Telescopes

Telescopes

- Telescopes collect more light than the eye can which is why they allow us to see much fainter objects than is possible with the naked eye
- In the past astronomers look through them, now professional telescopes use special instruments
- Some forms of telescopes detect kinds of light that the eye cannot see (radio waves and x-rays)
  - Some of these are made into satellites and put into the atmosphere

Lenses

- Lenses have been around since the Greeks
- Lenses were not introduced to Europe until around the 13th century
- By 1300 eyeglasses were available in cities such as Venice and Florence
- The tools for making a telescope available long before the first telescope was invented.

First Telescope

- The telescope first appeared in the Netherlands in **1608**
- **Hans Lippershey**, an eyeglass maker, asked for a patent on a "certain instrument for seeing far"
  - One of the stories says that Lippershey got the idea for his invention when children playing in his shop held two eyeglass lenses up together and found they could see the weathervane atop a distant church
- The telescope consisted of a convex and concave lens in a tube and magnified objects three to four times
- The government found the device too easy to copy and did not award a patent

Galileo

- Galileo made telescopes famous in 1609 at the University of Padua near Venice
- Galileo did not invent the telescope but he did design and build telescopes with increasingly higher magnification for his own use
- Galileo's first telescope was basically a tube containing two lenses
  - His first attempt was a three-power instrument, which was followed by one that magnified objects approximately nine times
  - Galileo's best telescope magnified objects about 30 times, but because of flaws in its design the images were blurry and distorted
  - He showed the device to the Venetian senate, hoping to impress them with its commercial and military potential

Problems with the Telescope

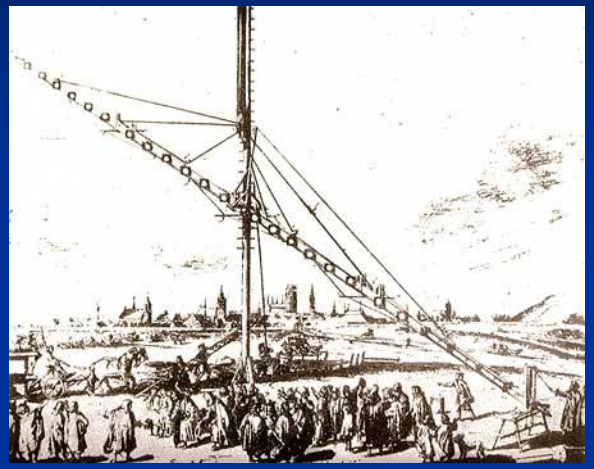
- finding clear and homogenous glass for lenses
  - The glass was full of little bubbles and had a greenish tinge
- It was also hard to shape the lenses perfectly
- The images of stars were blurry, and surrounded by color haloes (chromatic aberration: http://amazing-space.stsci.edu/resources/explorations/groundup/lesson/basics/g15/index.php)
- Early telescopes had a very small field of view
  - Only part of the Moon could be seen at one time
- Some people argued that the telescope made people see illusions and others claimed that the planets' details couldn't be seen with the naked eye, and therefore didn't matter
- The politically powerful Catholic Church promoted the idea that that the celestial bodies were perfect spheres, not covered with mountains and valleys

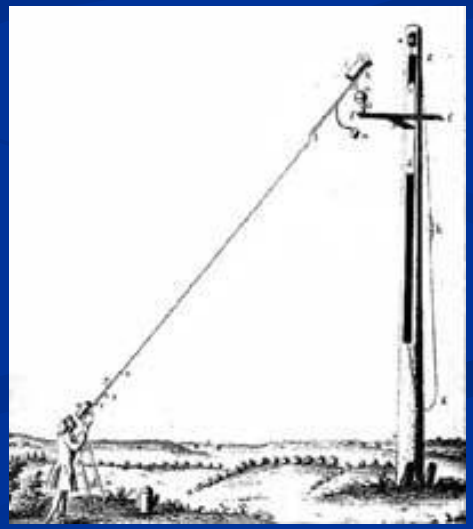
Kepler's Telescope

- Kepler suggested a variation on the telescope in 1630
- He noted that a telescopic device could be built using two convex lenses, but the image it produced would be upside down
- Kepler's telescope had a larger field of view and higher magnification
- He also managed to reduce spherical aberration (http://amazing-space.stsci.edu/resources/explorations/groundup/lesson/basics/g13/index.php)

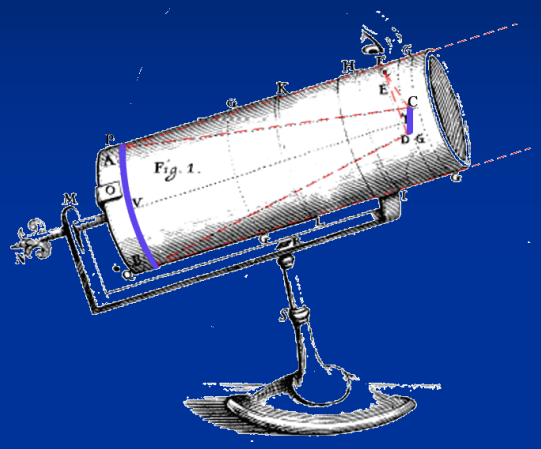
Christian Huygens

- A Dutch astronomer and mathematician
- Built a telescope 23 feet long that magnified objects about 100 times
- He was able to view the great Orion Nebula
- Also developed aerial telescopes





Early Reflectors



- Scottish mathematician, **James Gregory,** designed a reflecting telescope in 1663
- In 1668, **Isaac Newton devised** a reflecting telescope
  - Instead of a lens, it used a single curved main mirror, together with a smaller flat mirror
  - Reduced chromatic aberration,
  - Smaller Scopes could magnify more : 6 inches long = magnified 40 times

Problems With the Reflective Telescope

- The copper and tin mirrors tarnished quickly and had to be polished often
- Newton's mirrors reflected only 16 percent of the light they encountered.
  - Refractors still produced much brighter images
- The spherical shape of the mirror caused blurriness but there was not a way to grind the image in any other shape

John Hadley

- Hadley experimented with the grinding and polishing of mirrors
- Hadley managed to polish his metal mirror so that it had an approximately parabolic shape, avoiding the distortion in previous telescopes with spherical curves
  - http://amazing-space.stsci.edu/resources/explorations/groundup/lesson/basics/g14/index.php

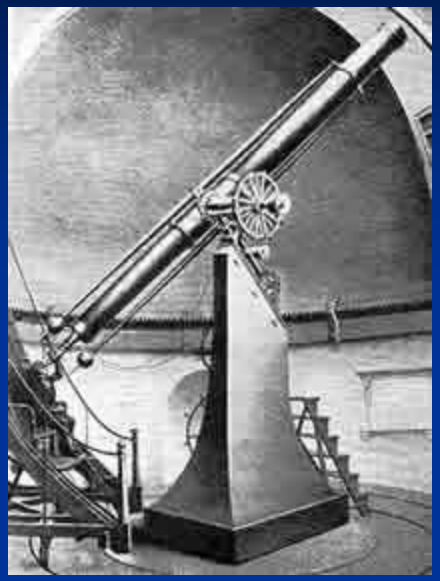
William and Caroline Herschel

- William and his sister Caroline began experimenting with making mirrors and building reflecting telescopes
- Together they made many discoveries
  - Catalog of double stars
  - Uranus
  - Nebulae
  - Satellites of Saturn

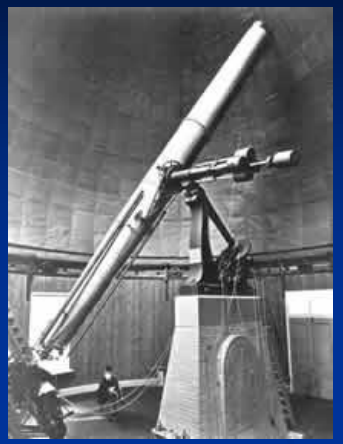
Refractor Advances

- Refracting telescopes were being replaced with reflecting telescopes, but technological advances improved refracting telescope
- Combining convex and concave lenses eliminated chromatic and spherical aberration
  - http://amazing-space.stsci.edu/resources/explorations/groundup/lesson/basics/g16b/index.php
  - http://amazing-space.stsci.edu/resources/explorations/groundup/lesson/basics/g16a/index.php
- Advances in the production of optical glass led to the development of large lenses with fewer flaws
- By the mid 1800's, 40 of 48 British observatories used refractors.
- Astronomers stopped building large refractors in the 1890s

Large Refractors



The Harvard 15-inch Refractor
Year completed:**1847**
Light collector:**Glass lenses**
Lens diameter:**15 inches**
Light observed:**Visible**
Discovery Highlights:
First telescope to make photographic images of the Moon



The Naval Observatory 26-inch Refractor
Year completed:**1873**
Light collector:**Glass lenses**
Lens diameter:**26 inches**
Light observed:**Visible**
Discovery Highlights:
While being used to study the motion of the planets, discovered the two moons of Mars, Phobos and Deimos.

The Yerkes 40-inch Refractor
Year completed:**1895**
Light collector:**Glass lenses**
Lens diameter:**40 inches**
Light observed:**Visible**
Discovery Highlights:
Measured changes in nearby star positions accurately enough to calculate their distances from Earth.

Reflector Advances

- In the 1850s, a German chemist named Justus von Liebig made a new kind of mirror
  - He used a newly discovered chemical reaction to cover the surface of a piece of glass with a thin film of silver
  - The silver could easily be polished to create a mirror
  - Now astronomers had an inexpensive, lightweight, glass mirror that reflected **50 percent** more light than metal mirrors had
  - The silver still tarnished, but it was easier to replace the silver coating than it was to polish a metal mirror

Huge Reflectors

The Hooker
100-inch Reflector
Year completed:**1917**
Light collector:**Silver-coated mirror**
Mirror diameter:**100 inches**
Light observed:**Visible**
Discovery Highlights:
Edwin Hubble used this telescope to establish that "spiral nebulae" are in fact galaxies outside our own Milky Way and that they are moving away from us, indicating that the universe is expanding.

The Hale 200-inch
Light collector:**Aluminum-coated glass mirror**
Mirror diameter:**200 inches**
Light observed:**Visible**
Discovery Highlights:
Discovered visible evidence of quasars — very bright objects at very great distances that were later found to be supermassive black holes at the centers of distant galaxies.

Ritchey's 60-inch Reflector
Year completed:**1908**
Light collector:**Silver-coated glass mirror**
Mirror diameter:**60 inches**
Light observed:**Visible**
Discovery Highlights:
Its findings were used to demonstrate that most stars at the same temperature have the same brightness and, surprisingly, contain the same amount of matter.

Photography

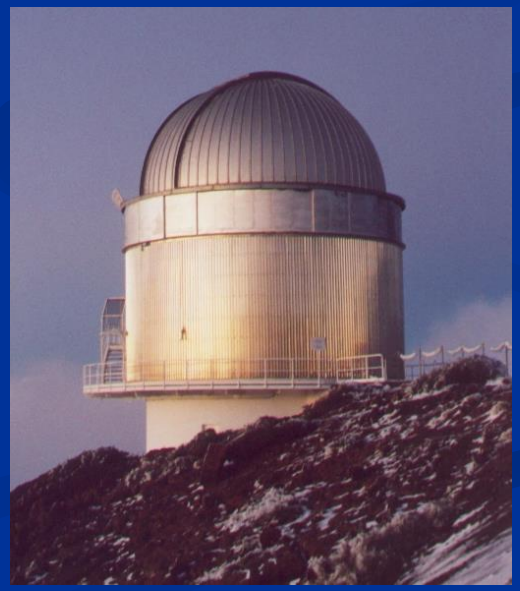
- In 1840, an English-American chemist and photographer, John William Draper, focused the Moon's image on a light-sensitive photographic plate
  - After an exposure of 20 minutes, he had taken the first-ever photograph of the Moon
- Photography was then applied to telescopes
  - Now images could be recorded without endless sketching
  - It also provided a way for astronomers to observe objects that were too faint to be seen by the human eye
  - The first telescope to use this photography was a refractor

Types of Telescopes

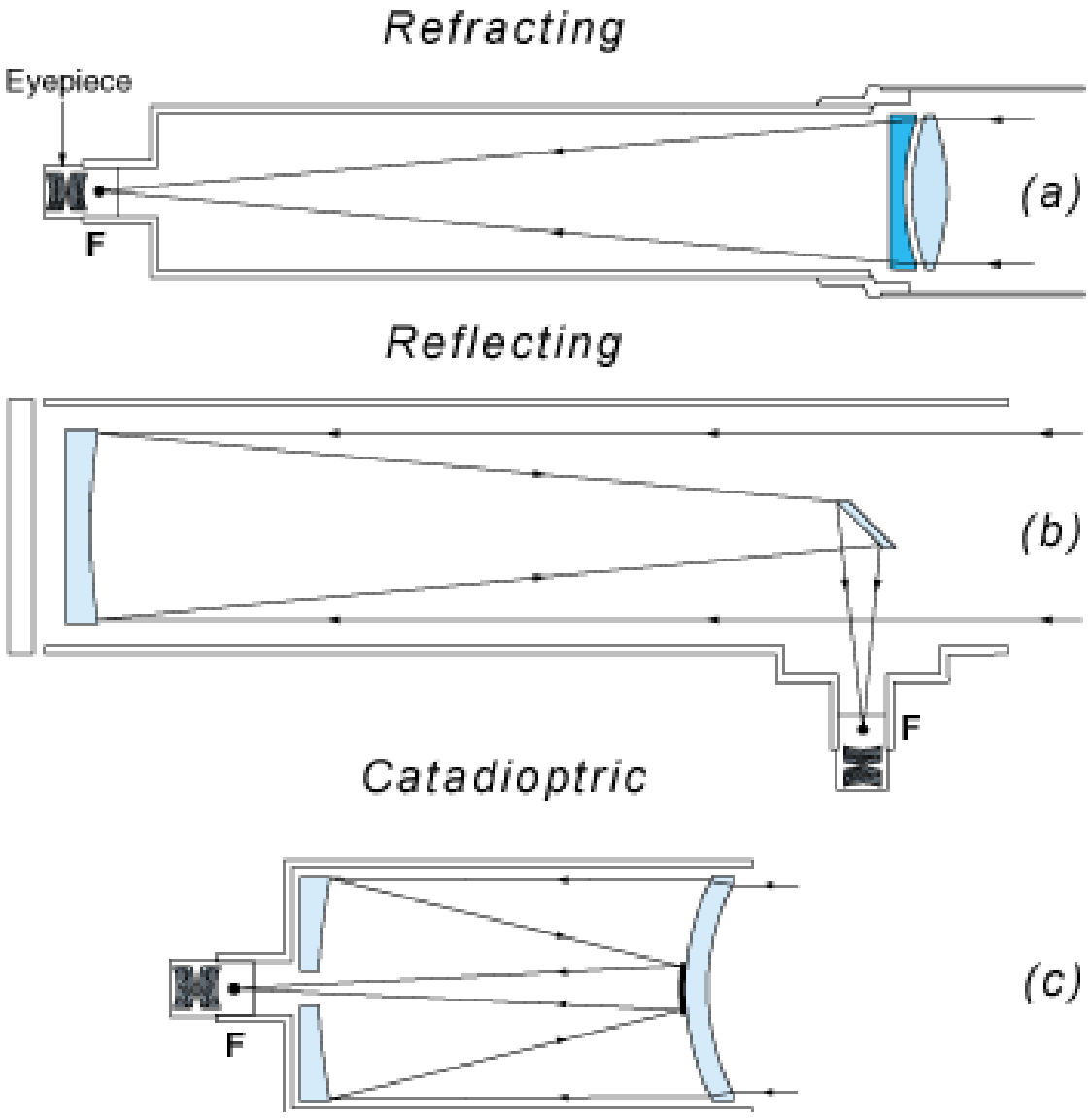
- Optical
  - Refracting
  - Reflecting
- Radio
- Infrared
- X-ray

Optical Telescopes

- Light reflects and refracts
- Have an eyepiece to magnify the image for looking at



How they work

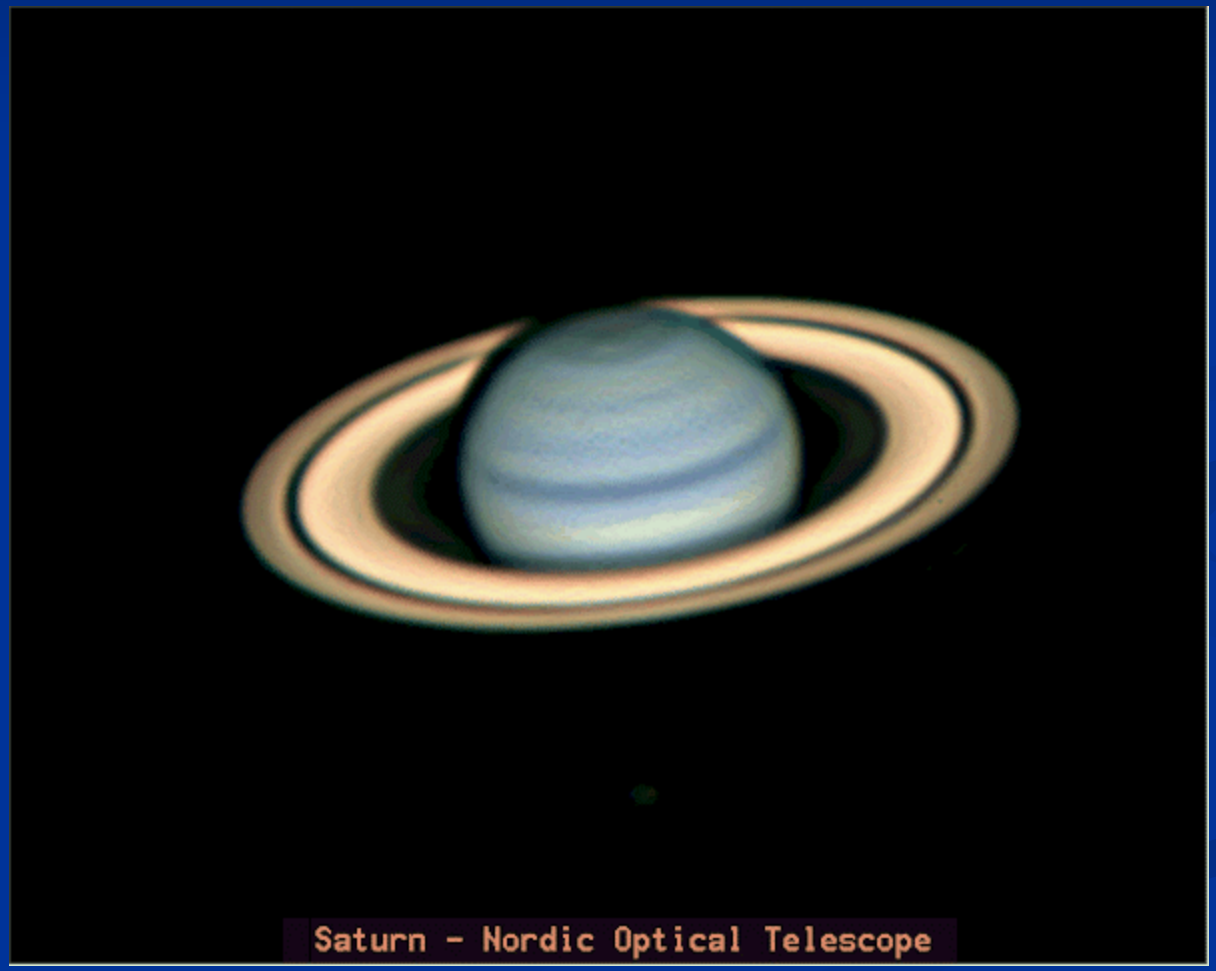


Lenses

Mirrors

Combination

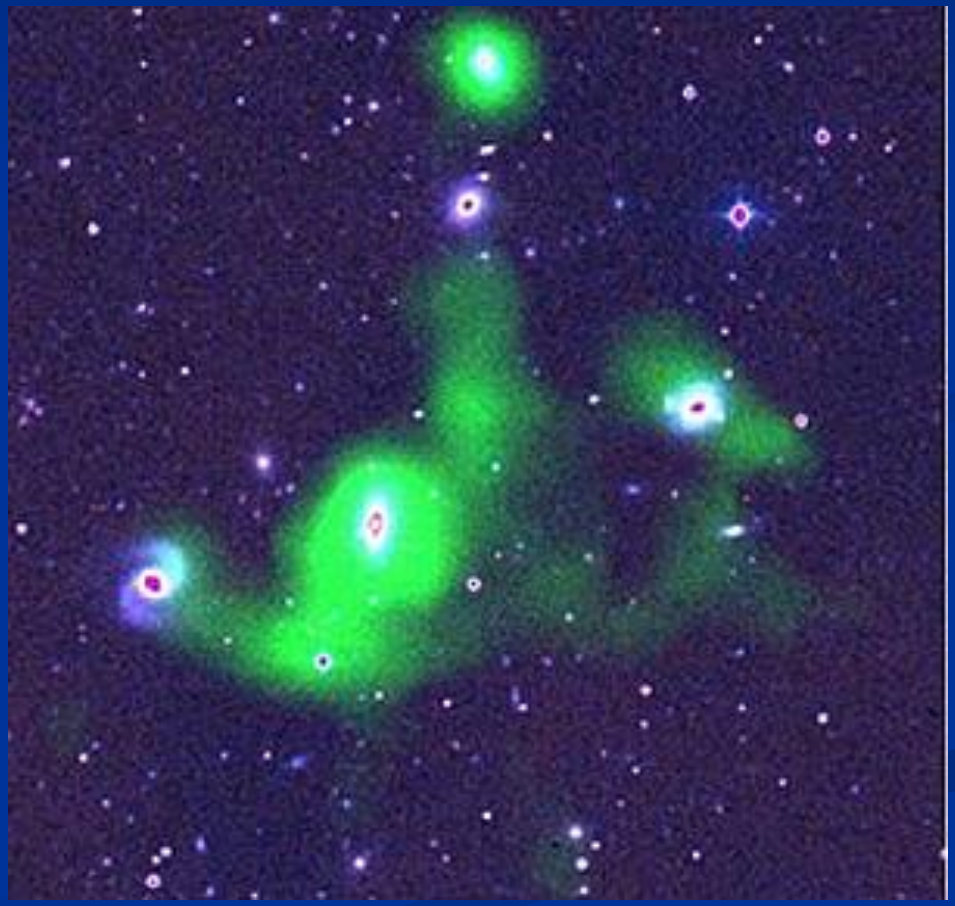
Optical Telescope



Radio Telescopes

- A single-dish radio telescope is usually an antenna shaped as a parabola that collects the radio waves from a celestial object and focuses them onto a **receiver.**
- The signal received is then electronically processed so that it can be stored and analyzed by a computer.
- The telescope has to have two important characteristics
  1. it should have a large collecting area (large telescopes can collect more electromagnetic waves and therefore detect fainter objects)
  2. the resolution (how close things can be together and still be distinguished as separate) should be as good as possible.

Radio Telescopes



Infrared Telescopes

- Light hits a parabolic mirror and is sent to a focal point
- Light is recorded by a computer and translated into visible light

- Problem: 99% of infrared rays are absorbed by water in our atmosphere (chart in EM Spectrum notes)
- Solution: dry areas, airplanes, weather balloons and space bound telescopes

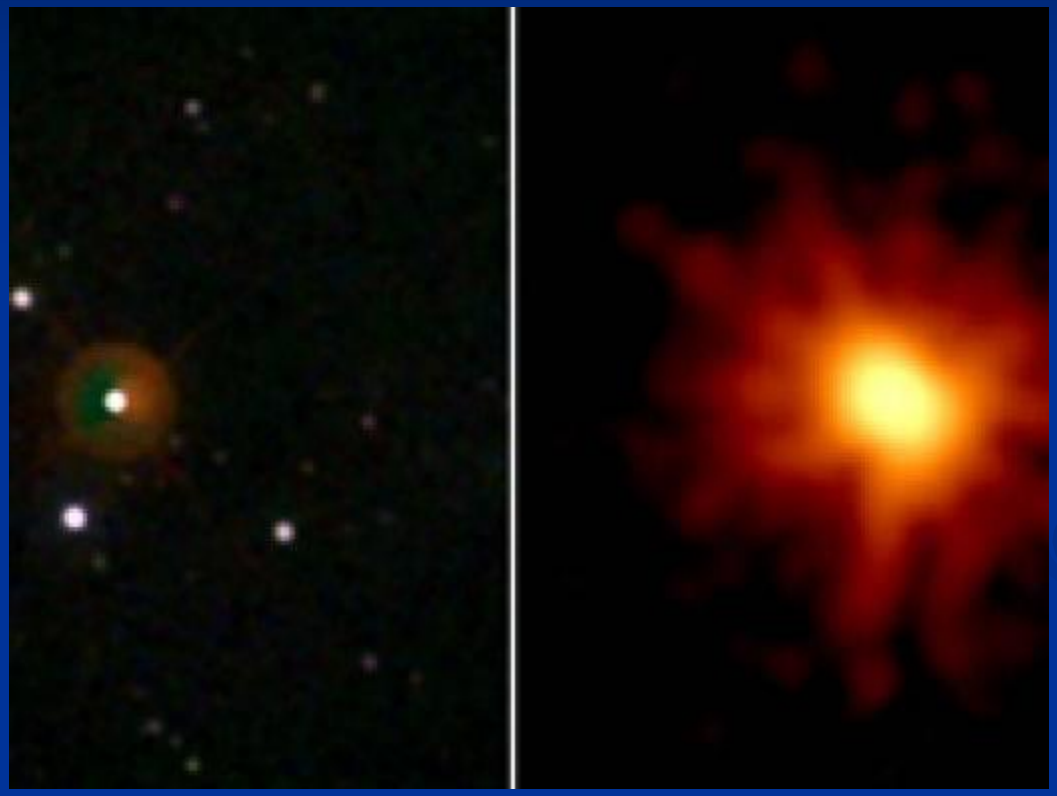
Infrared Telescopes

Infrared Telescope

The United Kingdom Infrared Telescope atop the dormant volcano Mauna Kea in Hawaii. Because infrared light is absorbed by carbon dioxide and water vapor, astronomers use this dry, high-altitude site to minimize the infrared light lost to surrounding air. *(Reproduced by permission of* Photo Researchers, Inc.*)*

Infrared Telescope

X-ray Telescopes



Optical / UV telescope

X-ray telescope

Observatories

- Choosing a location much take into account:
  - Weather
  - Light Pollution
  - Blurring (atmosphere makes images blurred or fuzzy, this is what makes stars appear to twinkle)
  - Transmission (light that gets through the atmosphere)
- Usually on high mountains above most clouds, well away from towns or cities and on islands where the surrounding sea helps make a more stable atmosphere
- Can also be placed on satellites above the atmosphere

Light Pollution

Light Pollution

Atmospheric Distortions

- Astronomers began building giant telescopes on high mountains, where the air was thin enough that the twinkling effect caused by atmospheric distortion was reduced, and the lights and pollution of cities were far away
  - http://amazing-space.stsci.edu/resources/explorations/groundup/lesson/basics/g18a/index.php

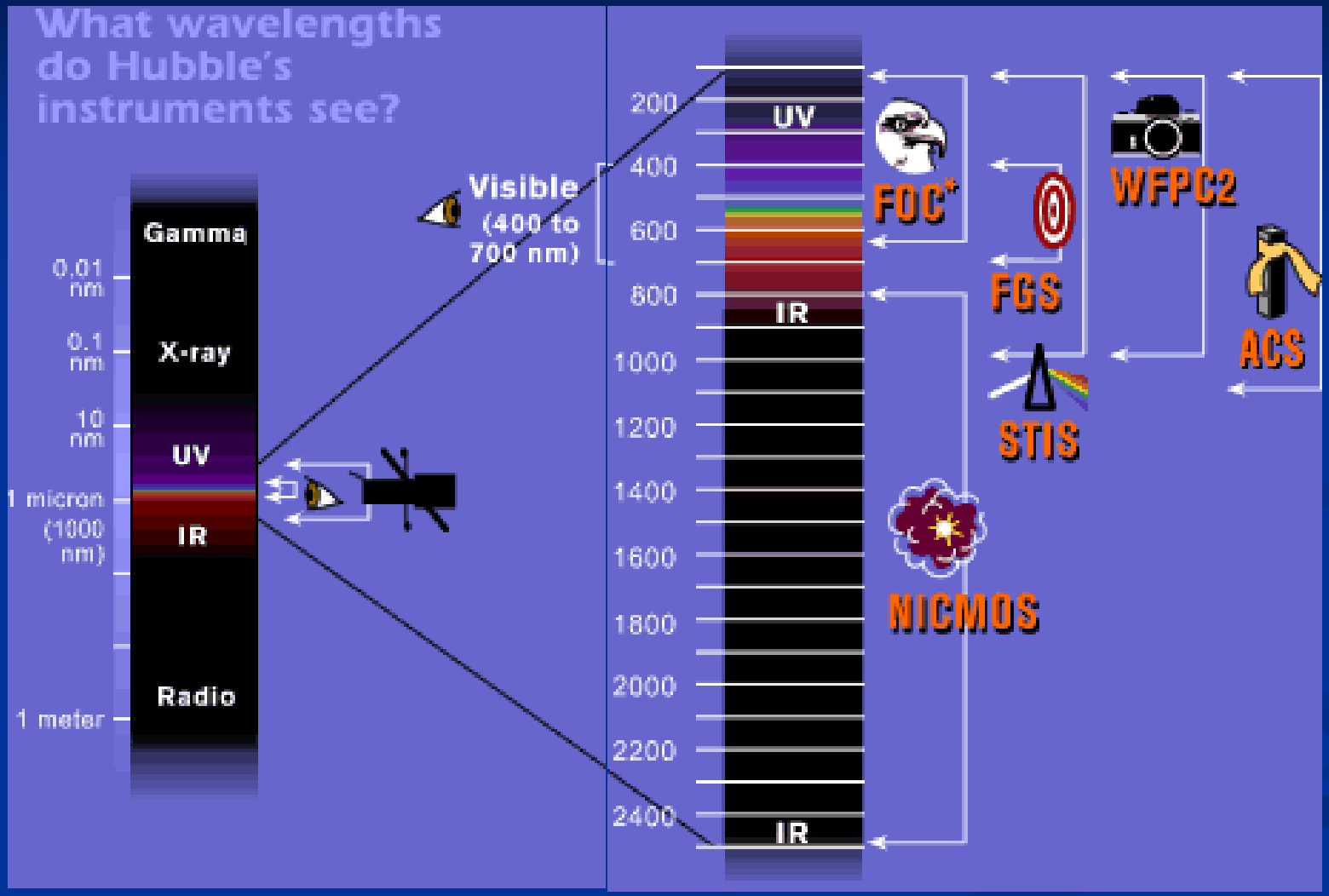
McDonald's Observatory
Fort Davis, TX

Link Observatory
Mt. Hamilton, Arizona

National Radio Astronomy Observatory Socorro, N.M

Rossi X-ray Satellite

Hubble Space Telescope


What wavelengths do Hubble's instruments see?
Gamma
X-ray
UV
IR
Radio
0.01 nm
0.1 nm
10 nm
1 micron (1000 nm)
1 meter
Visible (400 to 700 nm)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
UV
IR
IR
FOC*
FGS
STIS
NICMOS
WFPC2
ACS

James Webb Telescope - 2013

Hubble vs. James Webb