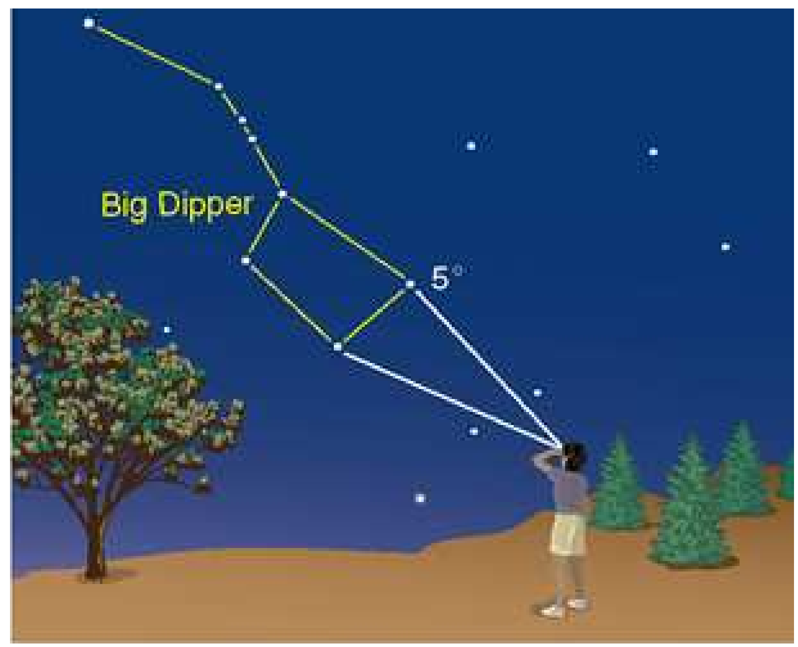


See in-class figure: For 2 objects with a fixed linear separation L, their angular separation will be lower if they are located further away

Angular size and angular separation



Use your hand to get angular sizes!



Angular diameter of Moon
= 0.5 degree = 30 arcmin

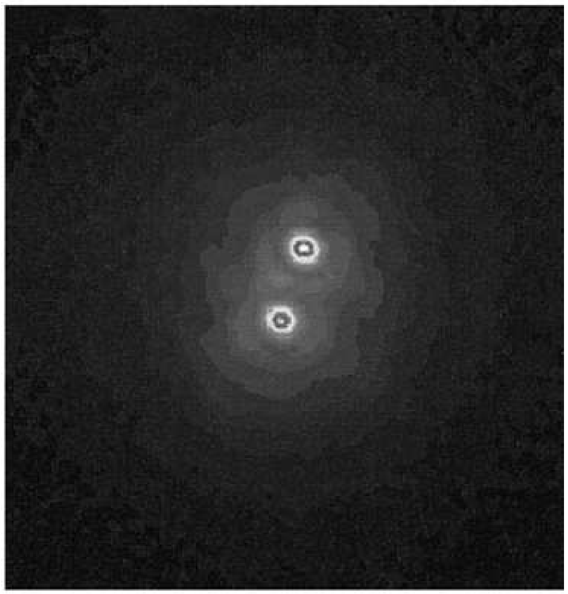
Angular separation of two stars on
the Big Dipper = 5 degrees.

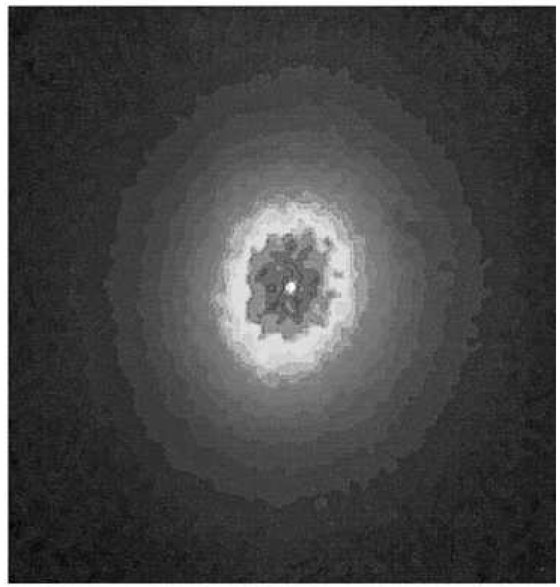
Angular Resolution or Resolving Power of Telescopes

The angular resolution of a telescope is

- the smallest angular separation that it can resolve
- the smallest angular separation of 2 point sources for which the telescope will still be able produce separate distinct images

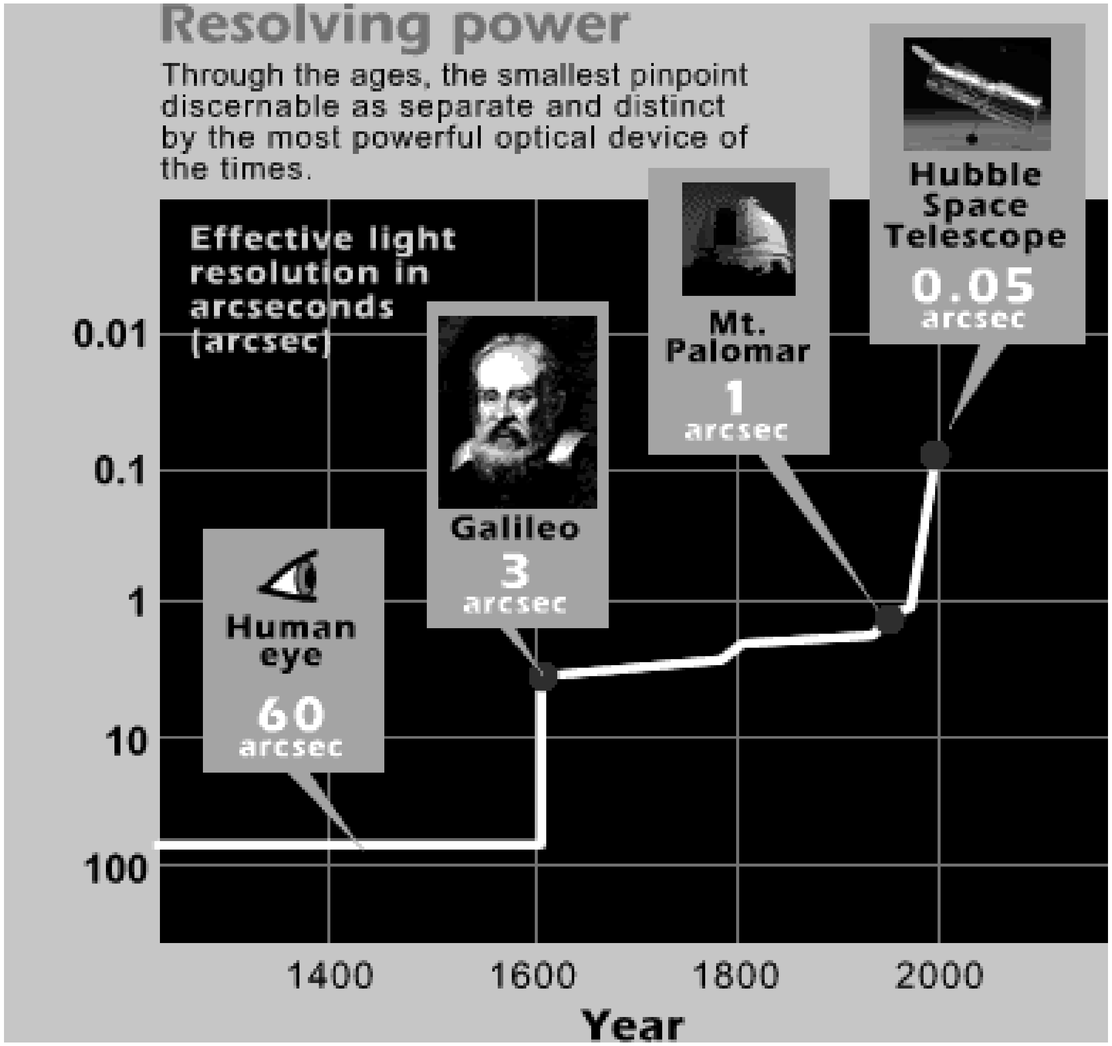
When a telescope takes an image of two objects whose separation is smaller than the angular resolution of the telescope, the image will 'blur'' the objects into one





A double star with an angular separation of 0.5" is imaged by two telescopes having an angular resolution of 0.1" (LEFT image) and of 3" (RIGHT image)

Resolving Power of Telescopes



A smaller angular resolution translates to a high resolving power.

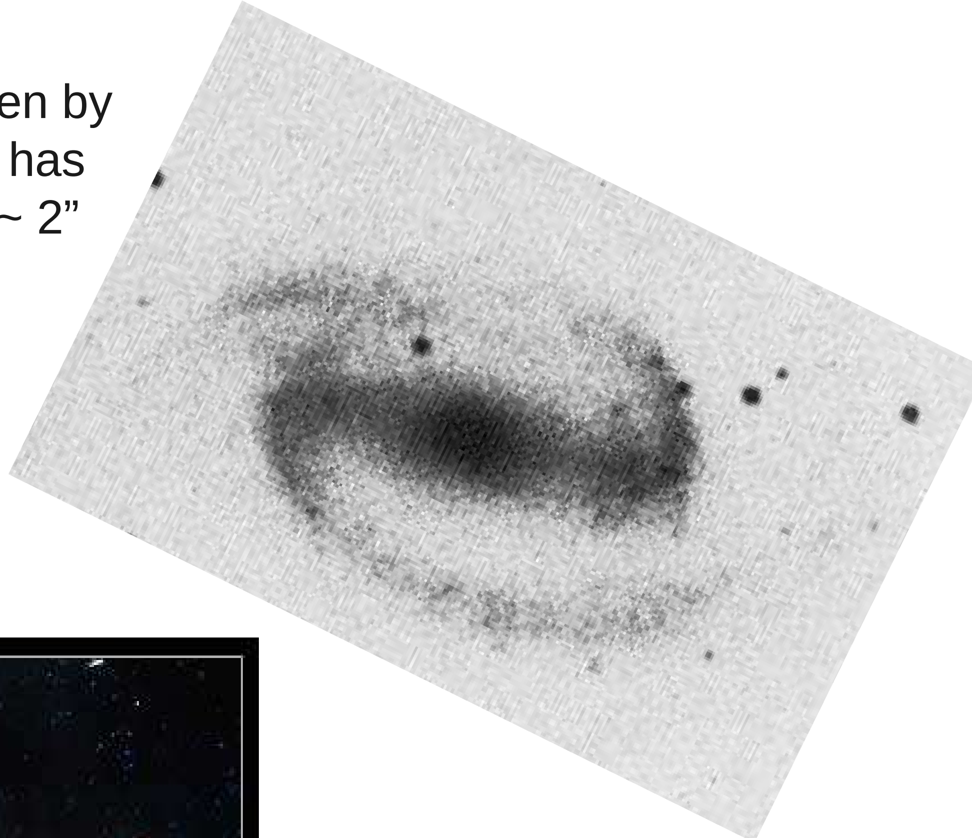
Why does the Hubble Space Telescope have an angular resolution 20 times superior to that of the Mount Palomar telescope?

Because it is observing in space ABOVE the turbulent Earth's atmosphere

The overall angular resolution of a telescope depends on (the telescope, the turbulence in the Earth's atmosphere and the turbulence in the dome/observatory

Resolving Power of Telescopes

NGC 1300 : this image was taken by a ground-based telescope and has an angular resolution s(eeing) ~ 2”

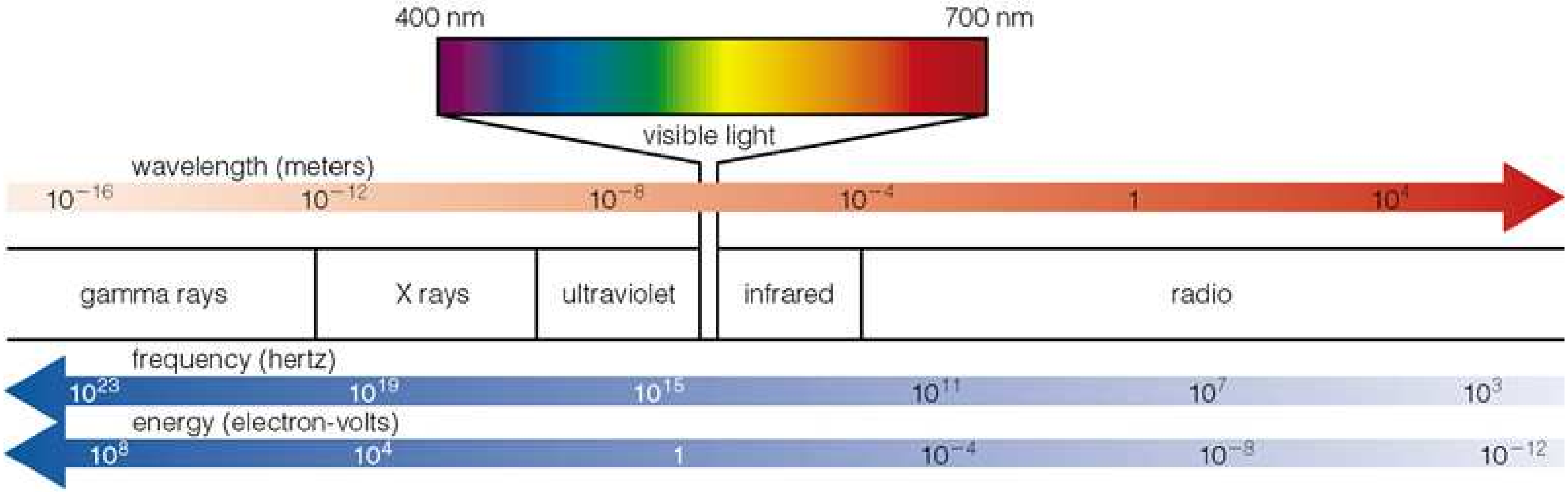


NGC 1300 : this image was taken by Hubble and has an angular resolution (seeing) ~ 0.05” . It shows much higher level of details within the galaxy

Resolving Power of Telescopes

HST image of spiral galaxy pair: seeing ~ 0.05”

Three problems introduced by the Earth's atmosphere



The Earth's Atmosphere Blocks Most Electromagnetic Radiation

Gamma-ray, X-ray,

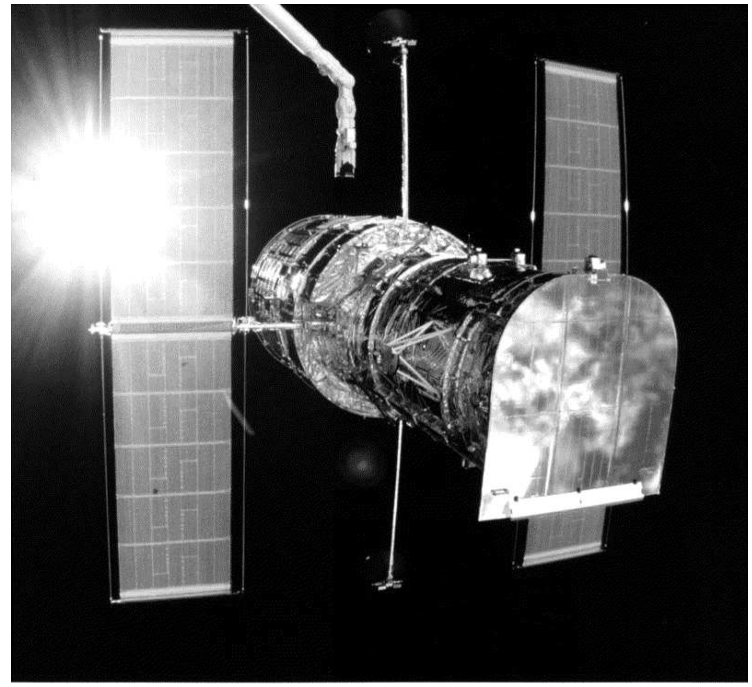
some UV bands

some IR bands

some sub-millimeter bands

- See in-class figure and notes

What are relative merits of putting telescopes in space?



Advantages

Avoid effects of the Earth's atmosphere

à No absorption by Earth's atmosphere of Gamma-ray, X-ray, UV, some IR, submm

à No blurring by Earths's atmosphere: images have high angular resolution.

à Avoid infrared background (glare) emission from Earth's atmosphere and sky : can see faint Infrared sources

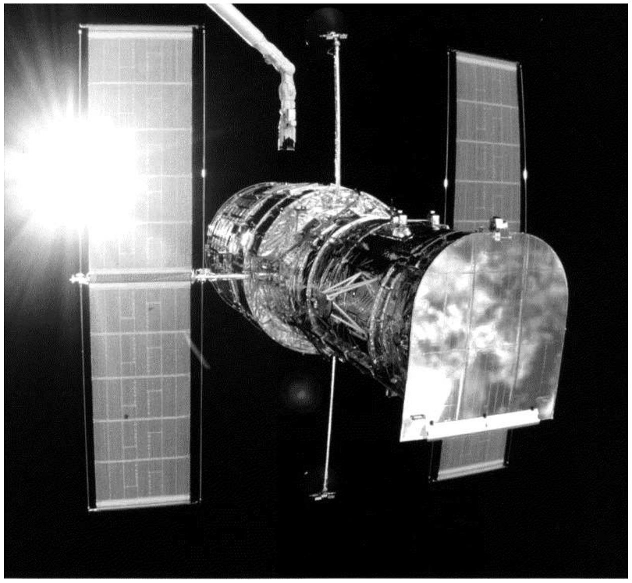
Disadvantages of space-based telescopes

à Cannot have large collecting area (else unstable and would need high power)

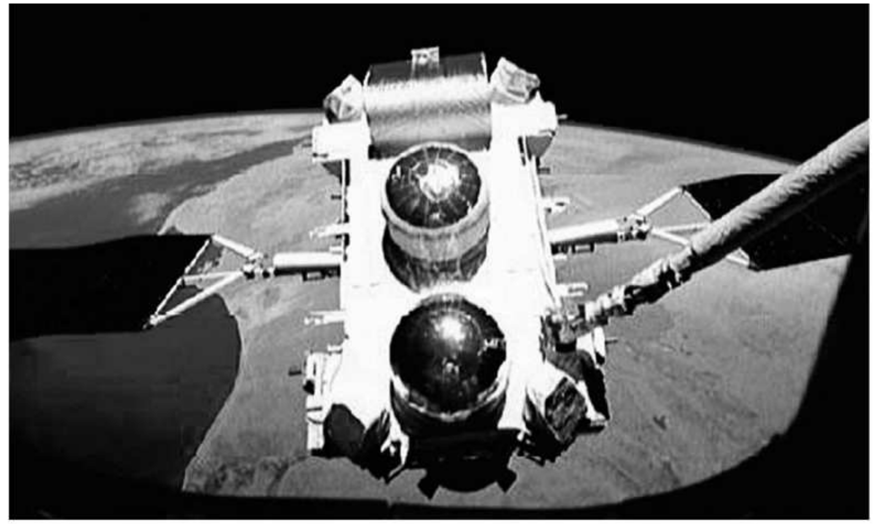
à Costly to repair and upgrade : servicing missions by astronauts

à Re-entry for larger telescopes can be dangerous (e.g., CGRO was 17 tons!)

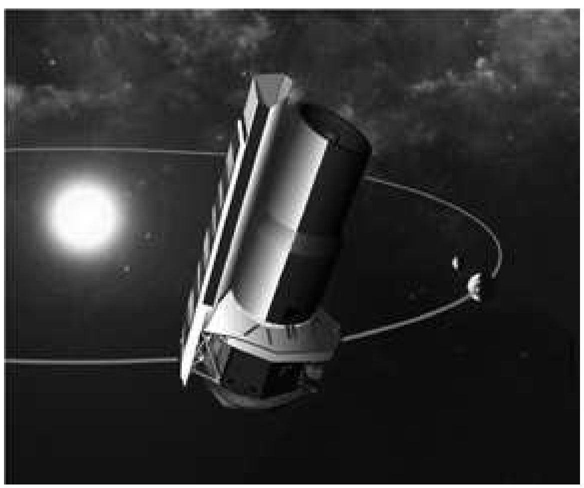
NASA's Four Great Observatories



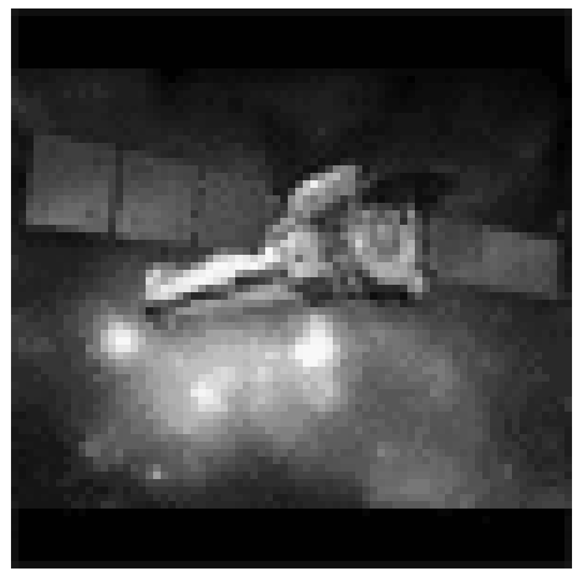
Hubble Space Telescope (HST; 1990)
for UV, optical and near-infrared



Compton Gamma-Ray Observatory (CGRO); 1991



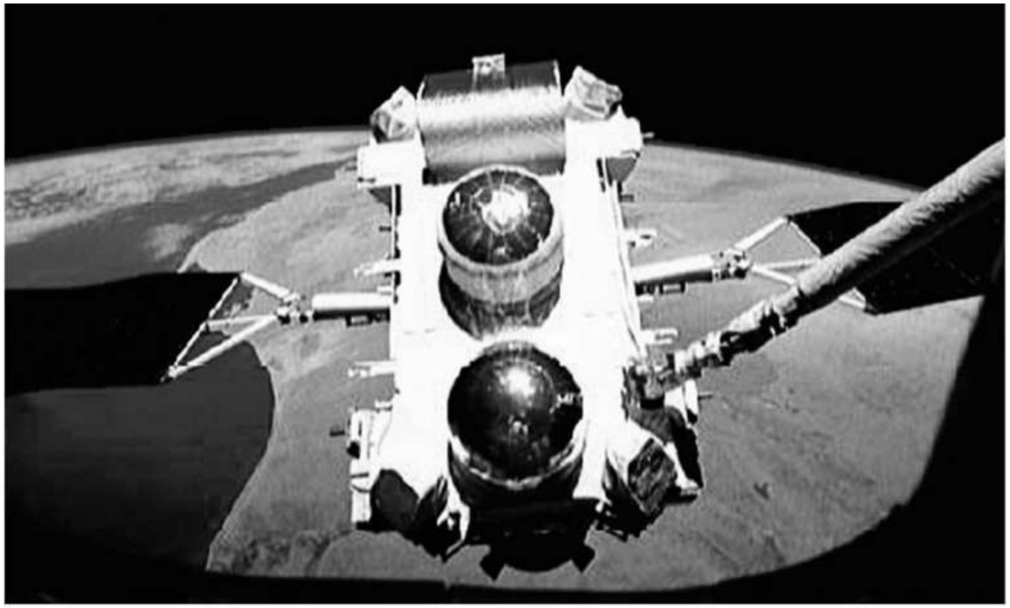
Chandra X-ray Observatory (CXO; 1999)



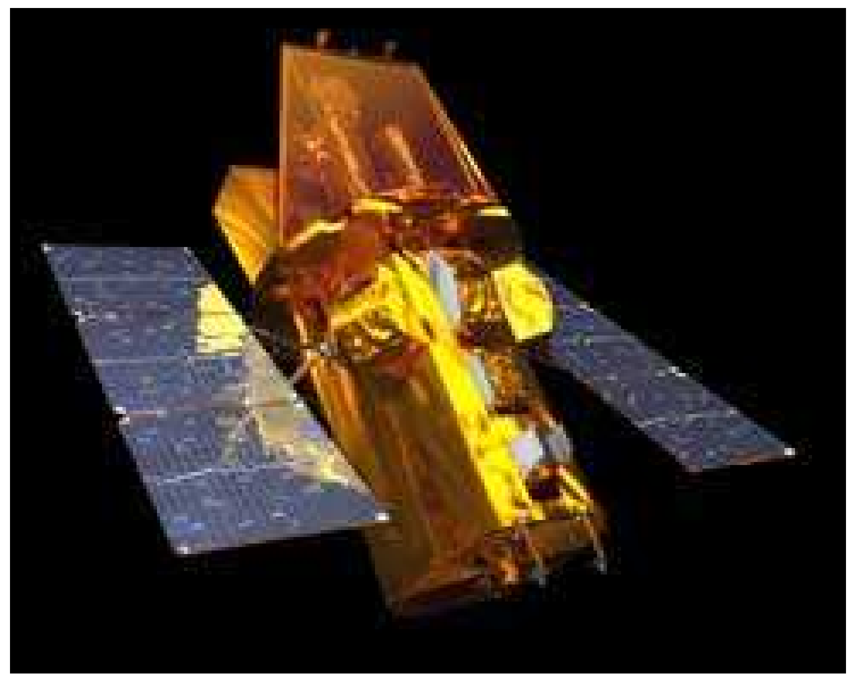
Spitzer Infrared Space Telescope (2003)

Imaging the Universe at Gamma-Ray Wavelengths

Gamma-Ray observations



- Compton Gamma- Ray Observatory
- 1991 to 2000; deployed at 17 tons from Space Shuttle; 17 tons!



- NASA’s Swift Gamma Ray Burst Explorer launched Nov 2004
- Dec 2004 : reported the brightest flash of light ever detected from beyond the solar system: more energy than the sun emits every 150,000 years!!!

à Gamma Ray Burst from a distant neutron star