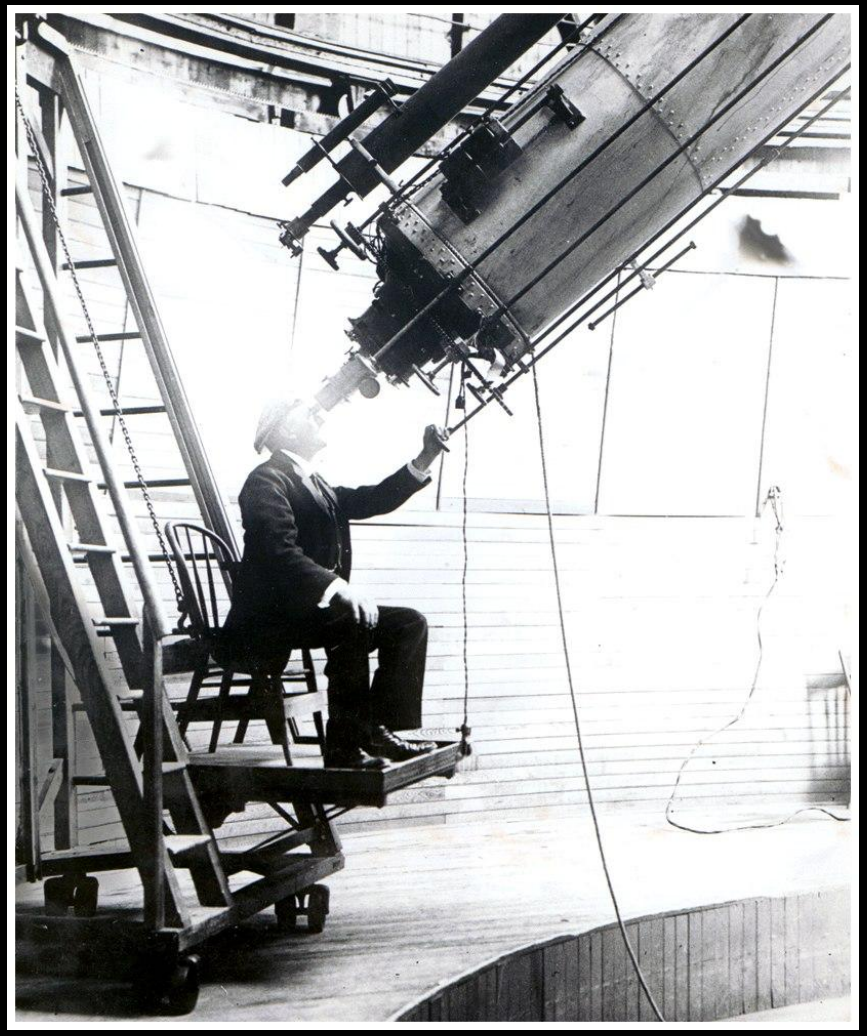

Telescopes



Why use a telescope?

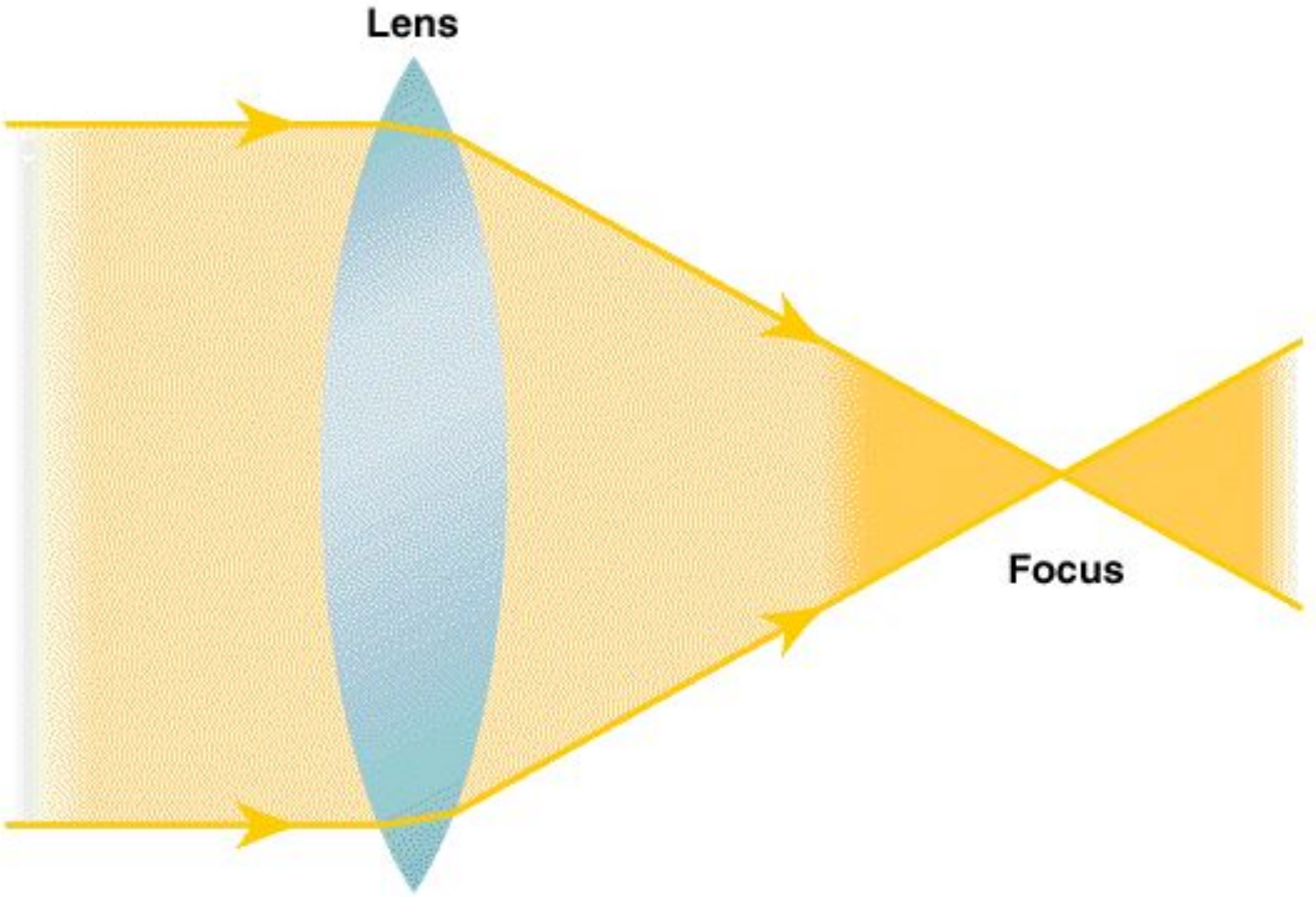
- Brighten
- Magnify
- Resolve

Properties of Lenses & Mirrors

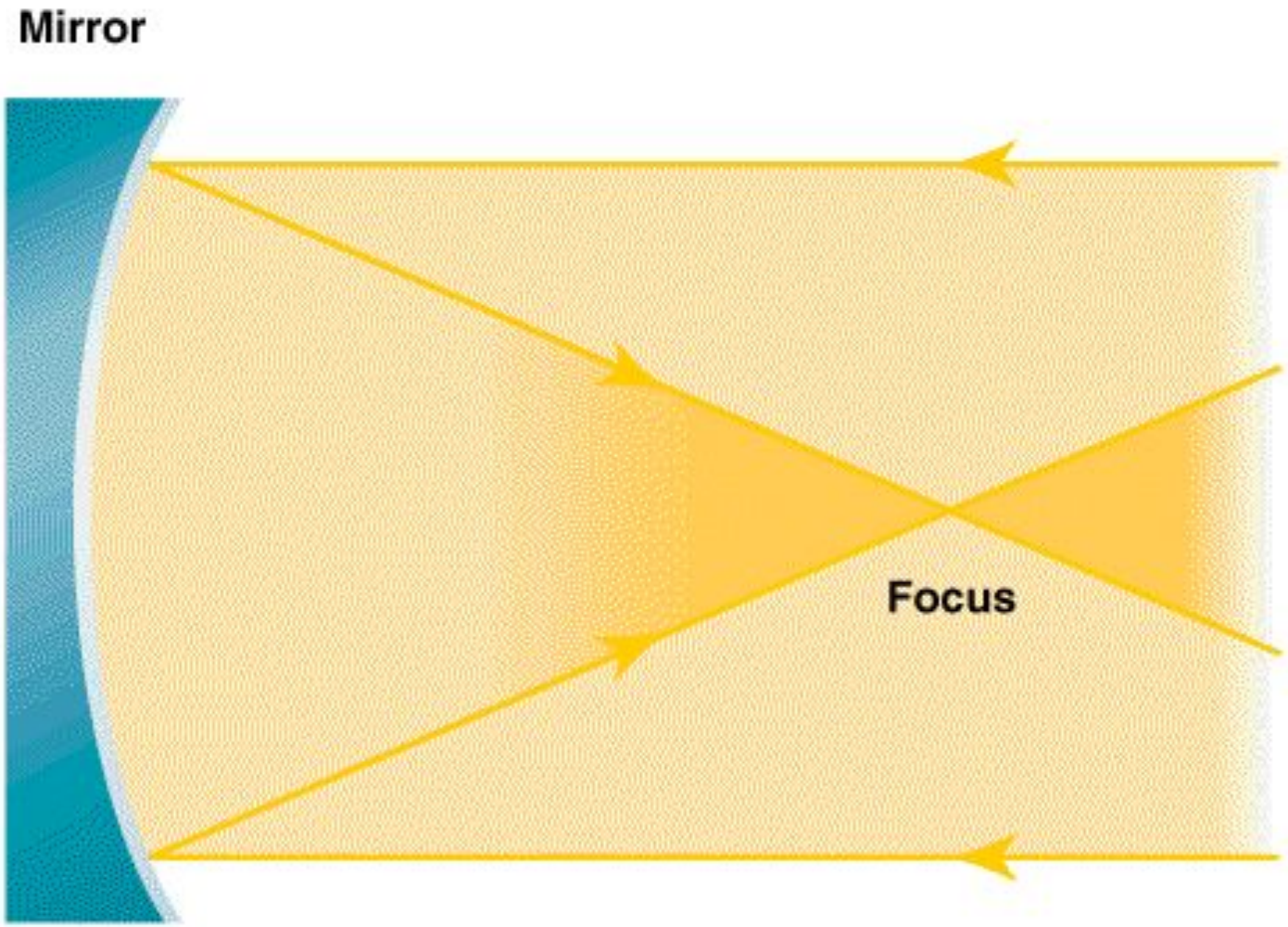
- Focal Point - the place where light rays converge to a point

- Focal Length - the distance from a curved mirror or lens to its focus

How a Lens Focuses Light



How a Mirror Focuses Light



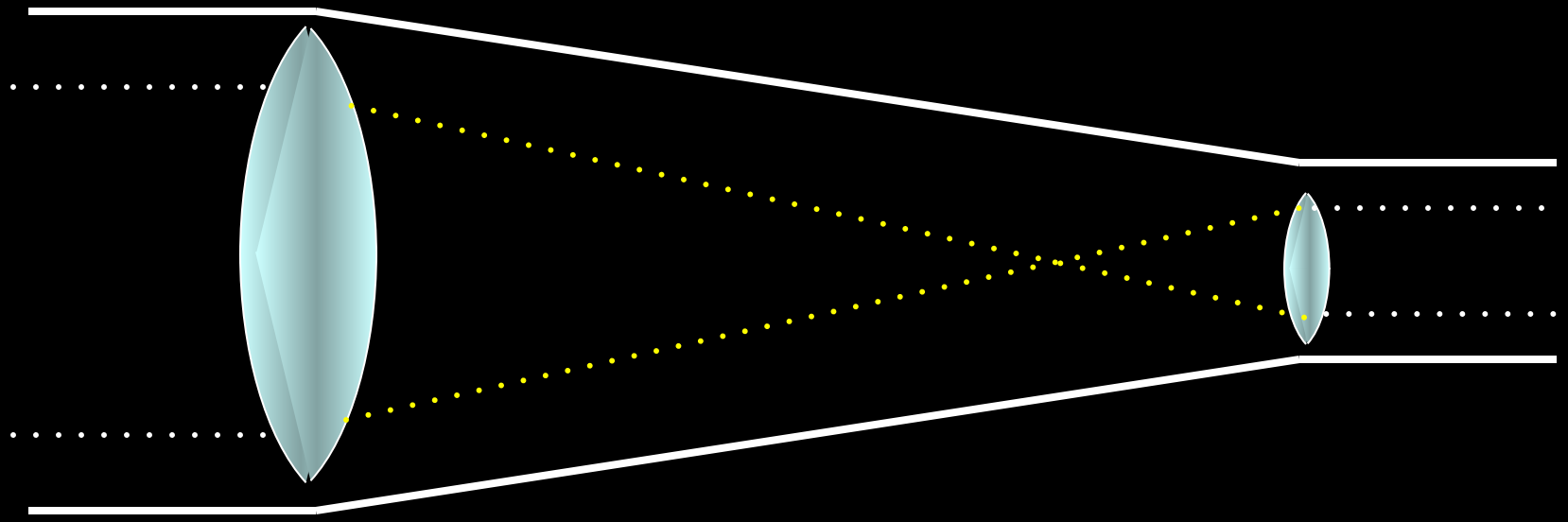
Types of Telescopes

- **REFRACTORS**
  - **Use lens to focus light.**
- **REFLECTORS**
  - **Use mirror to focus light.**

Refracting Telescopes

- objective lens
- assorted eyepieces

Light Path inside a Refracting Telescope

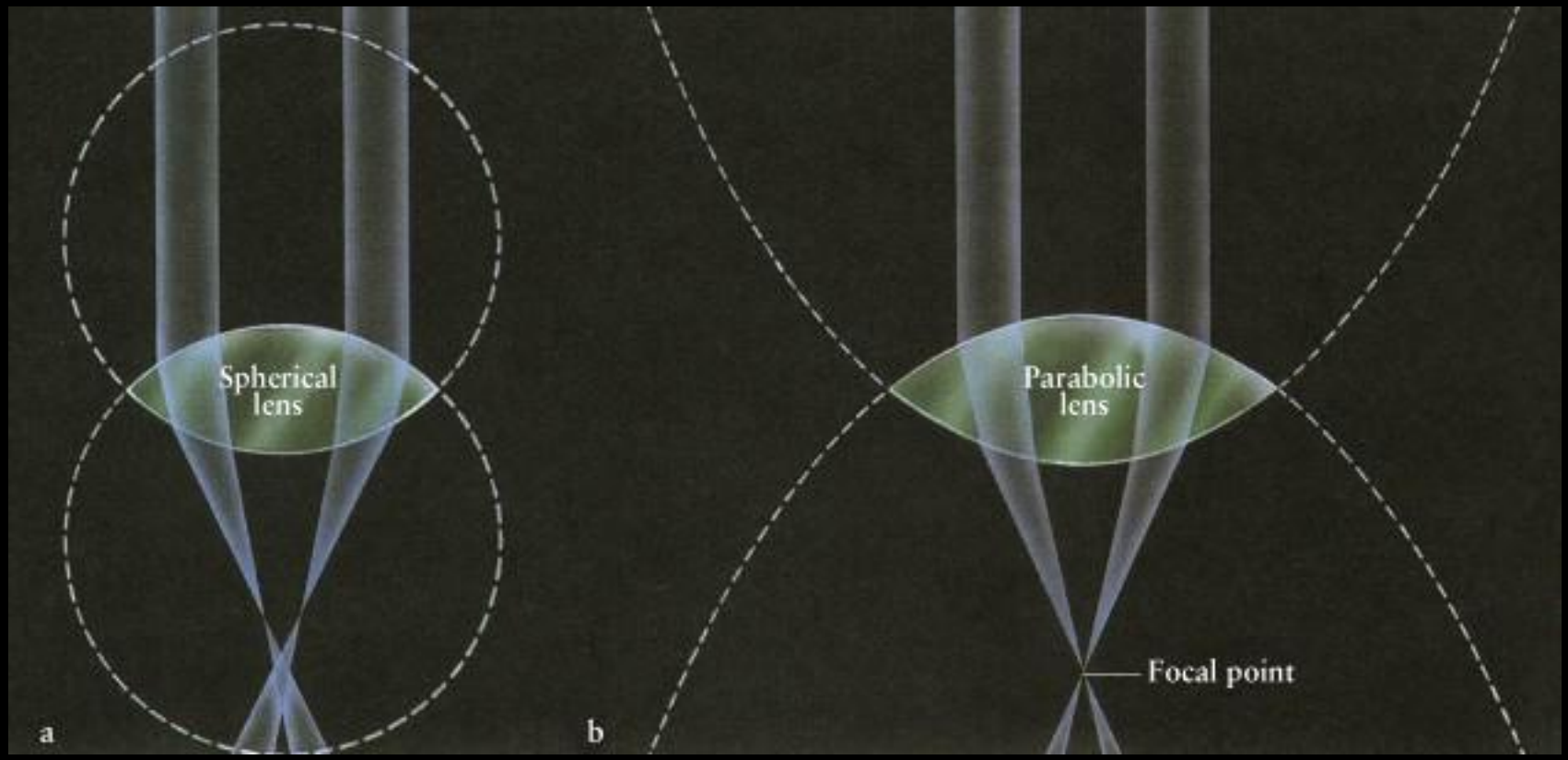


Light travels in this direction inside the refracting telescope.

GALILEO'S REFRACTING TELESCOPE (20X).

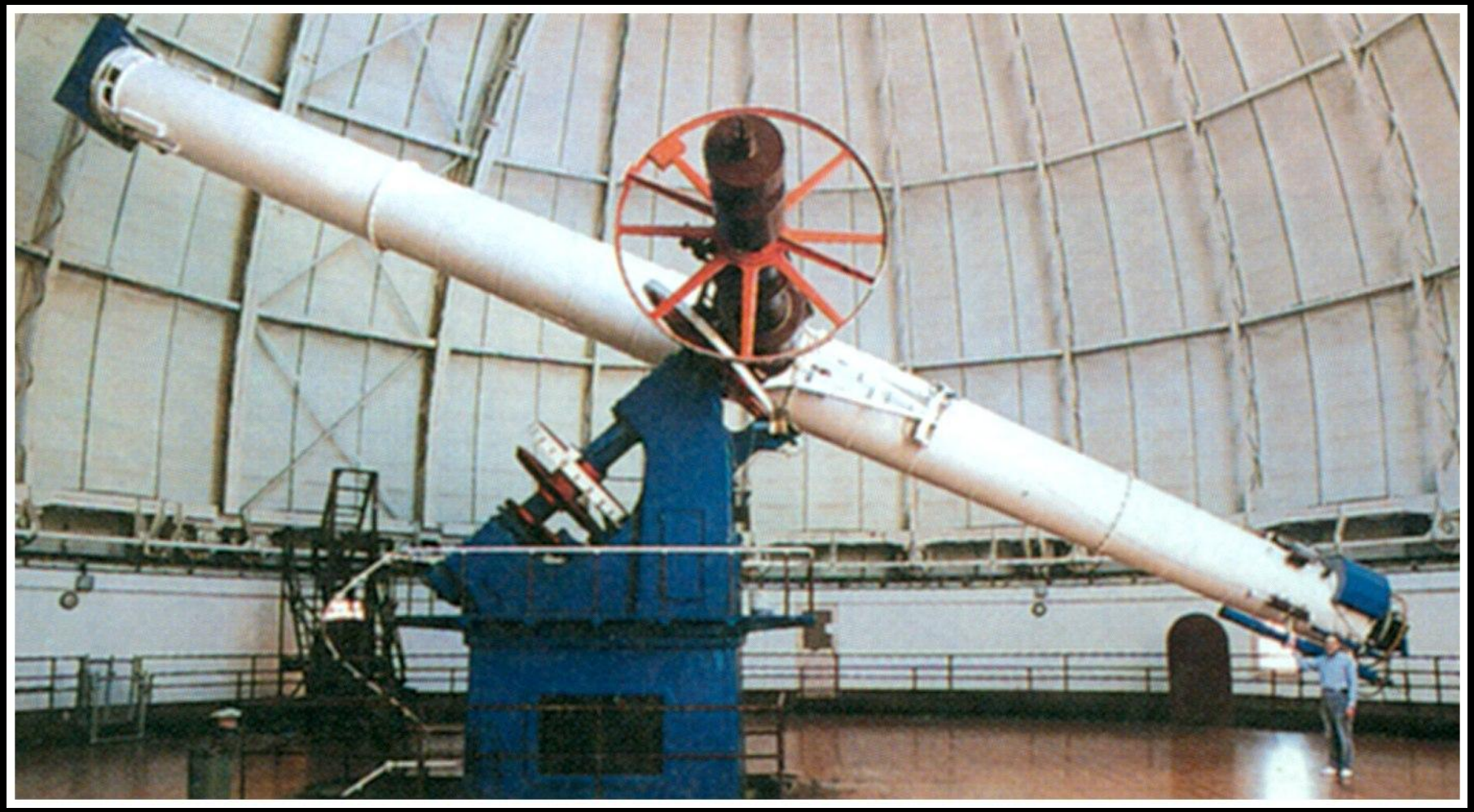
Johannes Hevelius observing with one of his telescopes (1647).

Johannes Hevelius and his long telescope



Spherical lens tend to exhibit spherical aberration.

Parabolic lens don't exhibit spherical aberration. This is the best shape for a telescope lens



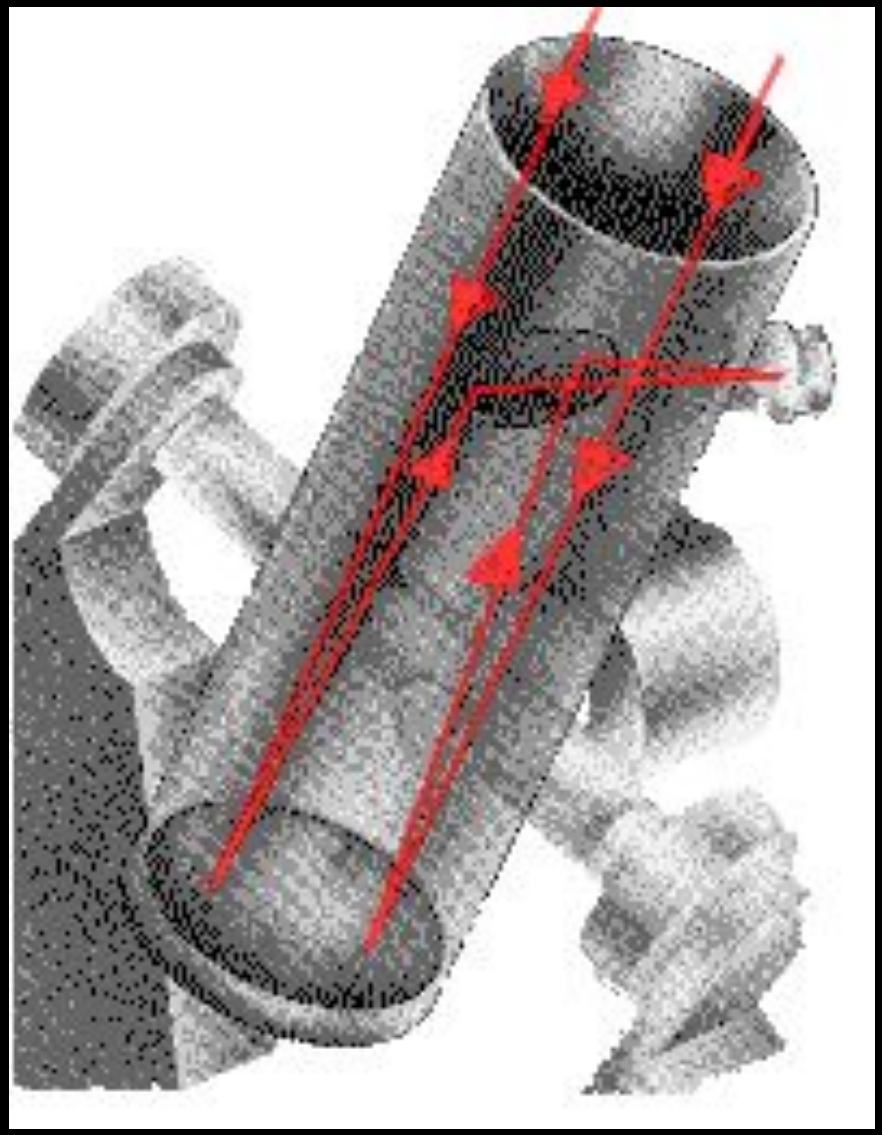
Large Refractor Problems

- can't support heavy lenses
- small lenses permit limited absorption of starlight
- larger lenses are prone to imperfections

Reflecting Telescopes

- primary mirror
- secondary mirror
- assorted eyepieces

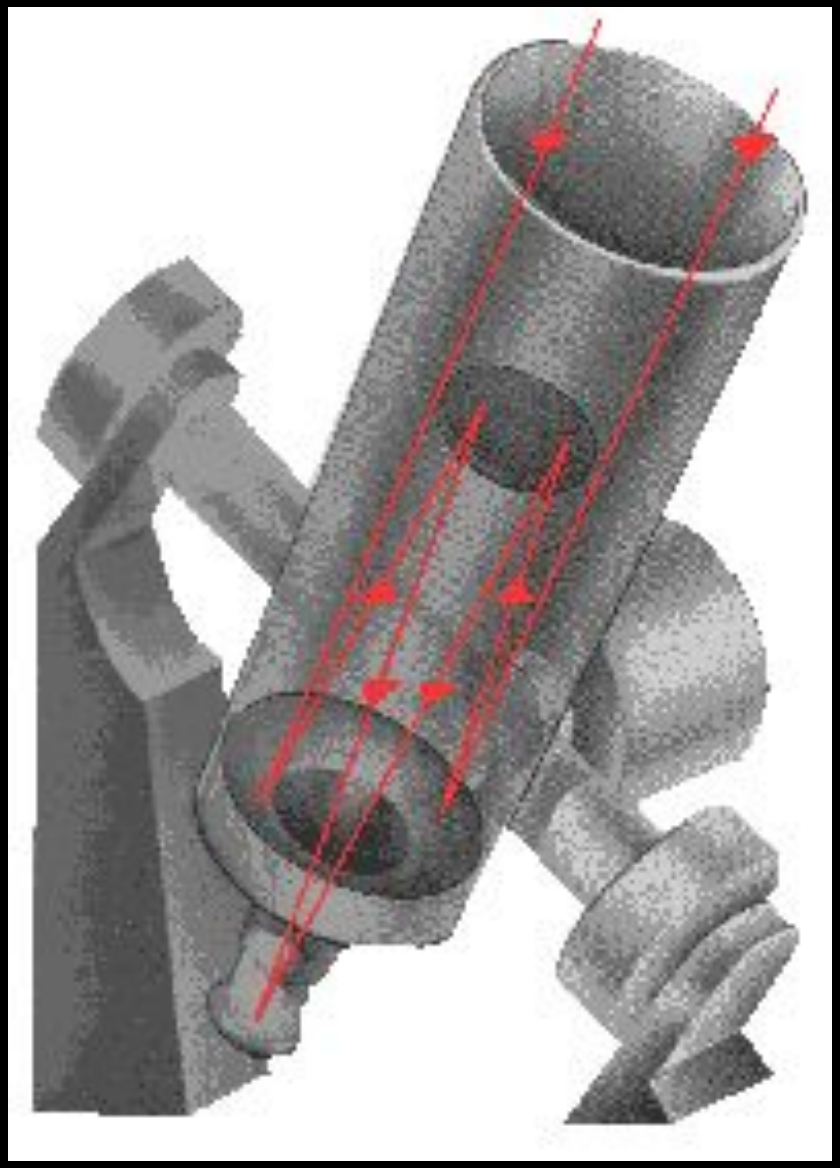
- Newtonian Reflector
  - a concave primary mirror
  - flat secondary mirror (diagonal)
  - eyepiece



Typical Newtonian reflector light path.

- Cassegrain Reflector
  - a concave primary mirror
  - a convex secondary mirror
  - eyepiece lens

10” Schmidt-Cassegrain



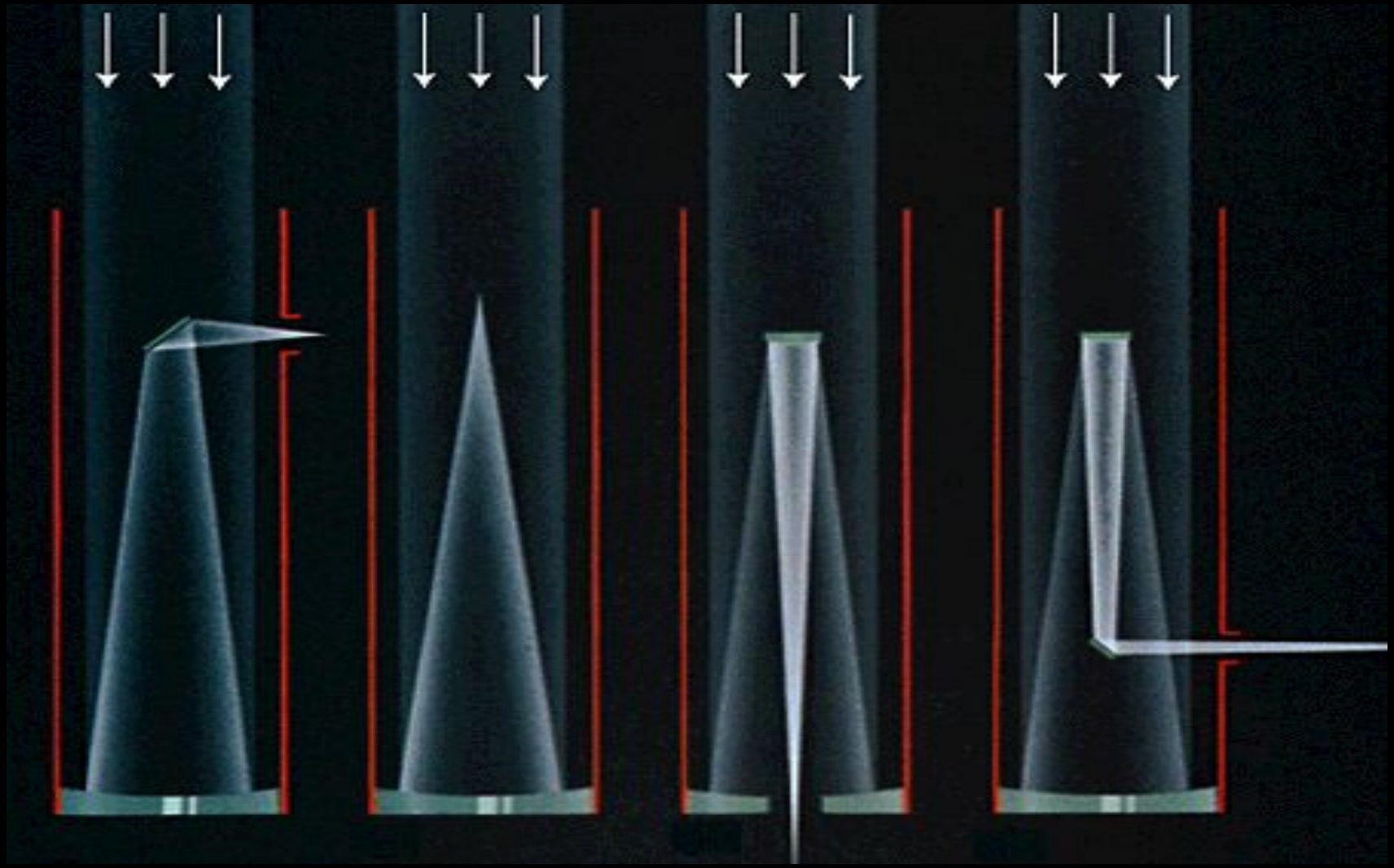
Typical Cassegrain reflector light path.

Cassegrain Telescopes

Hubble Space Telescopes

Hubble Space Telescope (13.6 m long) – HST

Types of Reflectors



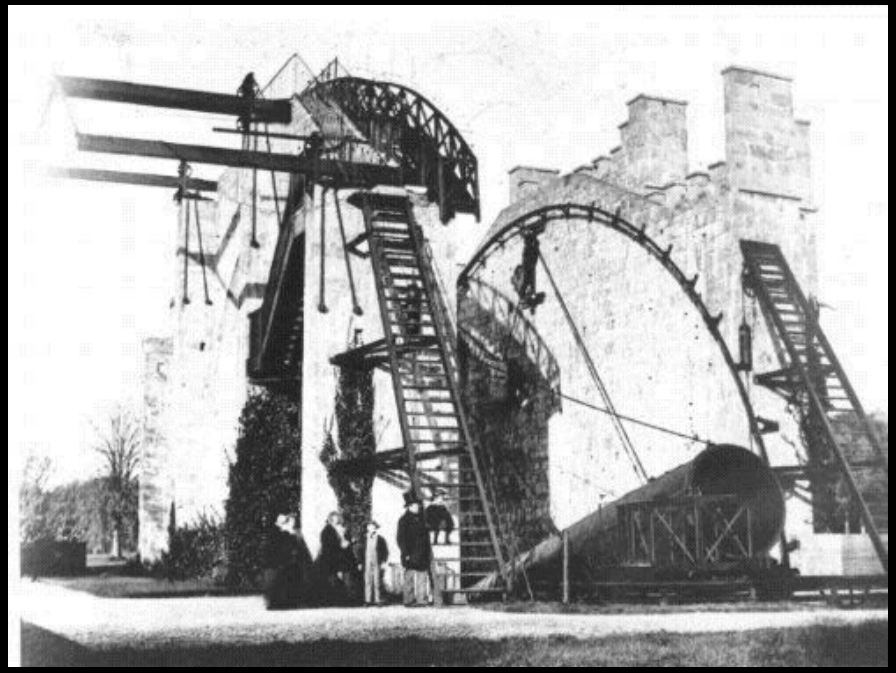
Newtonian Prime Focus Cassegrain Coudé

Problems of Reflectors

- Some light must be blocked
  - Usually a second mirror is inserted to divert light
  - Some kind of instrument must be placed at focal plane to collect information.

Advantages of Reflectors

- No chromatic aberration
- No spherical aberration
- Mirrors don’t have support problems
- No problems with imperfections in the mirror or absorption in the mirror



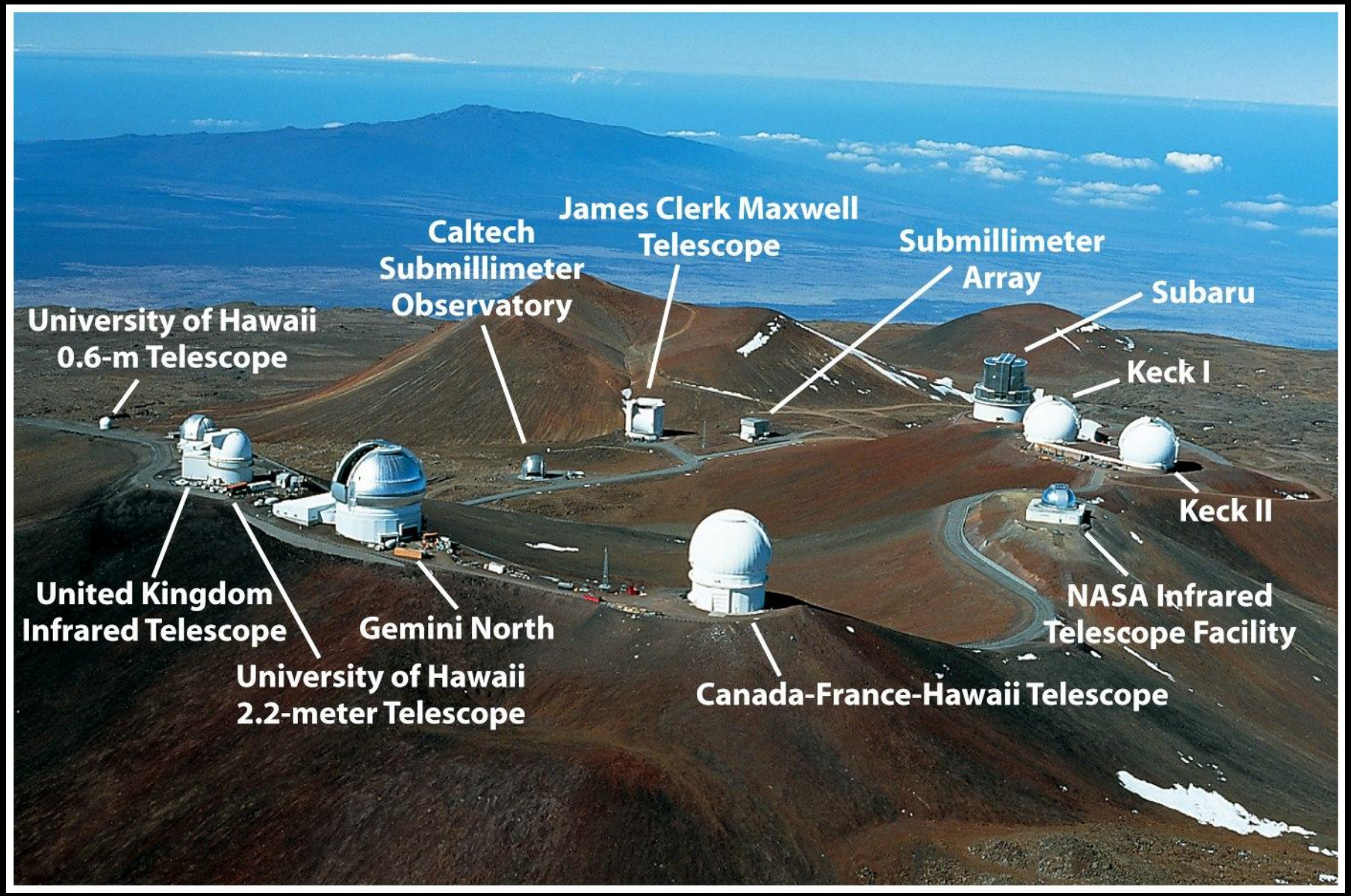
3rd Earl of Rosse's Leviathan

Parsontown, Ireland
Built by William Parsons
72" reflector was largest in world 1845-1917

Fully restored in 1999.
Recent photo =>

Mt. Wilson
100-inch Telescope
Built 1919
Retired from Research

Mt. Palomar
200-inch Telescope
Built 1947
Effective until 1993
Retired



Mauna Kea Observatory - Hawaii

Thirty Meter Telescope project

ESO Extremely Large Telescope project

137’ (41m) wide, 2700 tons
13x more light & 16x Sharper than HST!

Under construction now.
First Light = 2024

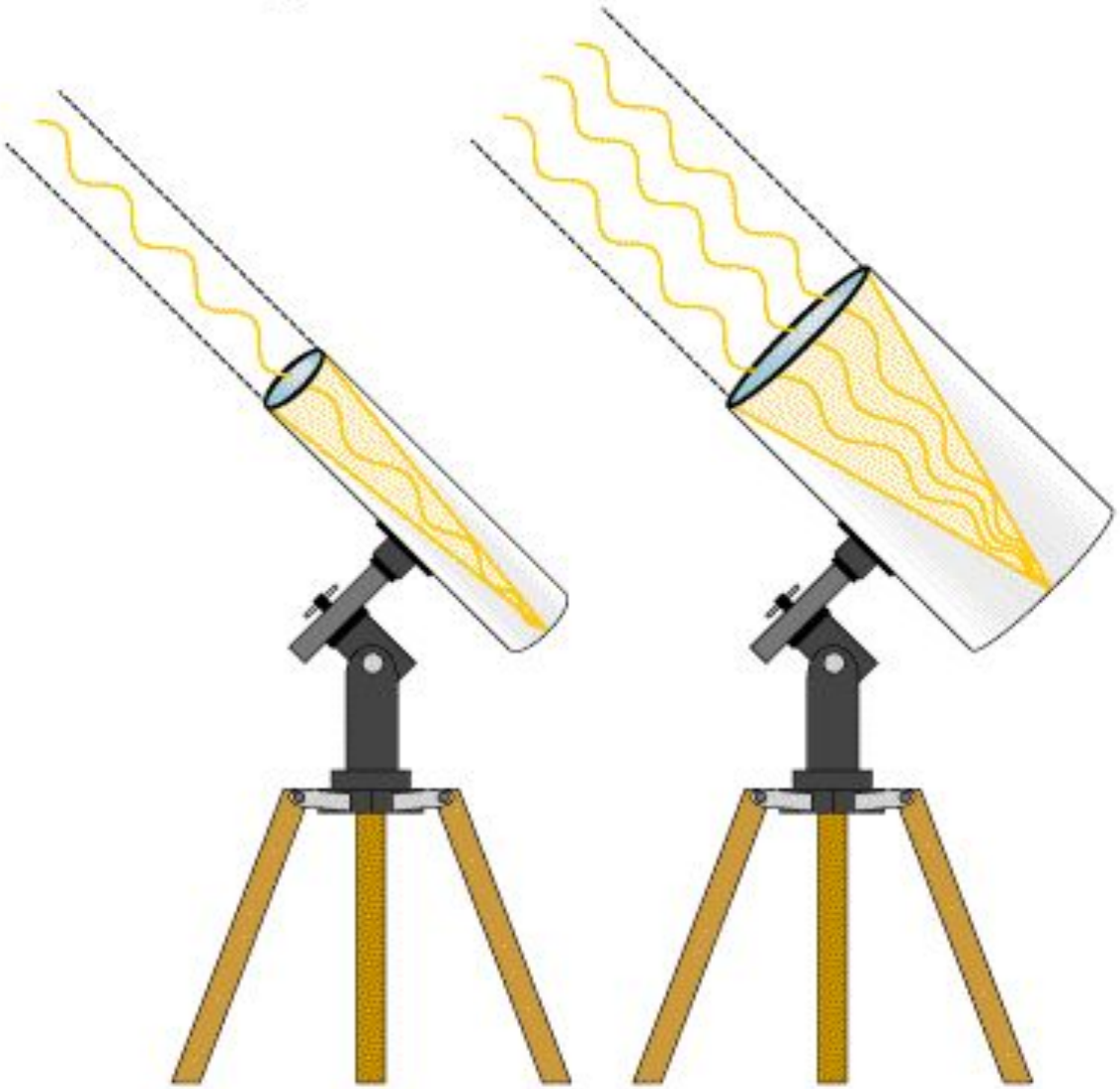
Telescope Mounts

Equatorial - RA and DEC

Altazimuth - Altitude and azimuth

example: Dobsonian

Collecting Area of Telescopes



Telescopes Brighten

- **Light-Gathering Power of a telescope depends upon the cross sectional area of the telescope tube**
- **Aperture - diameter of the telescope tube's opening where light enters**

$$LGP = \pi r^2 = \frac{\pi d^2}{4}$$

Light Gathering Power

10.7 cm
camera

15.2 cm
camera

Telescopes Magnify

- **<u>Magnification</u> - the number of times larger an object appears through a telescope than as seen by the naked eye**

$$\text{Magnification} = \frac{\text{Focal Length of the Objective Lens or Mirror}}{\text{Focal Length of the Eyepiece}}$$

For example...

- 6-inch Newtonian Reflector
- Objective Mirror Focal Length = 1000 mm
- Eyepiece Focal Length = 20 mm

- What is its Magnification?

$$M = \frac{1000mm}{20mm} = 50$$

- How would you change the magnification for this telescope?

Choose an eyepiece with a smaller focal length would increase magnification,an eyepiece with a larger focal length would decrease magnification.

Telescopes Resolve

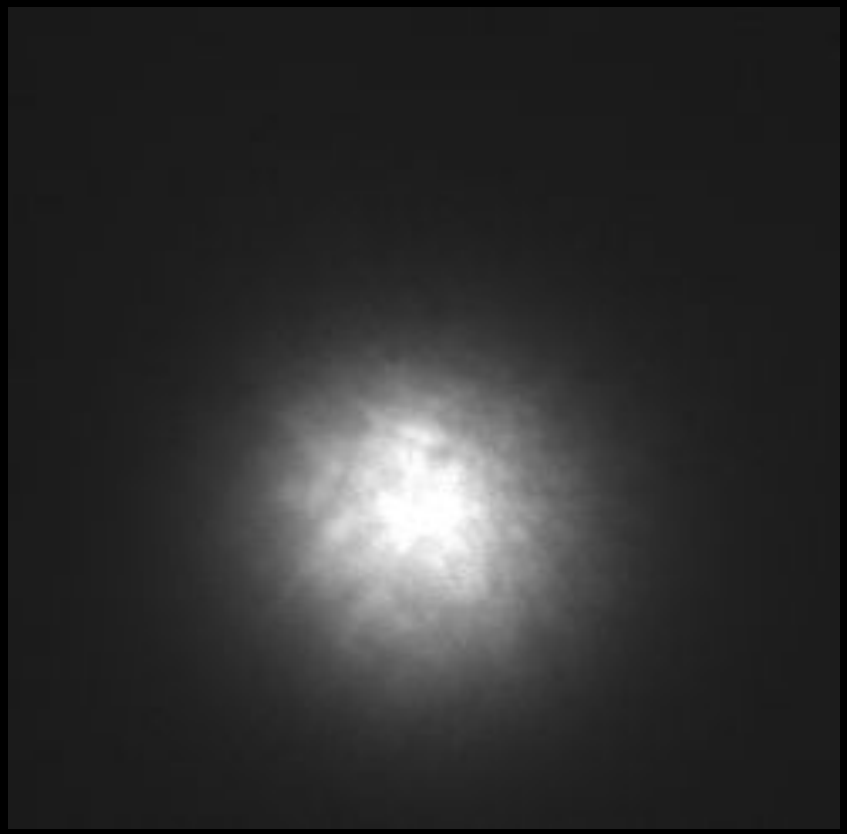
- **Angular Resolution - measure of the clarity of images**
- **Telescope with larger diameters are able to resolve smaller objects.**
- **Adaptive Optics – Various techniques used to cleanup/clarify the image in the telescope.**

ALTAIR

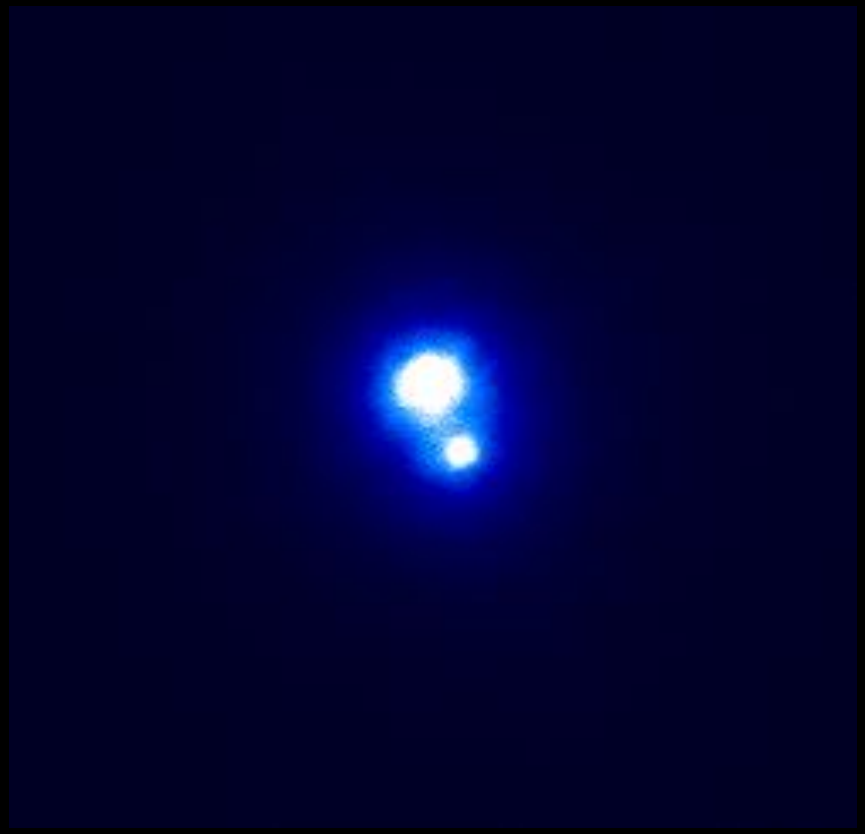
Without Adaptive Optics

With Adaptive Optics

Images of Beta Delphinus

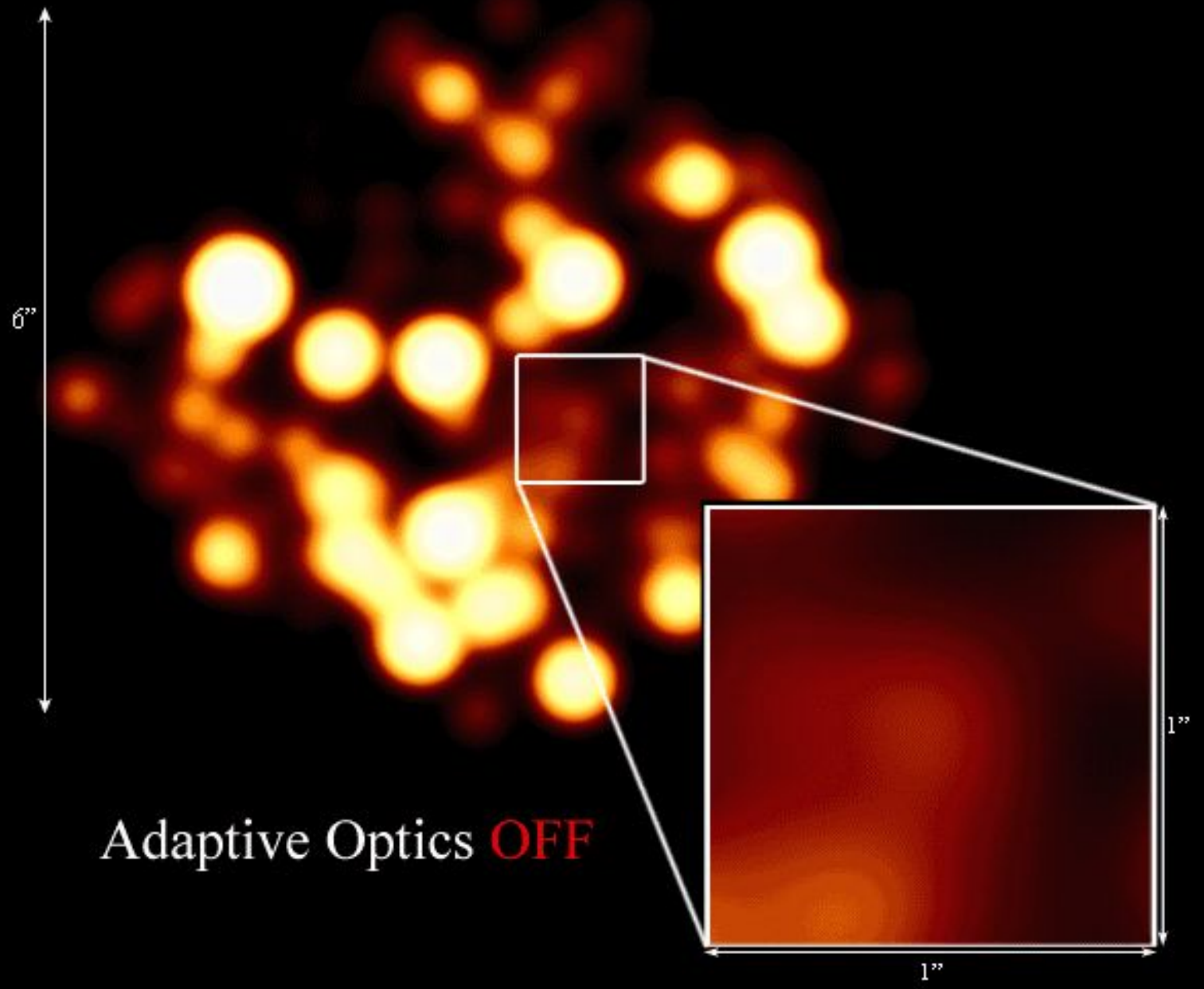


Without Adaptive Optics



With Adaptive Optics

The Galactic Center at 2.2 microns



Observing Problems

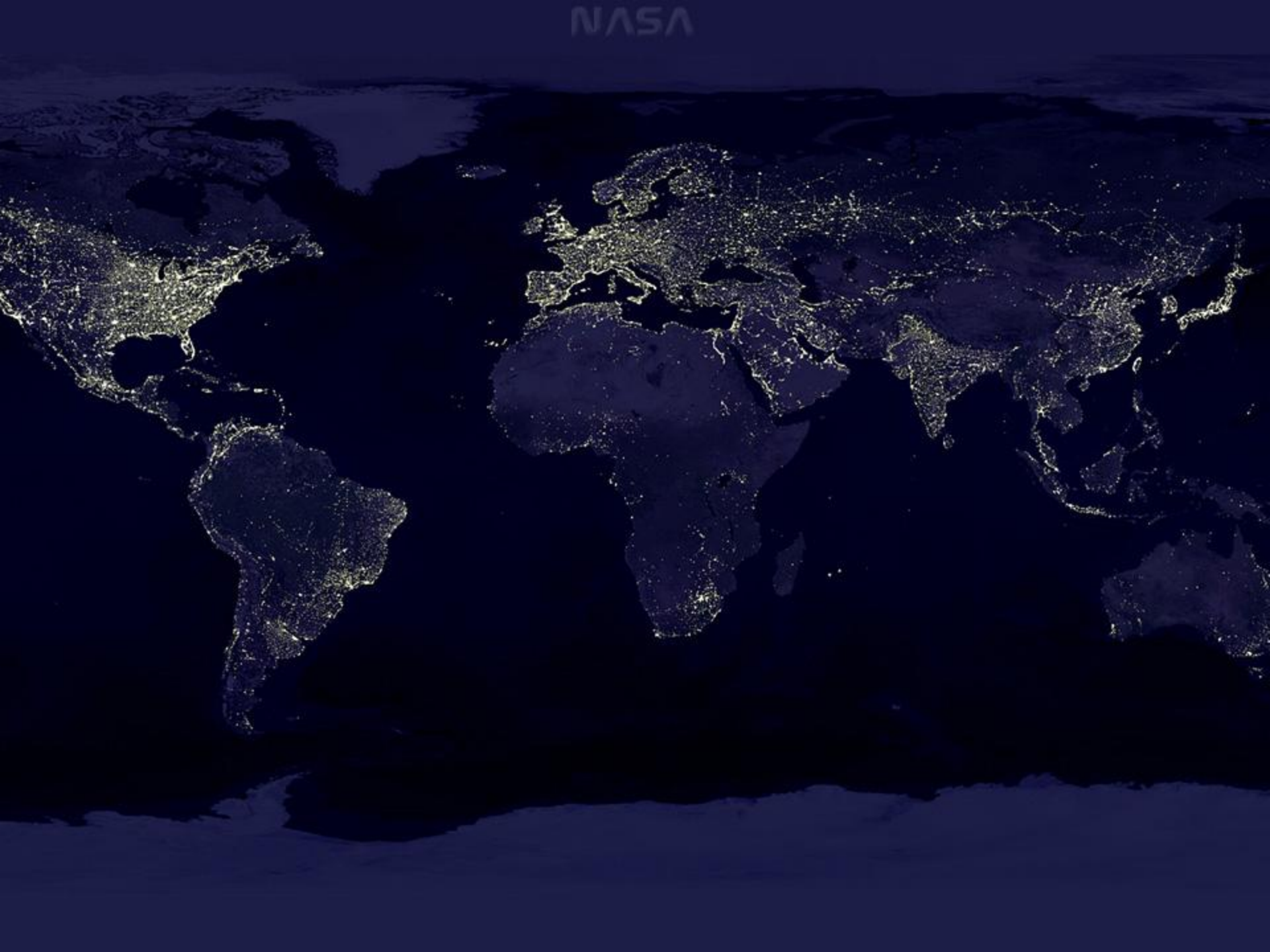
- Atmospheric dispersion is the spreading out of light into a spectrum by Earth's atmosphere.

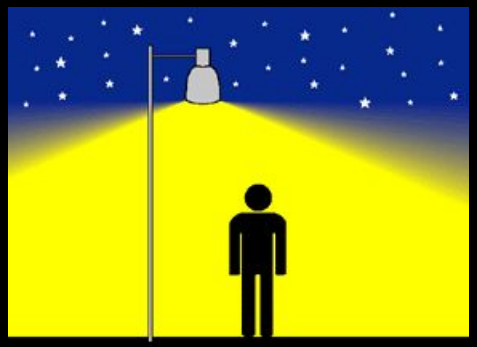
Venus

- Scintillation is the twinkling of stars caused by turbulence in the Earth's atmosphere.
  - Note: Planets do not twinkle.

- Light Pollution makes it difficult to see stars in the city.

Light Pollution


NASA

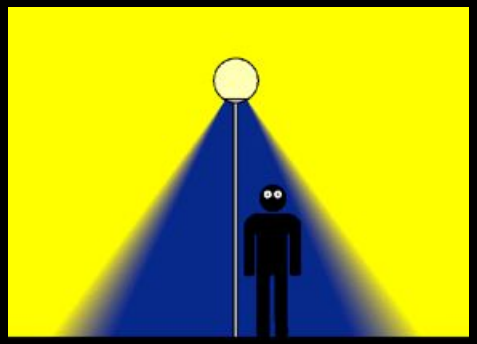


The Good

- More cost efficient.
- Directs light down and to the sides as needed; light control.
- Reduces glare; more even illumination.
- Reduces light trespass onto neighboring properties.
- Helps preserve the dark night sky.

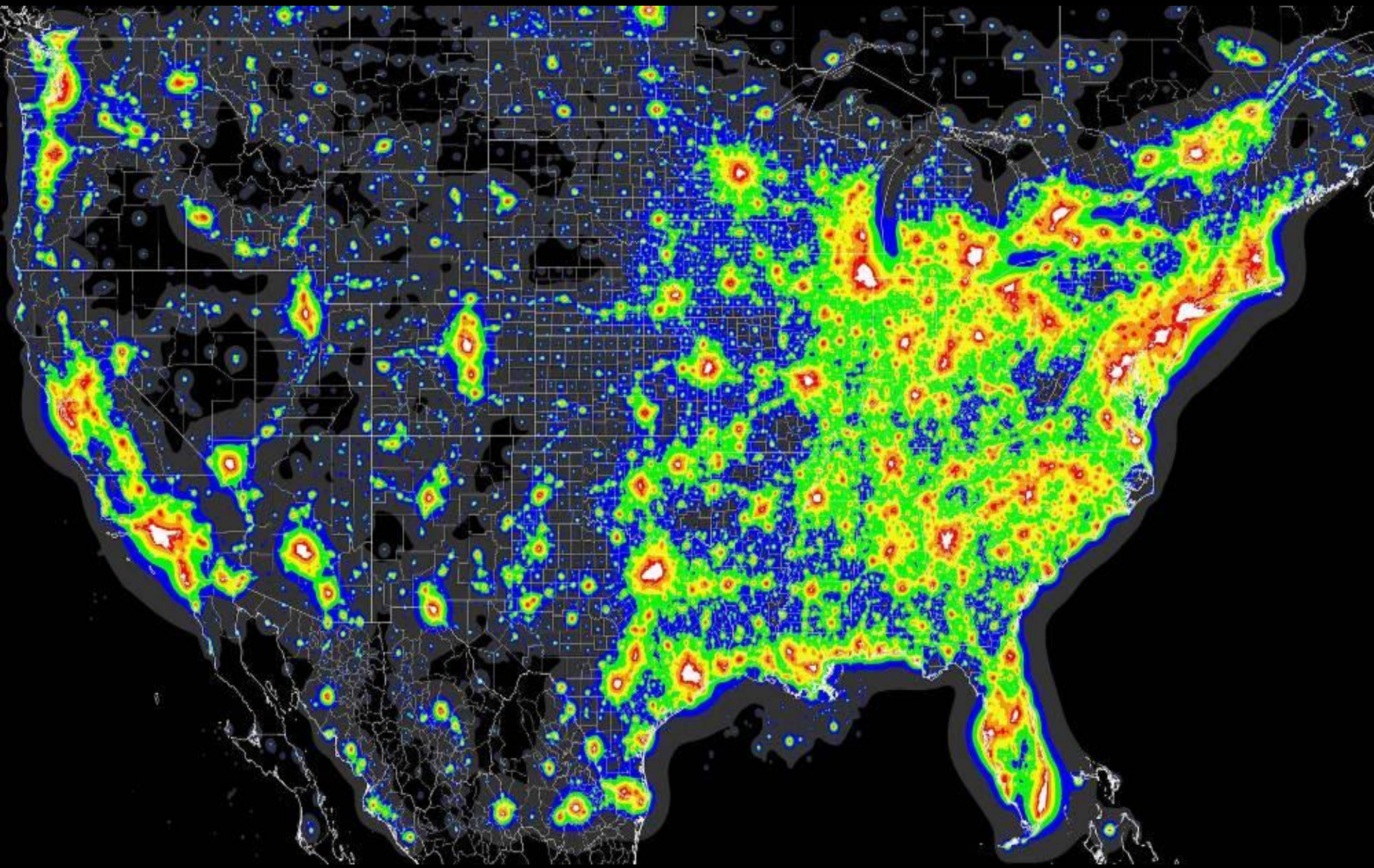
The Bad

- Wastes energy into the sky.
- Glare, light trespass and harsh illumination.

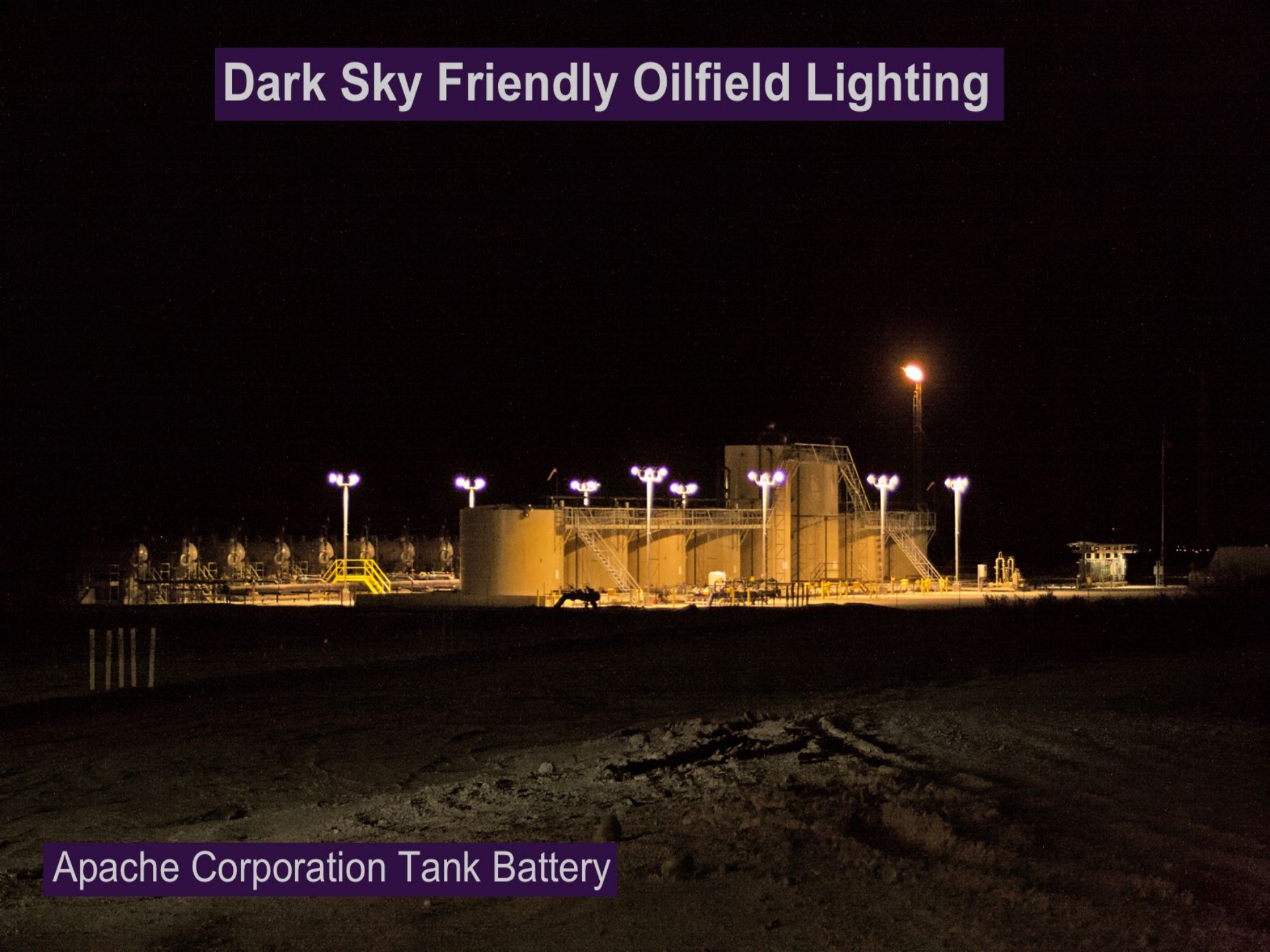


The Ugly

- Illuminates little but the bellies of birds.

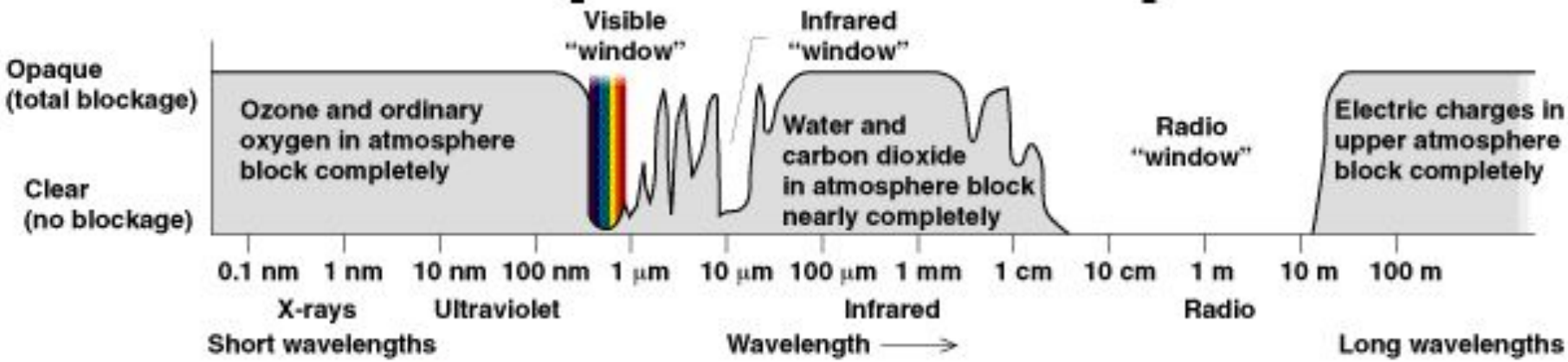


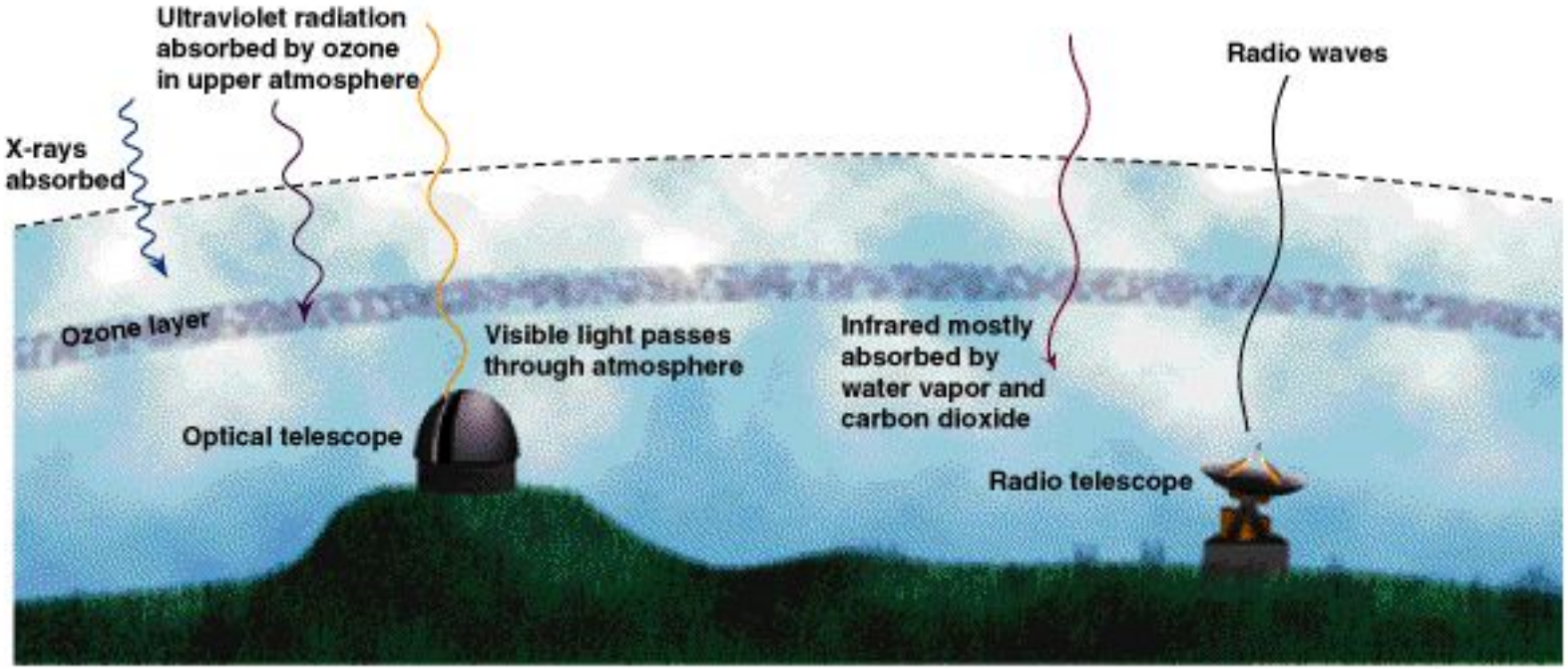
Dark Sky Friendly Oilfield Lighting



Apache Corporation Tank Battery

Atmospheric Absorption





Radio Telescopes

- Radio telescopes are similar to reflecting telescopes.
- Several radio telescopes can be used together to improve the resolution of images.
- This is called interfermometry.

Atacama Large Millimeter/submillimeter Array (ALMA) in Chile

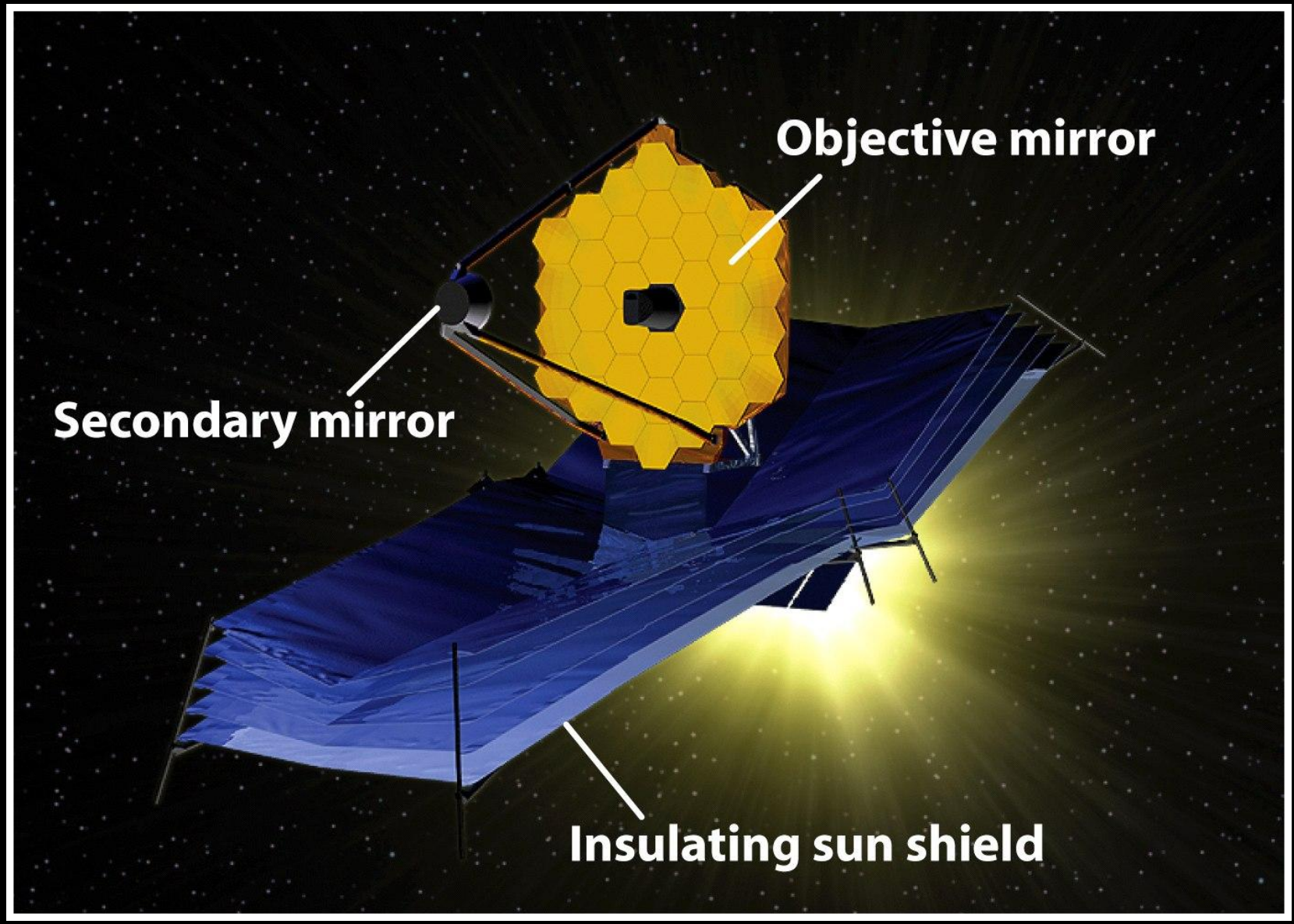
Hubble Space Telescopes

Hubble Space Telescope (13.6 m long) – HST

The Hubble Space Telescope...

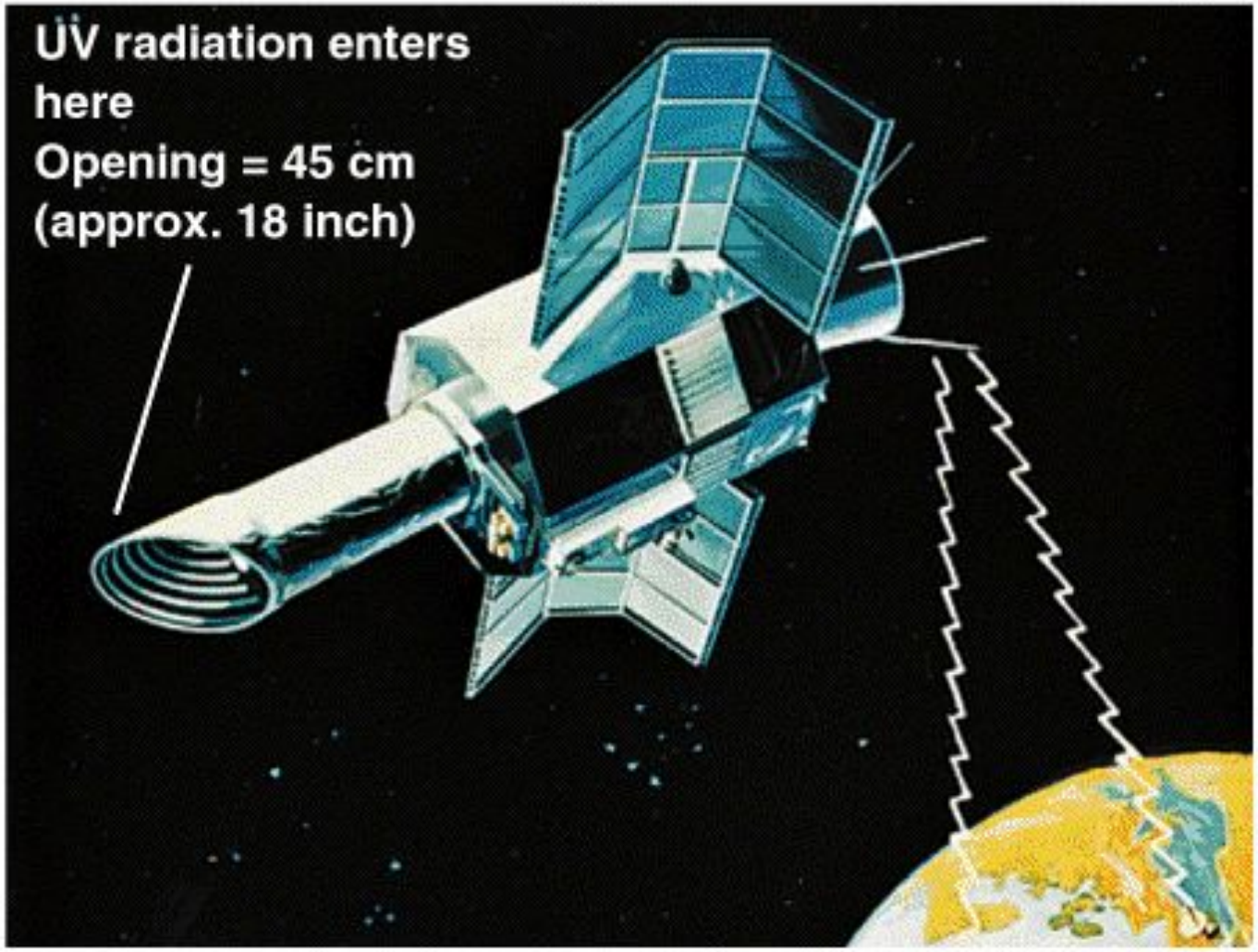
- …is the largest telescope in space.
- ...is 30 times more sensitive than ground based telescope.
- ...orbits the Earth every 95 minutes.
- …gives high resolution images because it does not suffer from the effects of atmospheric turbulence.
- …should continue to function until 2018.

Service Missions
4 – May 2009 – Atlantis
3B – March 2002 – Columbia
3A – Dec 1999 – Discovery
2 – Feb 1997 – Discovery
1 – Dec 1993 – Endeavor



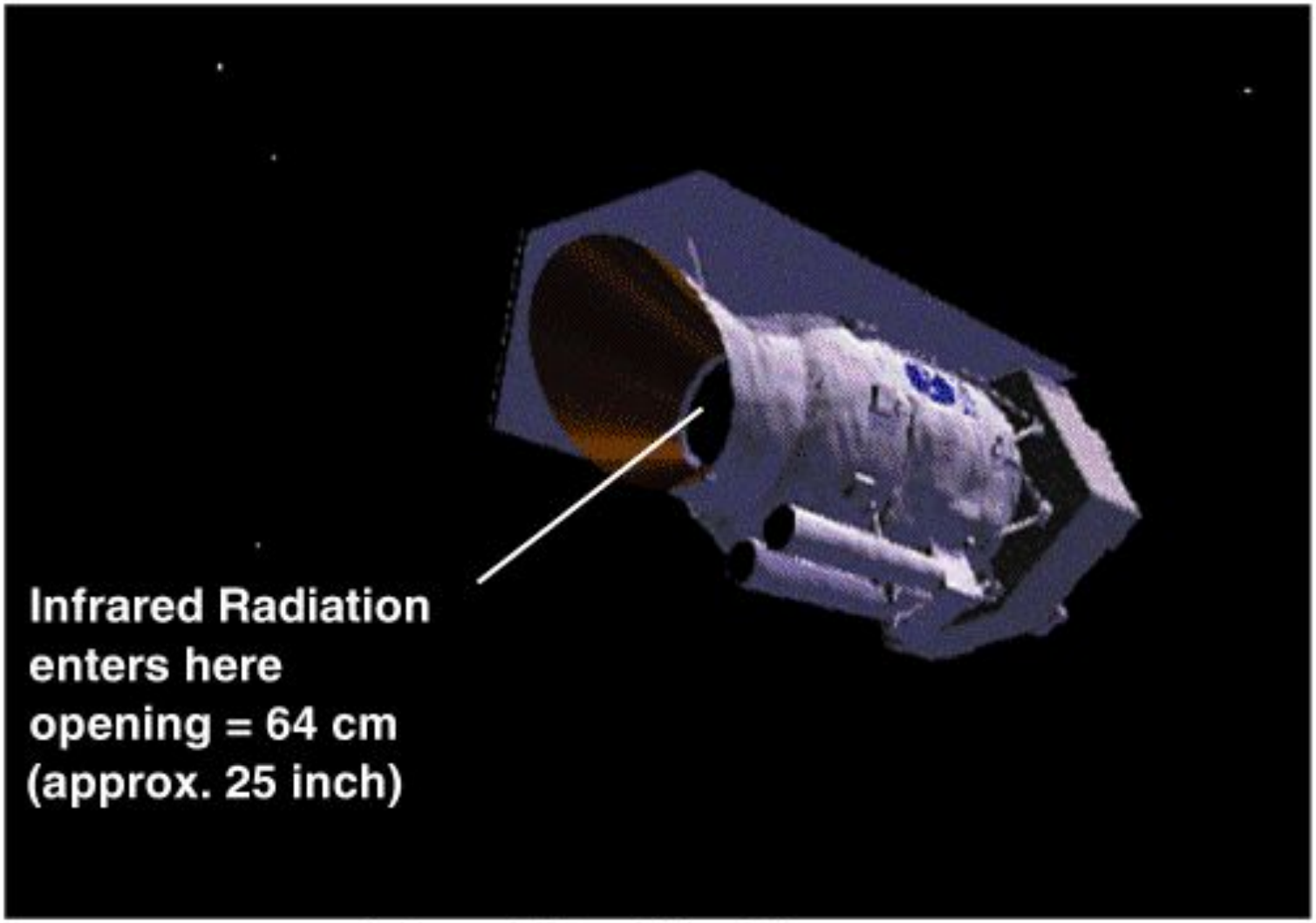
James Webb Space Telescope – 6.5m (21 ft)

IUE Orbiting Observatory

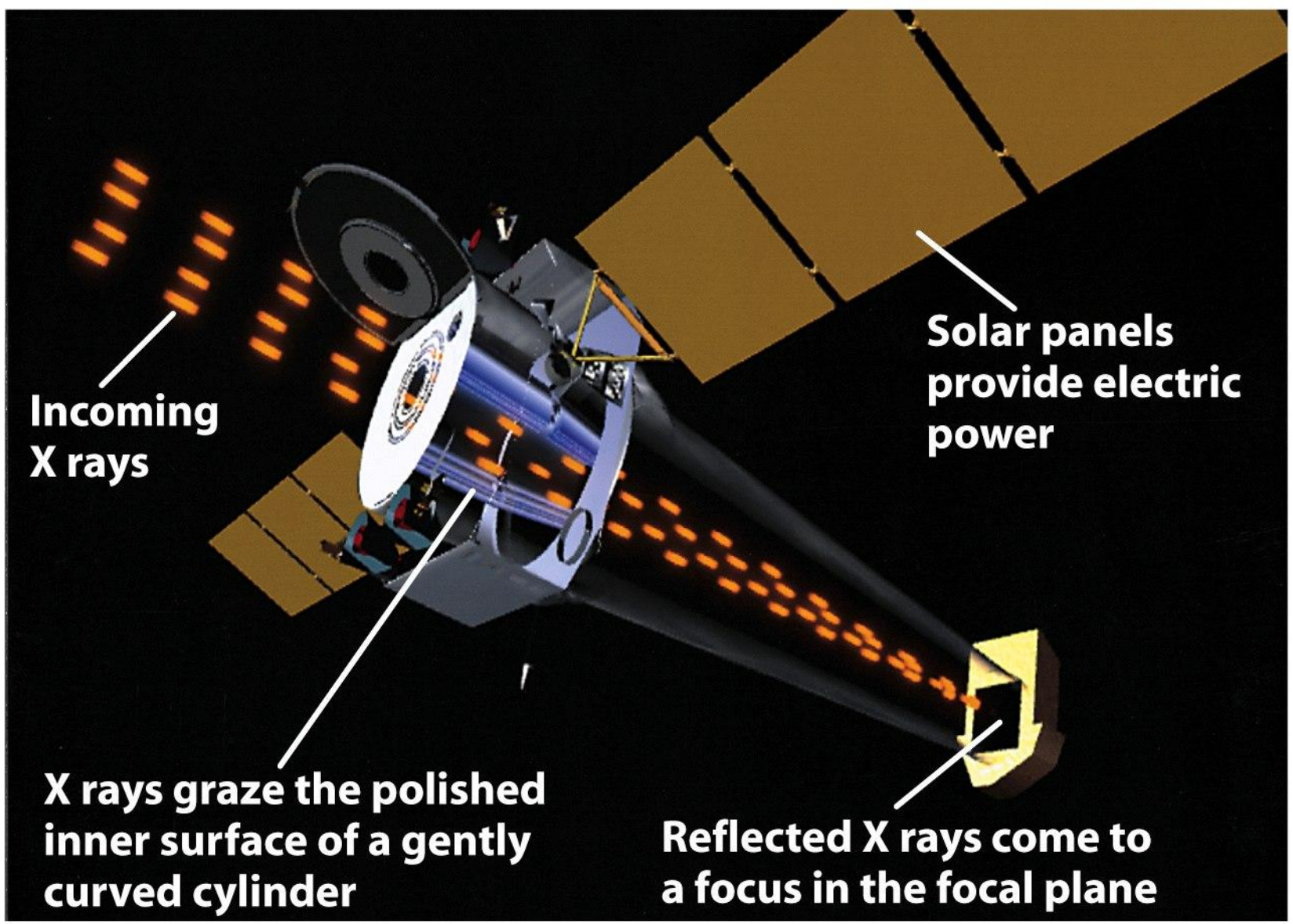


International Ultraviolet Explorer–IUE

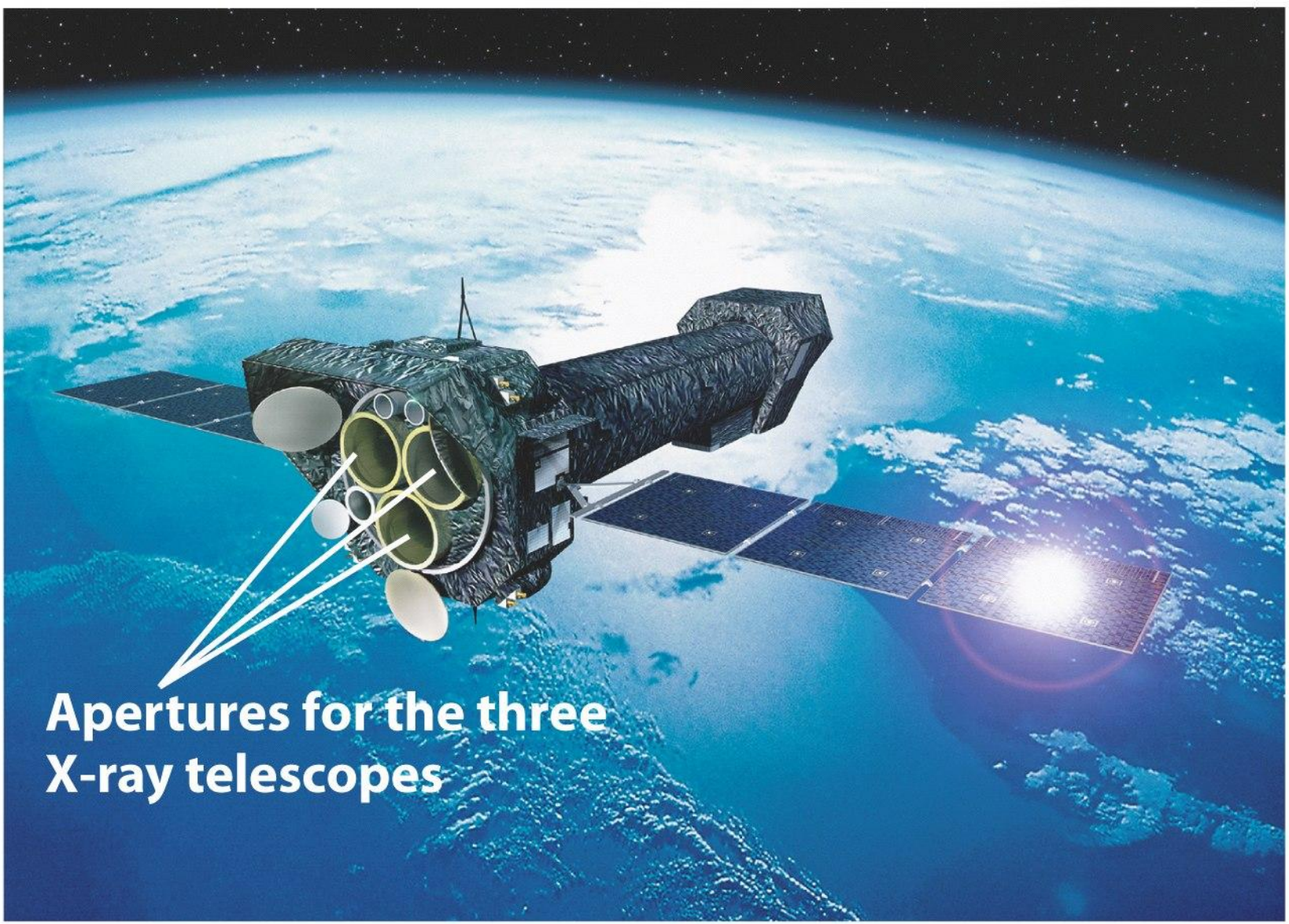
ISO Orbiting Observatory



Infrared Satellite Observatory



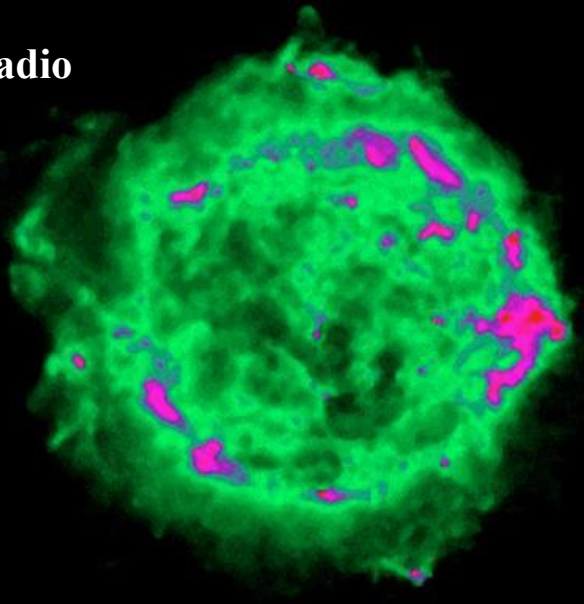
(a) Chandra X-ray Observatory



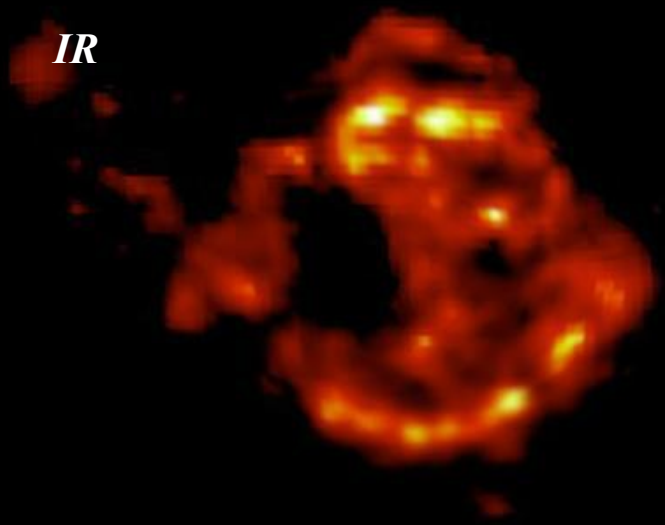
(b) XMM-Newton


Compton Gamma Ray Observatory

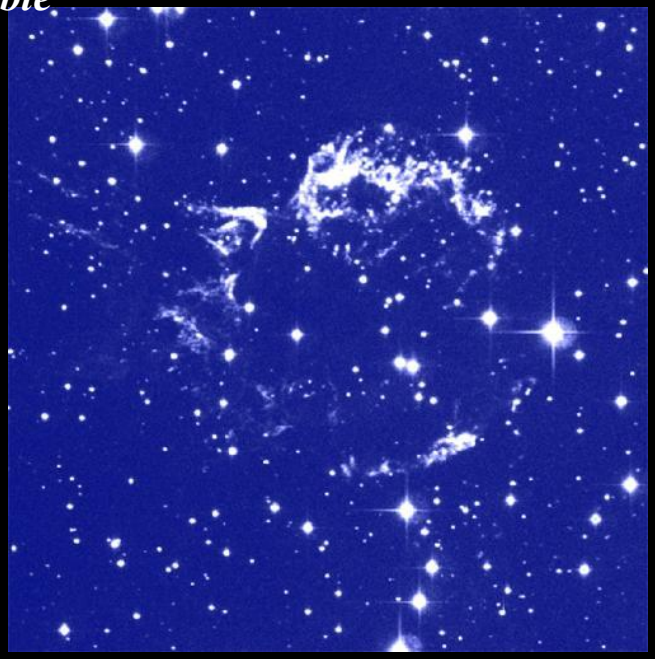
Radio



IR



Visible



X-ray

Binoculars

- Cheap alternative to telescopes
- 10x50 is a good pair for astronomical observations
- 10 refers to the power (magnification)
- 50 refers to the diameter of the aperture (mm).