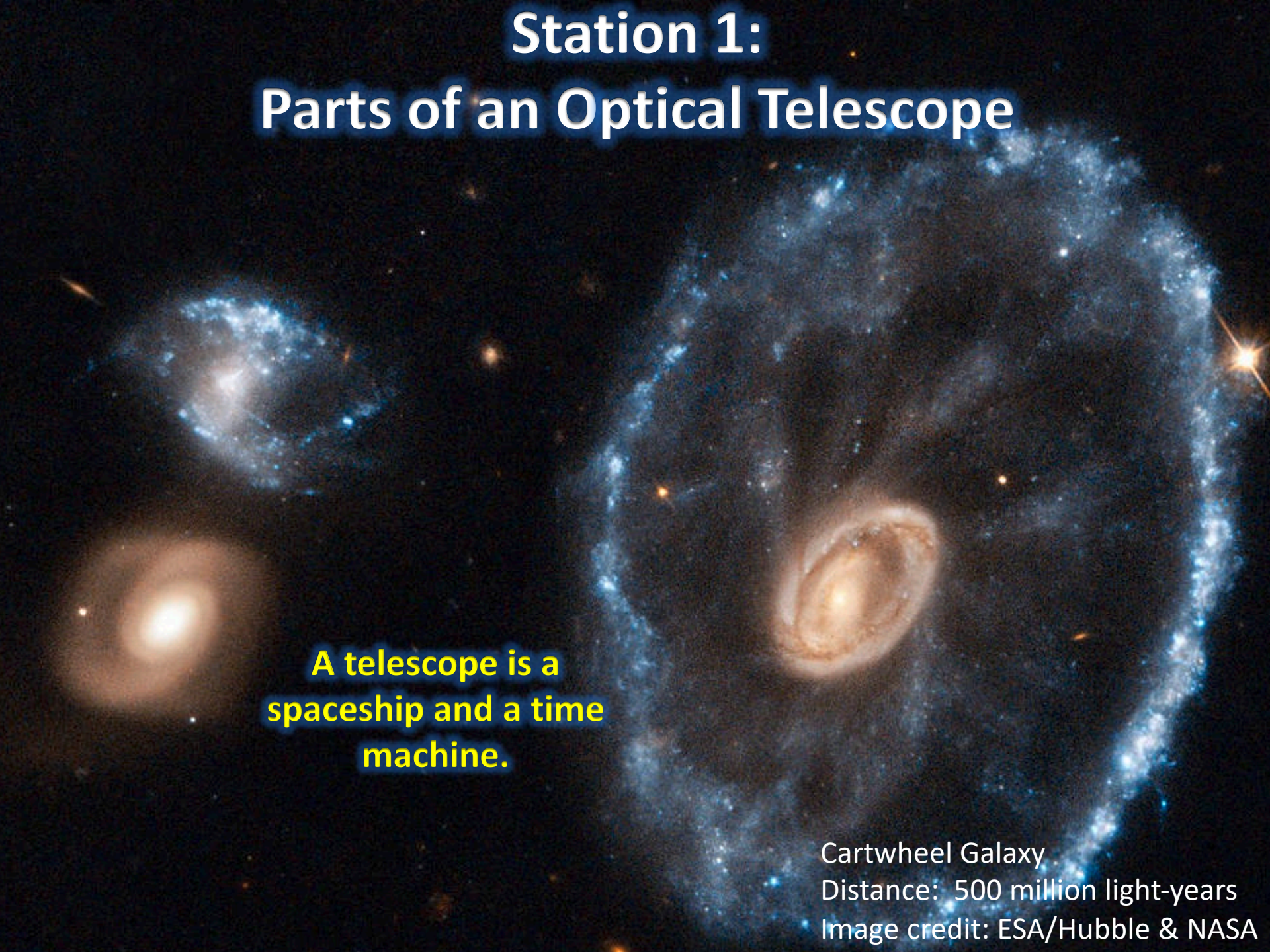
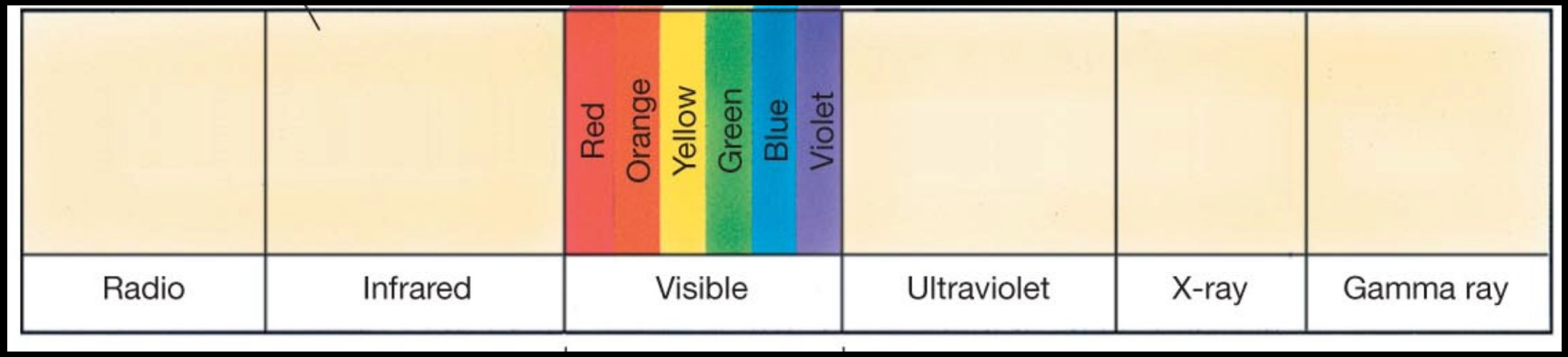
Station 1:
Parts of an Optical Telescope



A telescope is a spaceship and a time machine.

Cartwheel Galaxy
Distance: 500 million light-years
Image credit: ESA/Hubble & NASA

Different wavelengths require different telescopes in different locations

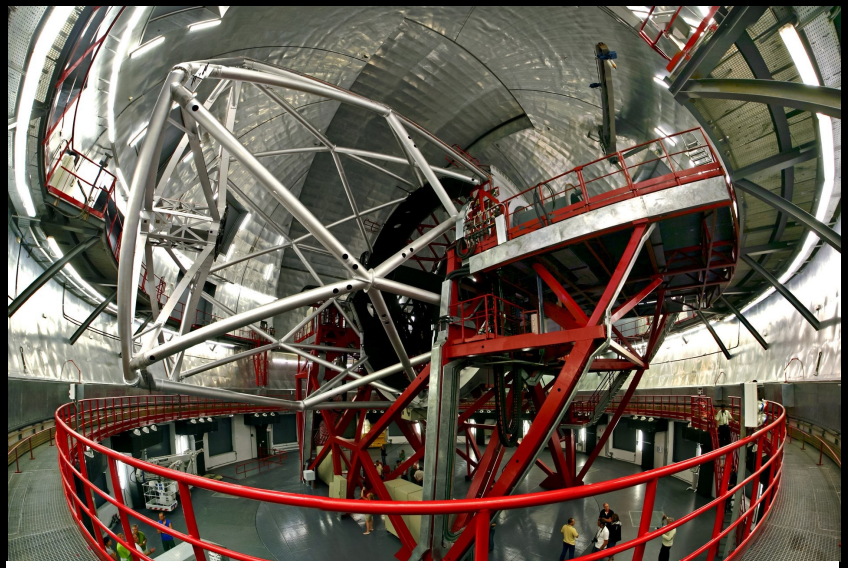


Radio telescopes: Ground based

Infrared telescopes Ground and space based

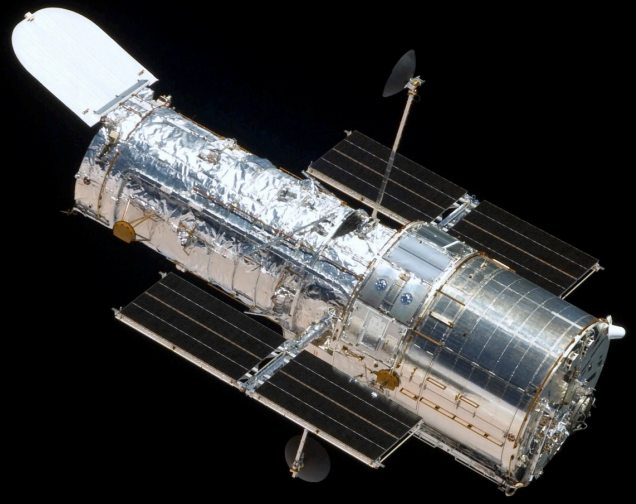
Optical telescopes: Ground and space based

X-ray and gamma ray: Always space based

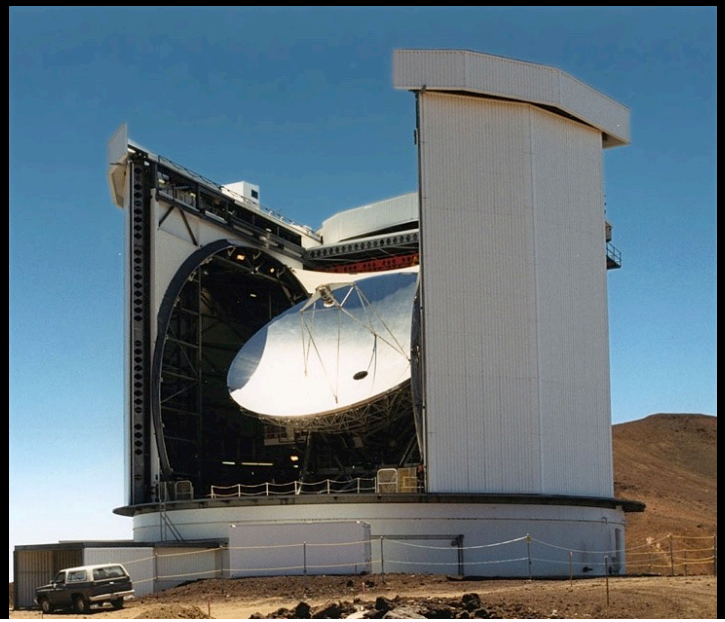


Gran Telescopio Canarias a 10m optical Telescope, La Palma, Canary Islands.

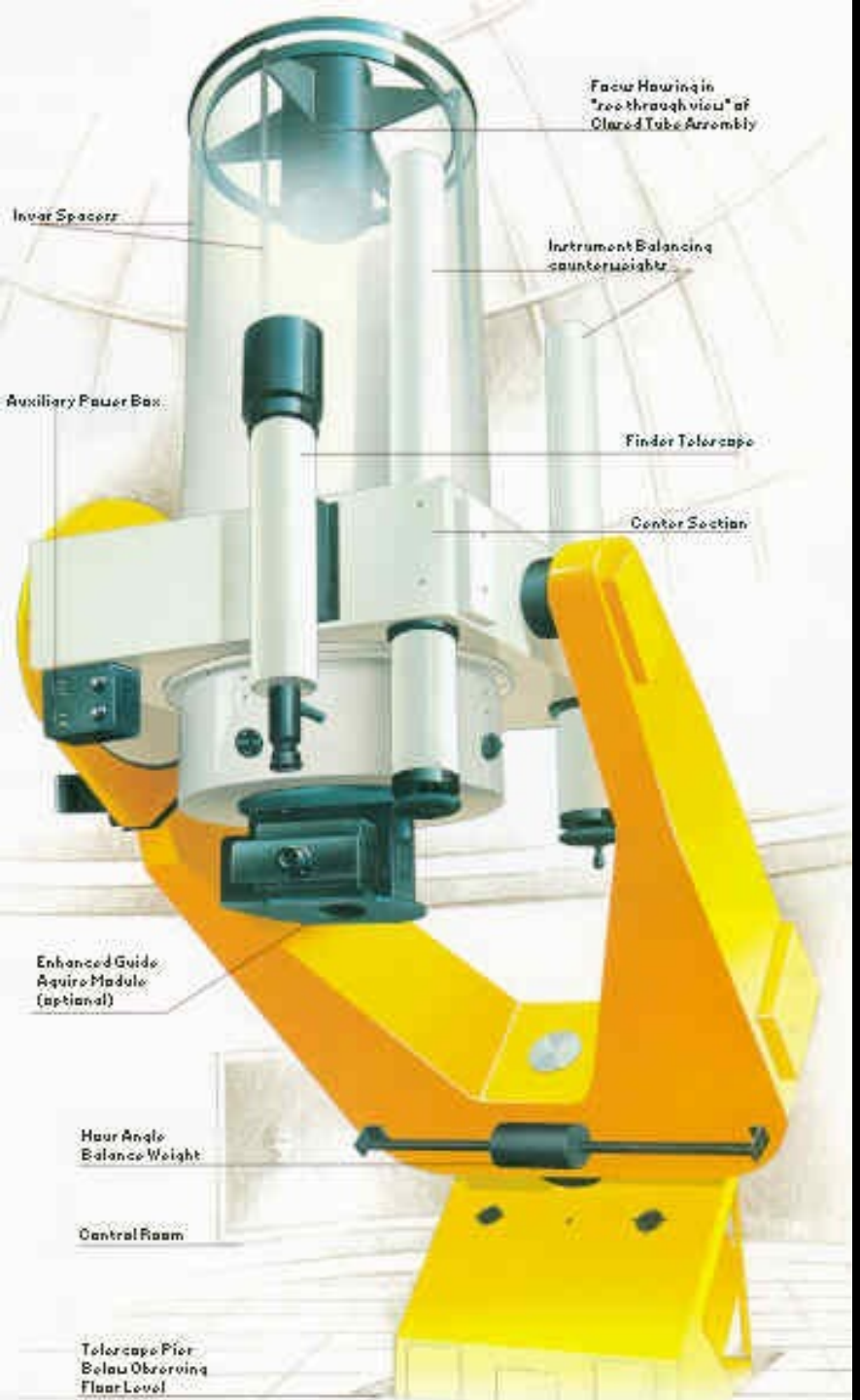
Spitzer infrared in space

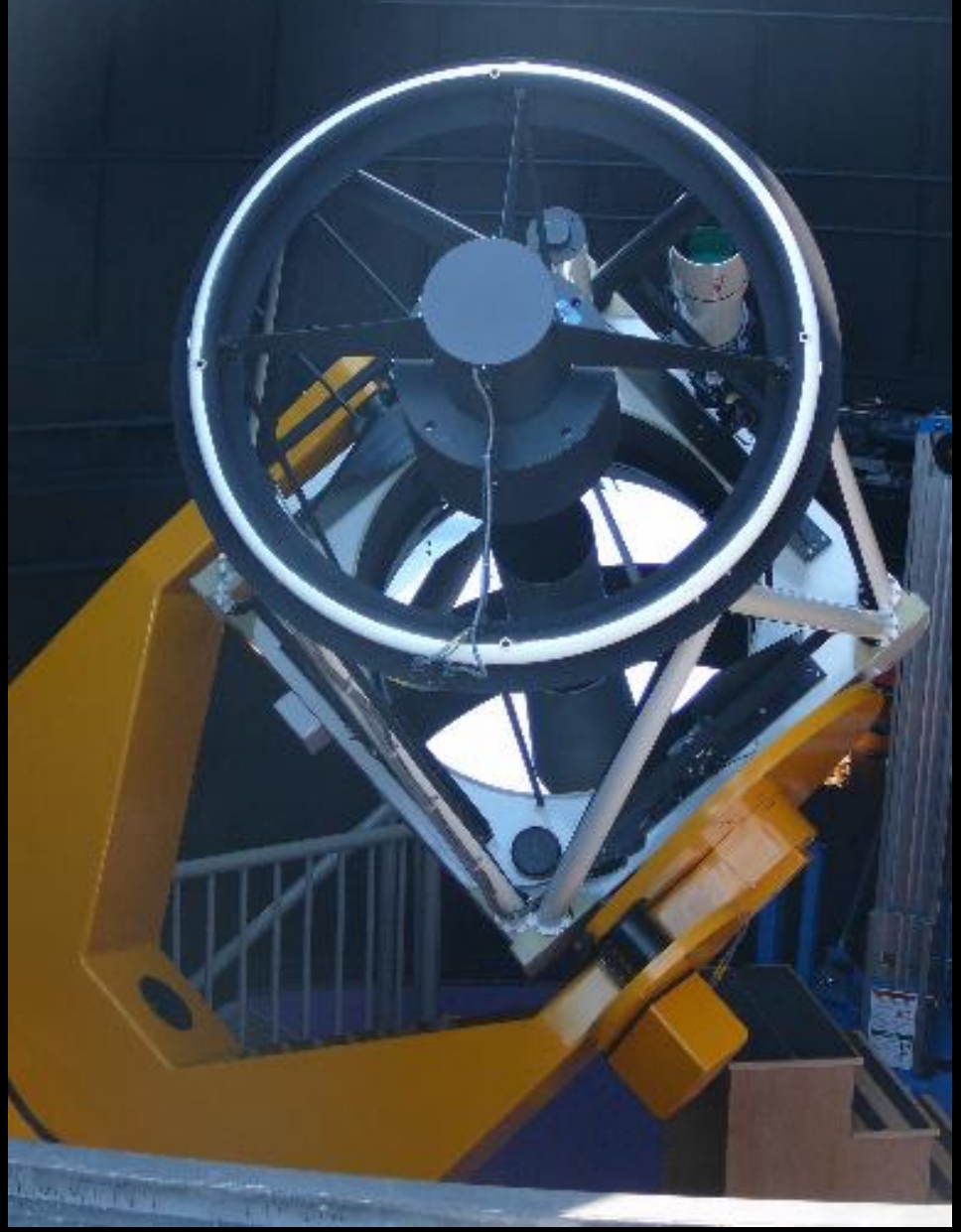


Hubble - optical in space



Infrared on the ground – 15m JCMT
(James Clerk Maxwell Telescope)





DFM CCT-32
University of Victoria

Optical Telescopes

Telescope

- an optical instrument used to magnify and enhance the view of faraway objects

Two main categories

- Refractor
  - uses a convex lens to collect light
- Reflector
  - uses a concave mirror to collect light

Hans Lippershey, a German-Dutch spectacle maker, in his shop the city of Middelburg, Netherlands. The year was 1600.

Invention of an Optical Refractor Telescope

- 1608 – Lipershey sells instrument to Dutch army
- 1609 – copies were sold in European stores
- 1609 – Galileo Galilei, an instrument maker, was asked to make such a device

Hens Lippershy
1570 – 1619

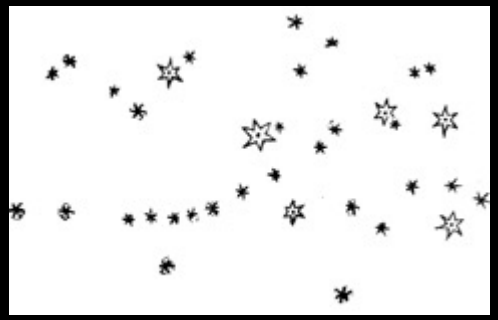
Lippershy's telescope, built in 1608

Galileo's telescope

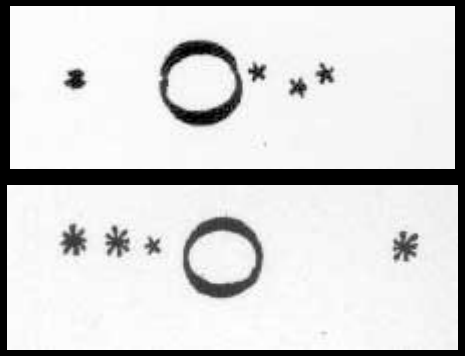
Galileo Galilei
1564 – 1642

Invention of the optical Telescope

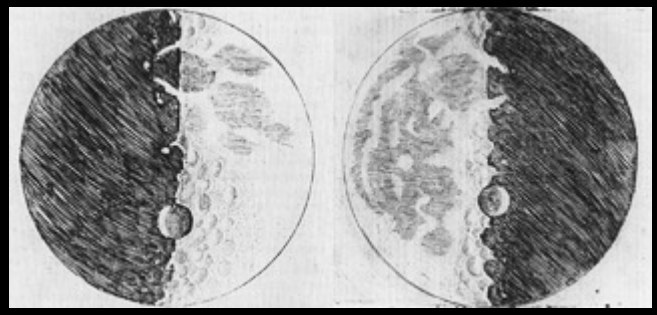
- 1610 - Galileo tilts cylinder to the sky and publishes *Sidereus Nuncius*
- 1611 - at a banquet honouring Galileo, the name ”telescope” , a Greek word meaning "to see into the distance“ was suggested



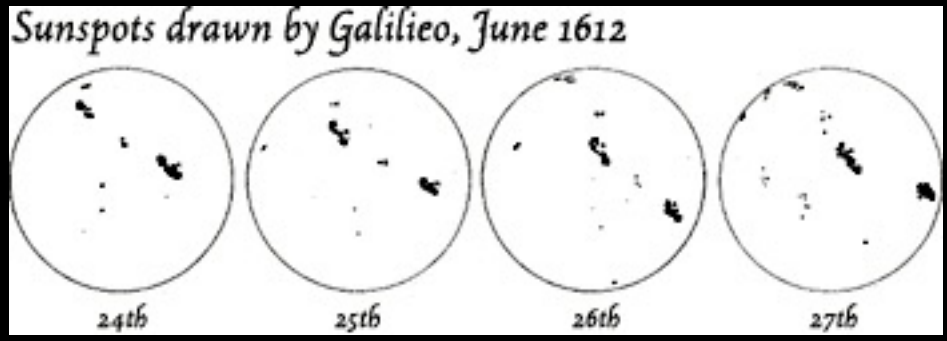
The Milky Way



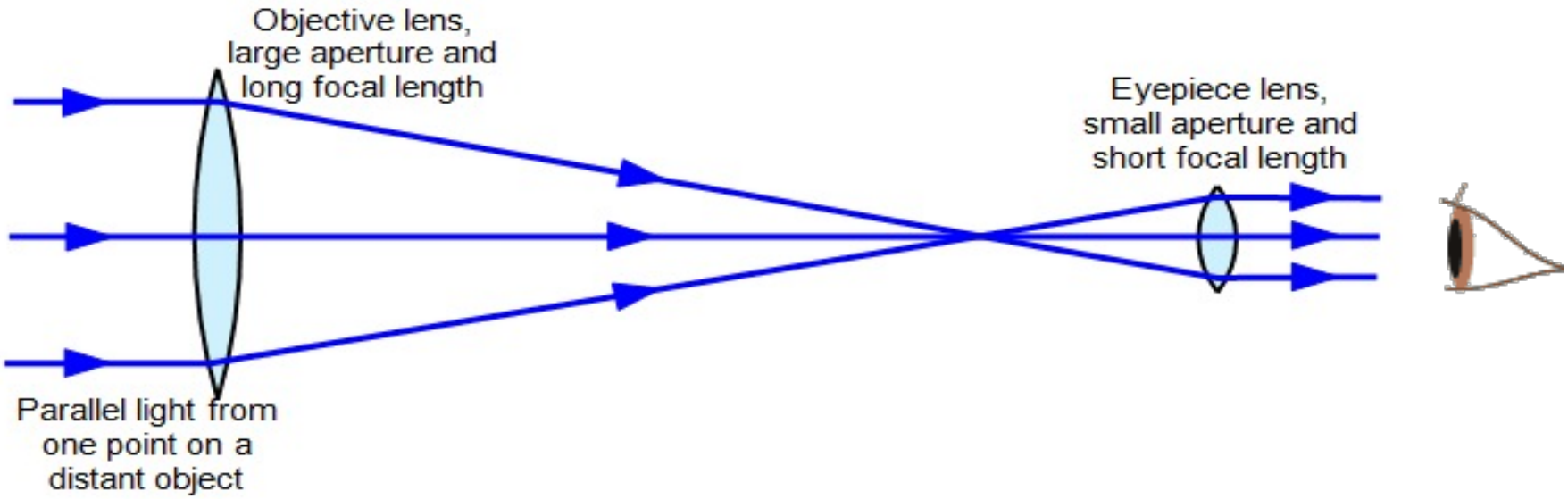
Jupiter



Moon



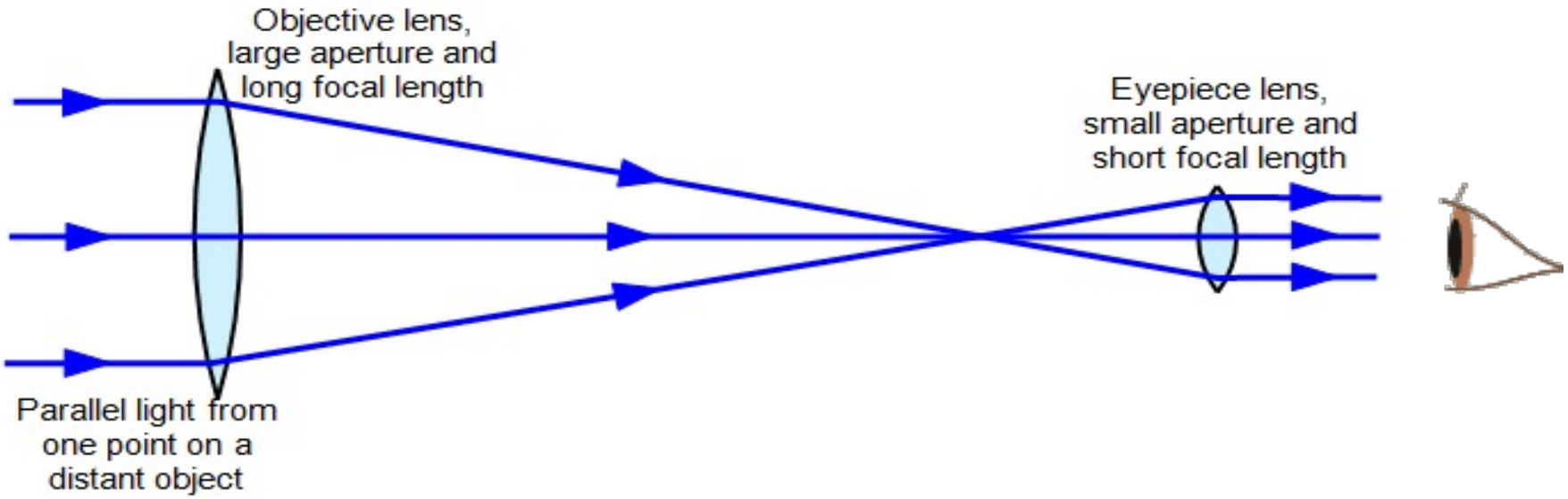
The Refractor



A Refracting Telescope

- In its most basic form, it is a tube with a lens at each end.
- Light enters through a main objective lens at one end and refracts (bends) to a point of focus at the other end where an image is formed by the eyepiece.
- The eyepiece moves back and forth to adjust the sharpness of the focus.

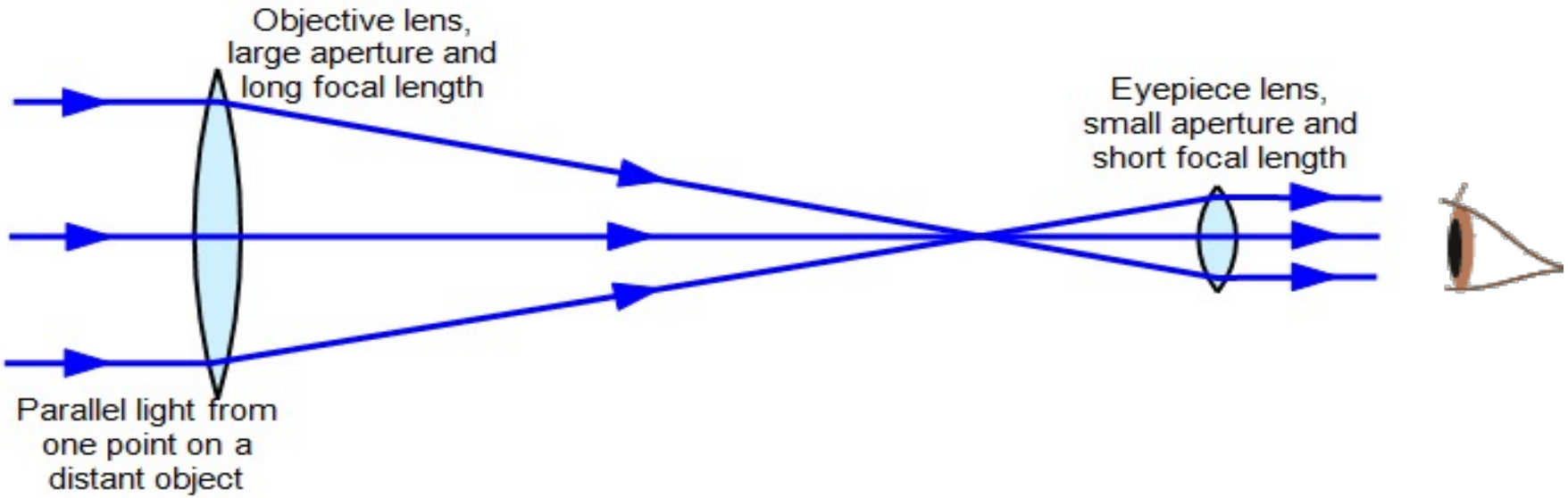
The Refractor



Advantages

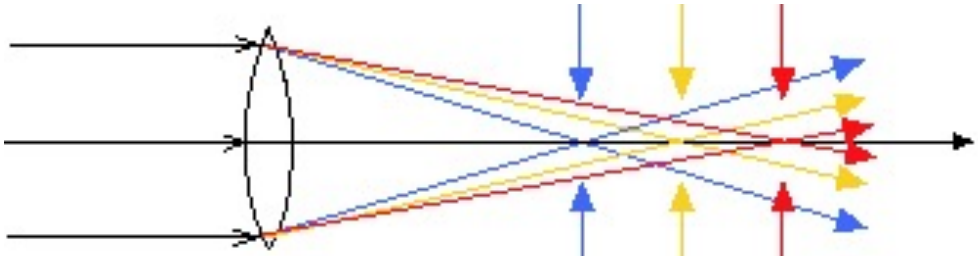
- The optical system is more resistant to misalignment than a reflector telescope.
- The glass surface inside the tube, sealed from the atmosphere, rarely needs cleaning.
- Due to sealed tube, air currents and effects from changing temperatures are reduced. The images are steadier and sharper than those from an open reflector telescope of the same size.
- Good for objects inside our solar system

The Refractor



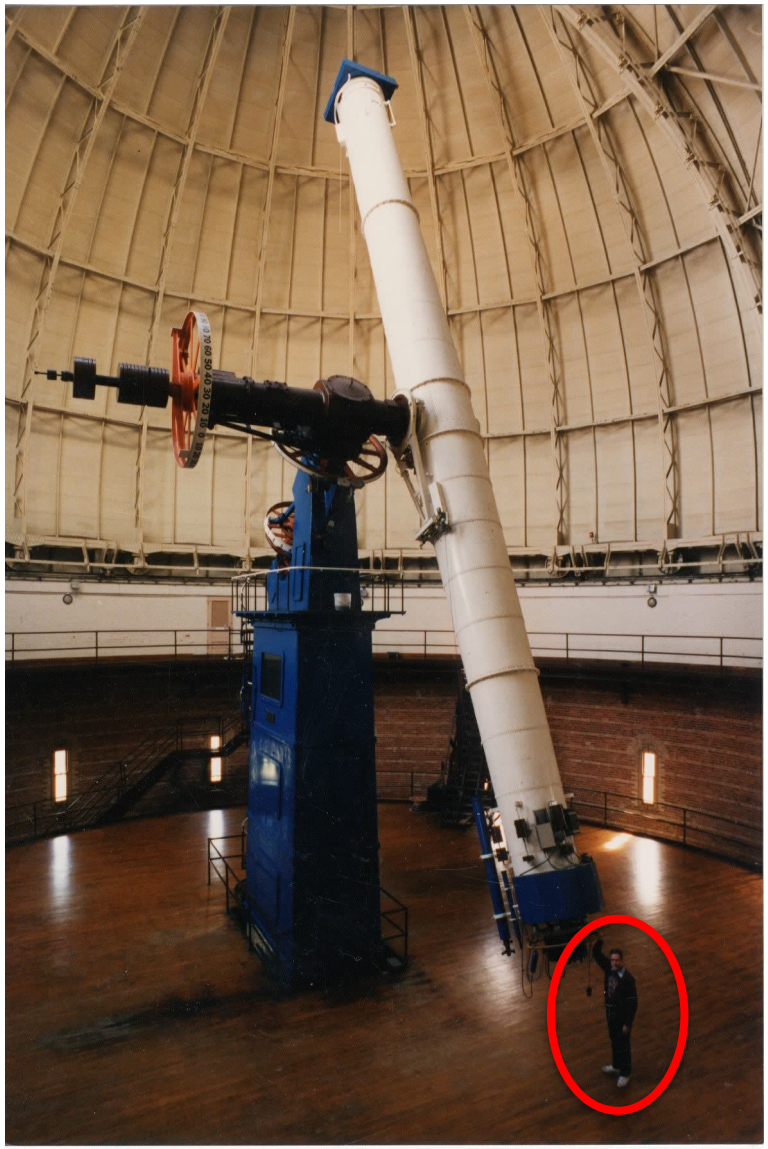
Disadvantages

- Refractors suffer from an effect called **chromatic aberration** (“color deviation or distortion'') that produces a rainbow of colours around the image.



- How well light passes through a lens decreases as the thickness of the lens increases and also varies with the wavelength of the light.
- Making a glass lens with no internal imperfections and with a perfect curvature on *both* sides becomes increasingly difficult and costly as the size of the lens increases.
- The lens can only be supported on its edge. A heavy glass lens will deform under its own weight.

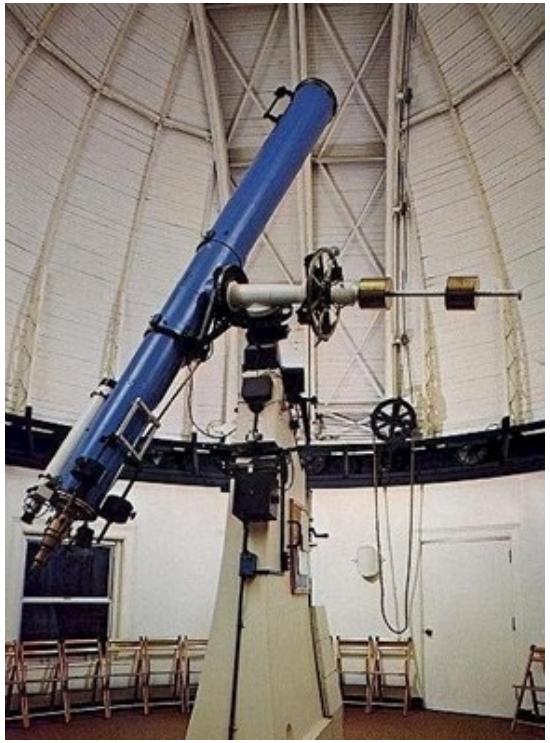
Refracting telescopes



Yerkes Observatory, University of Chicago

- largest currently operating refractor telescope
- objective lens 1.02 meters (40 inches)
- 19.2-meter (63 feet) tube

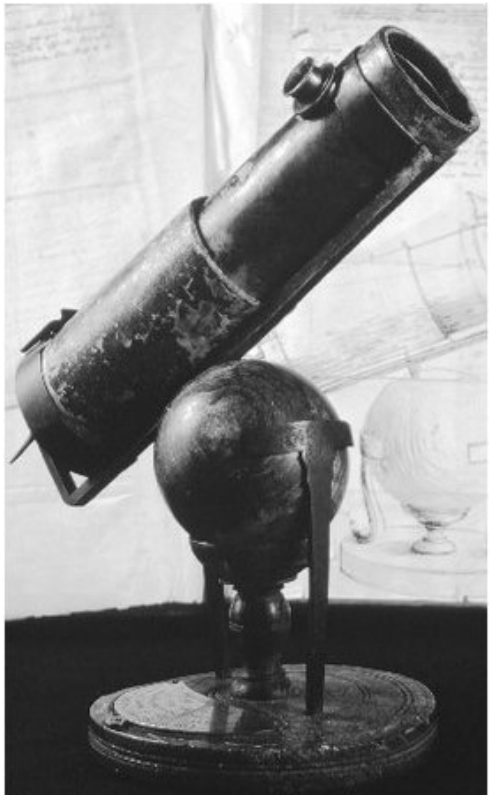
Celestron Refractor



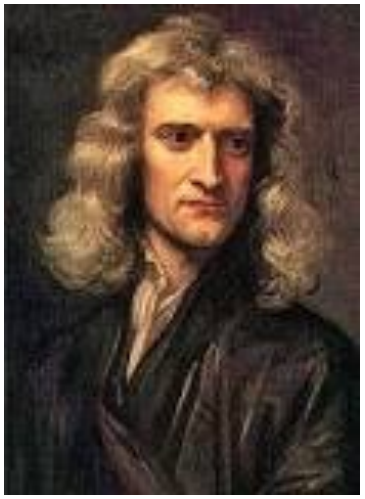
Fitz-Clark Refractor
Department of Physics & Astronomy
University of Pittsburgh

The Reflector

- Isaac Newton, Cambridge University, concluded that telescopes using lenses would always suffer chromatic aberration and that this could not be corrected.
- 1670 - constructed a new type of telescope that could magnify and focus light by reflecting it using a mirror rather than refracting it using a lens.
- Newton's telescope was 12 inches (30cm) long with a primary mirror 1.5 inches (3.8cm) in diameter

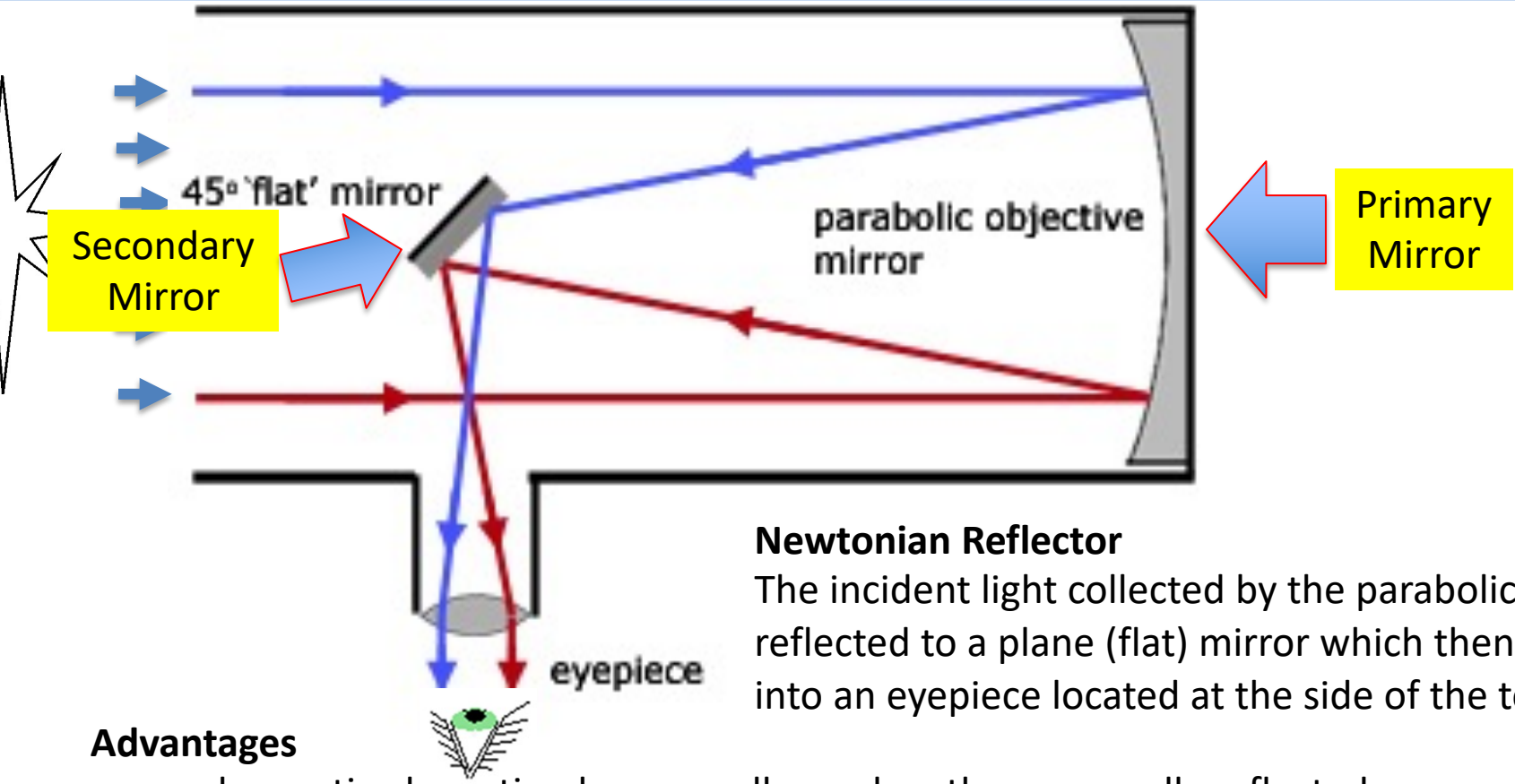


Isaac Newton invented this telescope that magnified and focused light using mirrors.



Isaac Newton
1643-1727

The Newtonian Reflector



Newtonian Reflector

The incident light collected by the parabolic mirror is reflected to a plane (flat) mirror which then directs it into an eyepiece located at the side of the telescope.

Advantages

- no chromatic aberration because all wavelengths are equally reflected
- objective mirror is fully supported along the back side
- Only one good surface on mirror is needed
- lower cost to make reflector than refractor of the same size

Disadvantages

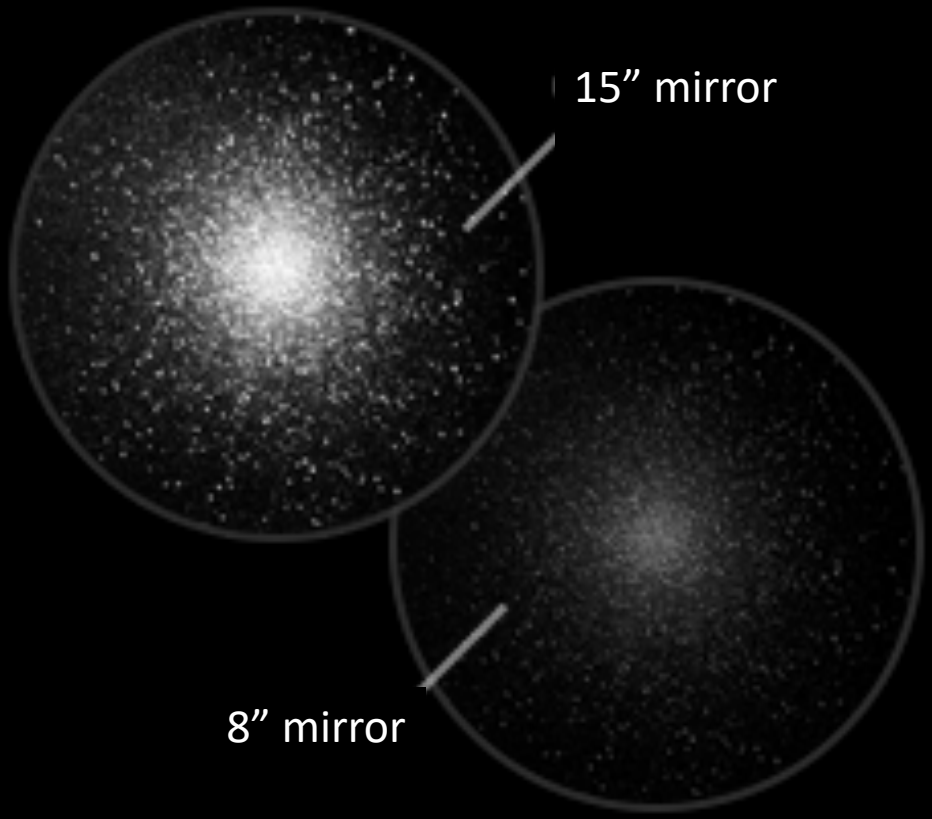
- a shadow is produced by the secondary mirror
- depending on the size of the secondary mirror, less light gets to the eye than originally enters the telescope tube.

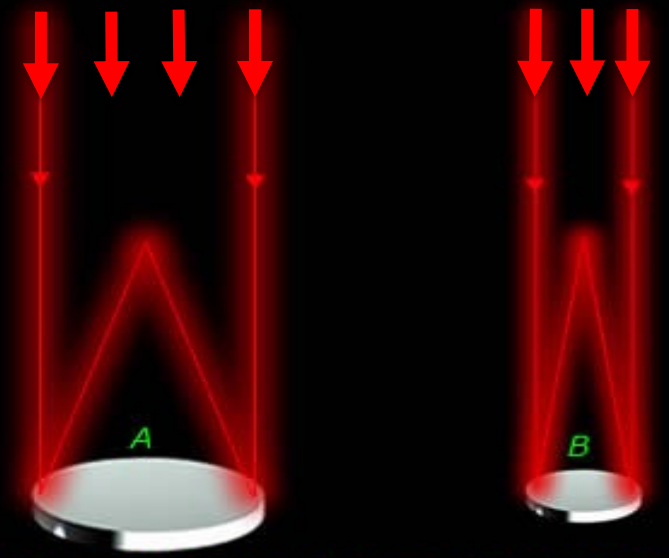
Parts of a Newtonian Telescope

Finderscope:

- a refractor
- an aiming device
- a small telescope mounted on the main telescope with the same line of sight
- it has a smaller magnification than the main telescope, providing a much larger field of view

Light Gathering Power of an Optical Telescope



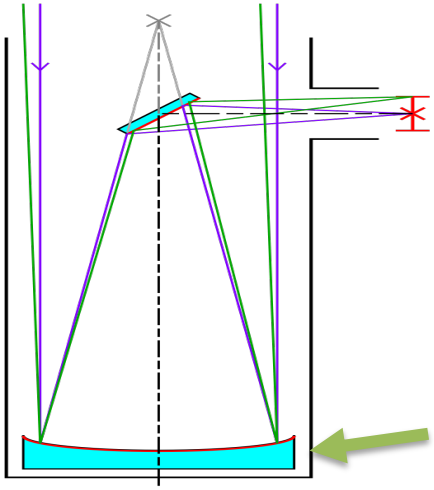


A larger mirror collects more photons making an object appear brighter

The light gathering power of a telescope is directly proportional to the area of the primary mirror.

Light Gathering Power of an Optical Telescope

Telescope #1

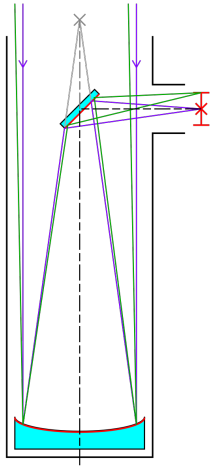


Primary mirror

Large mirror of radius R_L

$$\textbf{Area:} \quad A_L = \pi(R_L)^2$$

Telescope #2



Small mirror of radius R_S

$$\textbf{Area:} \quad A_S = \pi(R_S)^2$$

How much more light will the large telescope gather?

$$\frac{Area\ of\ large\ mirror}{Area\ of\ small\ mirror} = \frac{A_L}{A_S} = \frac{\cancel{\pi}(R_L)^2}{\cancel{\pi}(R_S)^2} = \left[\frac{R_L}{R_S}\right]^2$$

Light Gathering Power of an Optical Telescope

How much more light will the large telescope gather?

$$\frac{A_L}{A_S} = \left[\frac{\boldsymbol{R_L}}{\boldsymbol{R_S}}\right]^2$$

Example:

$$R_L = 20cm \qquad R_S = 5cm$$

$$\frac{A_L}{A_S} = \left[\frac{R_L}{R_S}\right]^2 = \left[\frac{20cm}{5cm}\right]^2 = 4^2 = 16$$

Therefore, the telescope with the $20cm$ mirror would gather 16 times more light than the telescope with the $5cm$ mirror.

Parts of a Newtonian Optical Telescope

Tube

- **Holds the whole optic system**

Mount (Base)

- **Supports and allows movement of the telescope tube**

Primary mirror (concave mirror)

- **Gathers the light and reflects it back toward the secondary mirror**

Secondary mirror

- **A flat mirror reflects the light to the side of the telescope towards the eyepiece**

Eyepiece

- **Creates the final focus correction**

Finder (a refractor)

- **Locates the object in a much larger FOV**

Focuser

- **Adjusts the focus**