Beginners Workshop 1

Mike Whybray

- What is astronomy?
- Our universe - Cosmology
- Observing - What can you actually see?
- Telescopes - Choosing one


WELCOME TO BASIC ASTRONOMY. BEFORE WE START, ARE THERE ANY QUESTIONS?
YEAH, LIKE, WHAT MAKES ASTRONOMY DIFFERENT FROM ASTROLOGY?
2-18

Spaceflight

Solar System

Observing

Armchair

Astronomy

History

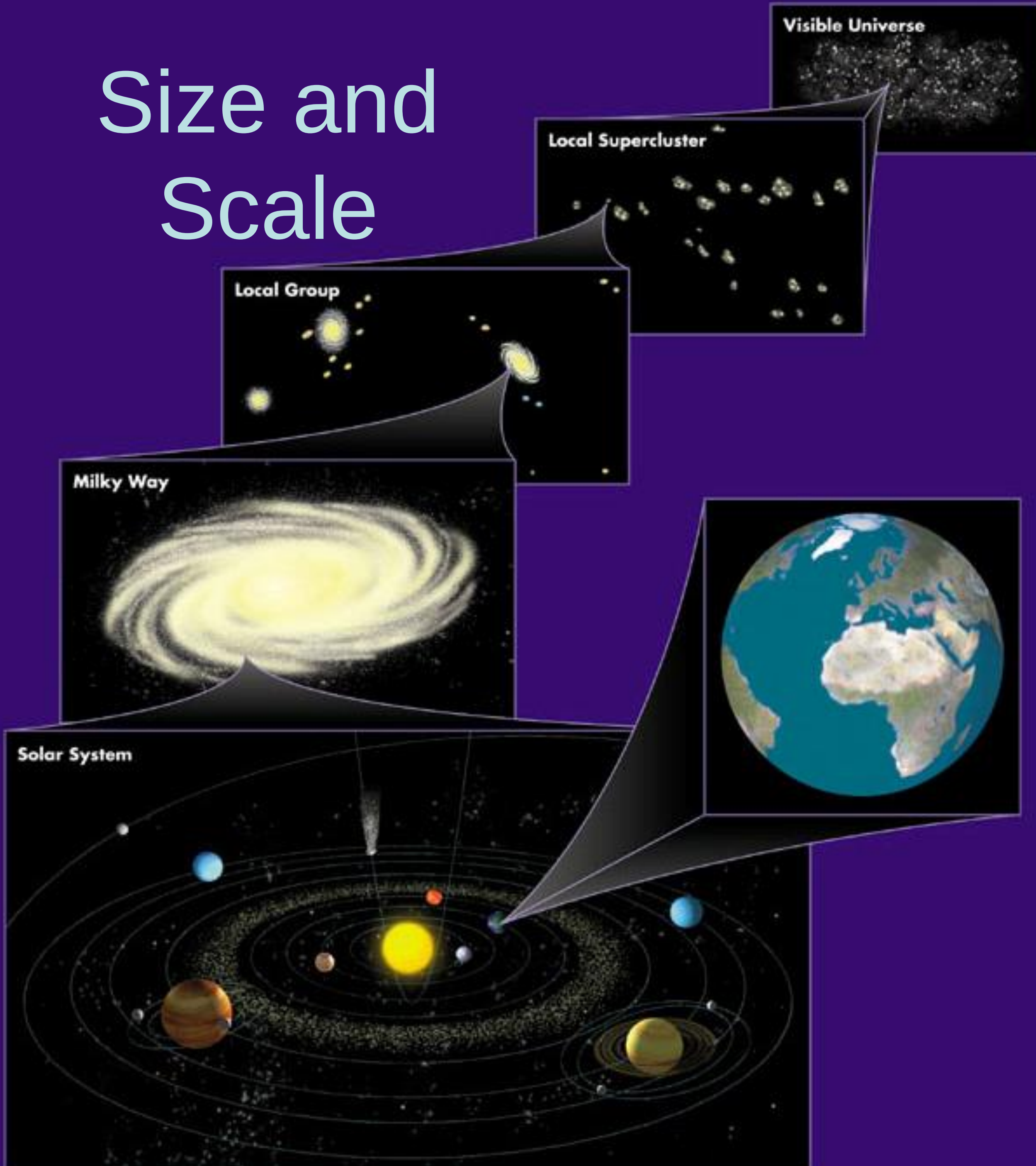
Cosmology

Social activity

Cosmology

- Structure of the universe
- Size and scale:
  - solar system
  - stars
  - galaxies
  - everything
- History of the universe: Big Bang, Inflation etc.

Size and Scale



From the Earth to the farthest edge of the visible Universe

Moon (not to scale!)

Radius: $\frac{1}{4}$ Earth's radius

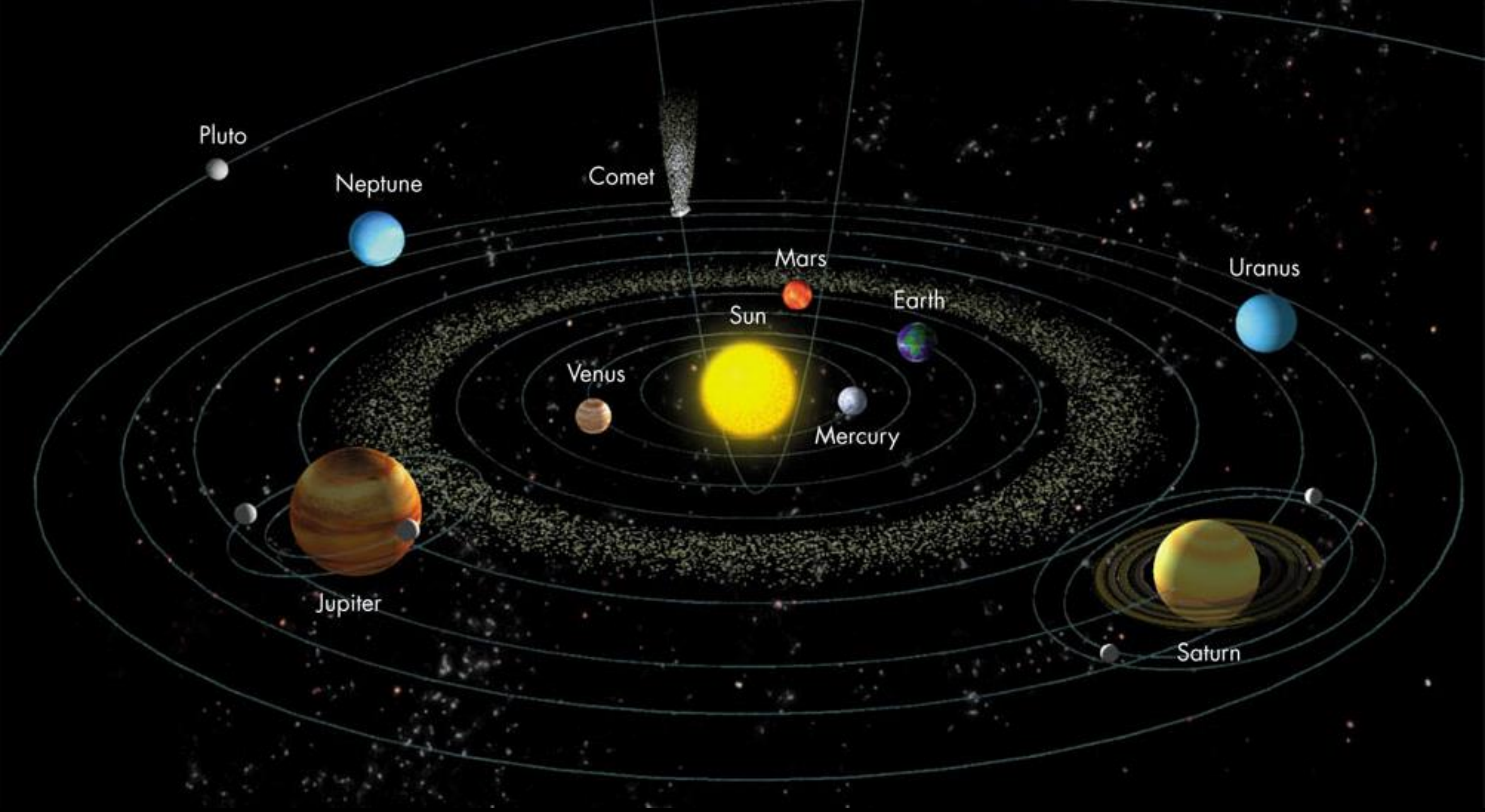
Distance from Earth: 384,000 km

Earth

Radius: 6400 km

Distance from Sun: 150,000,000 km

1 AU, 8 light minutes



Solar System

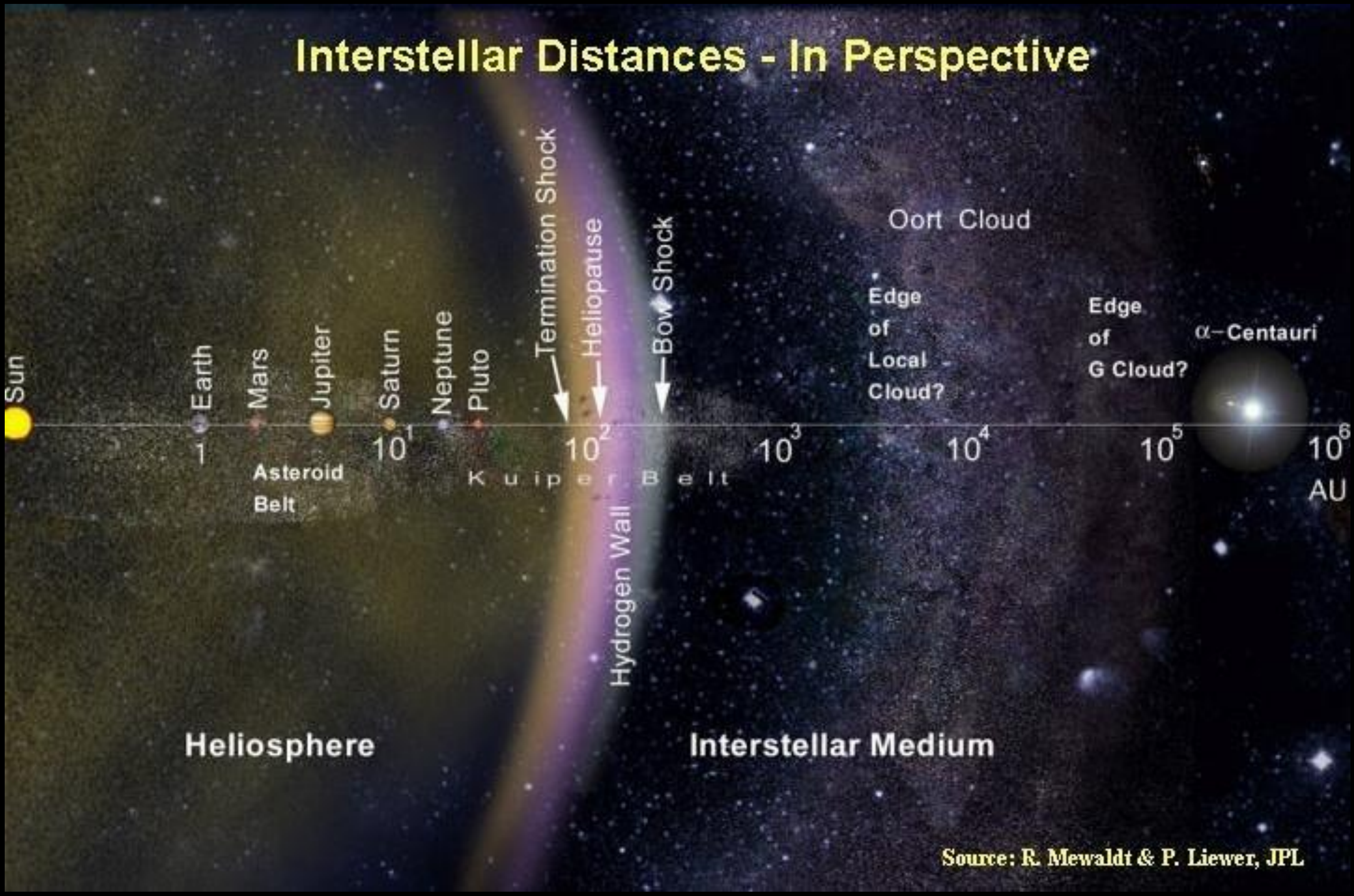
Sizes and distances
NOT to scale
Distance to Pluto: about 40 AU
(about 320 light minutes)

Solar system objects to scale

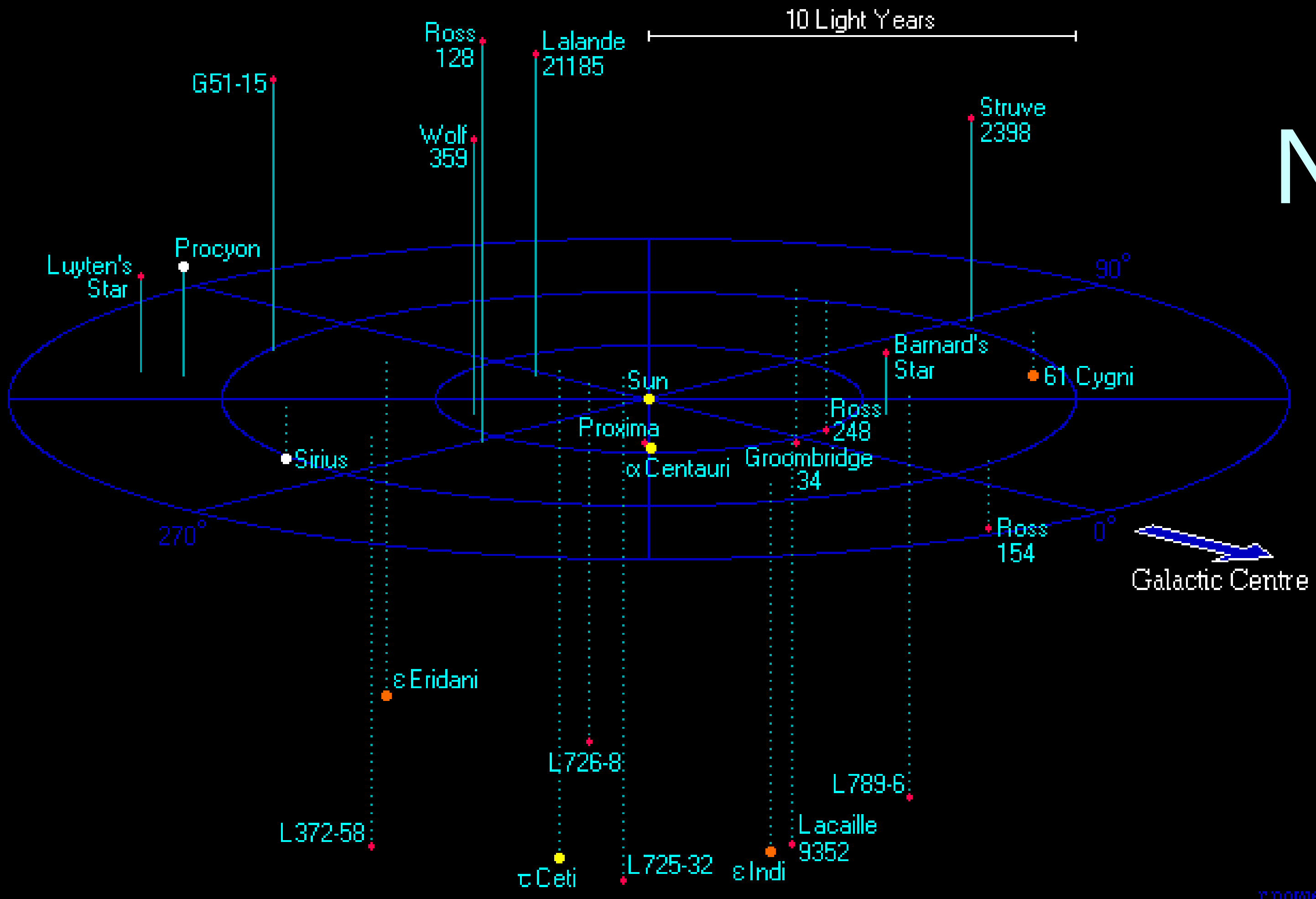
How far to a star?

1 AU = 1.5×10^8 km = 8.3 light mins (Pluto-5.5 lt hrs)

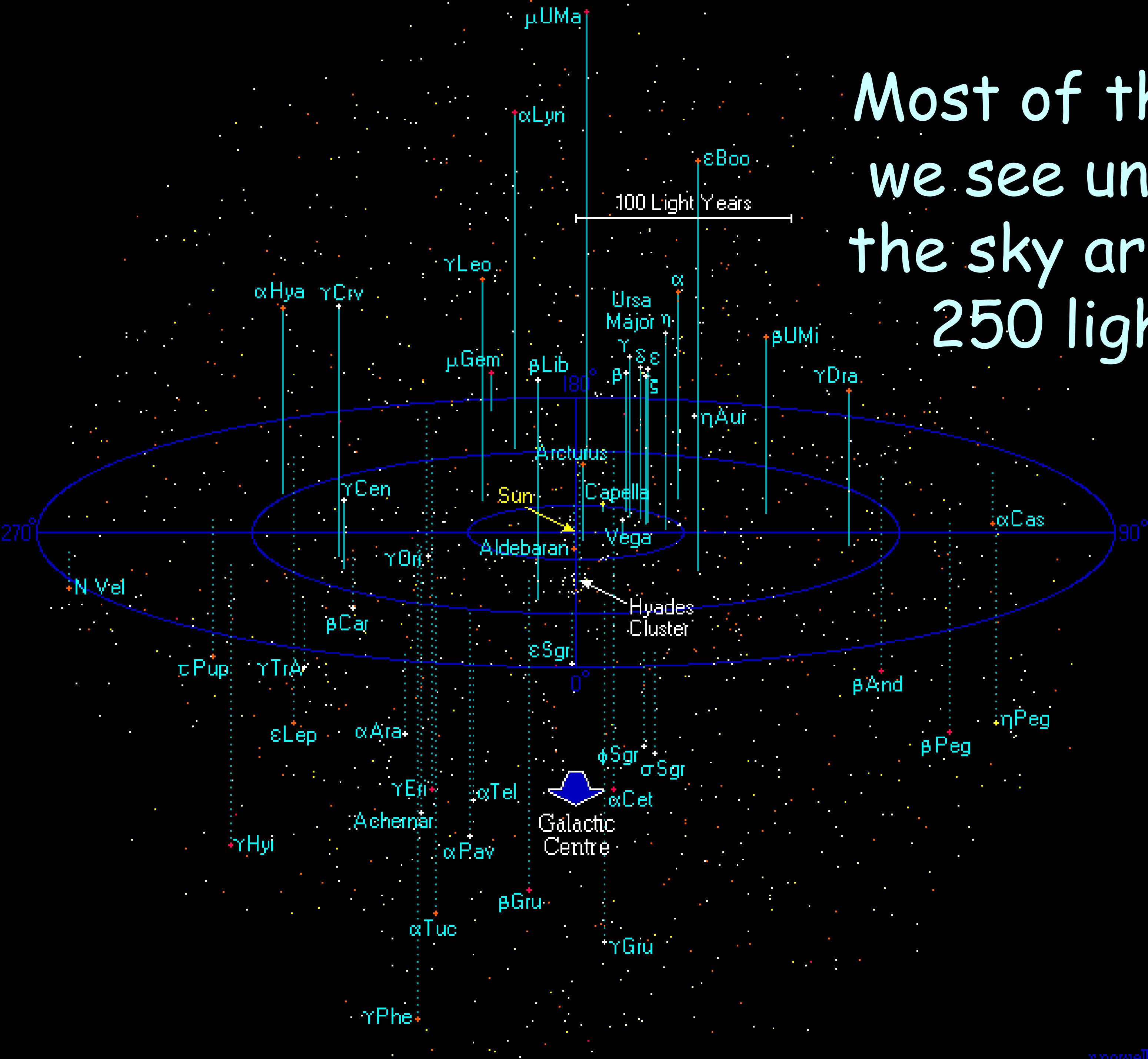
~8,000 Pluto distances to nearest star - Proxima Centauri



The Nearest Stars

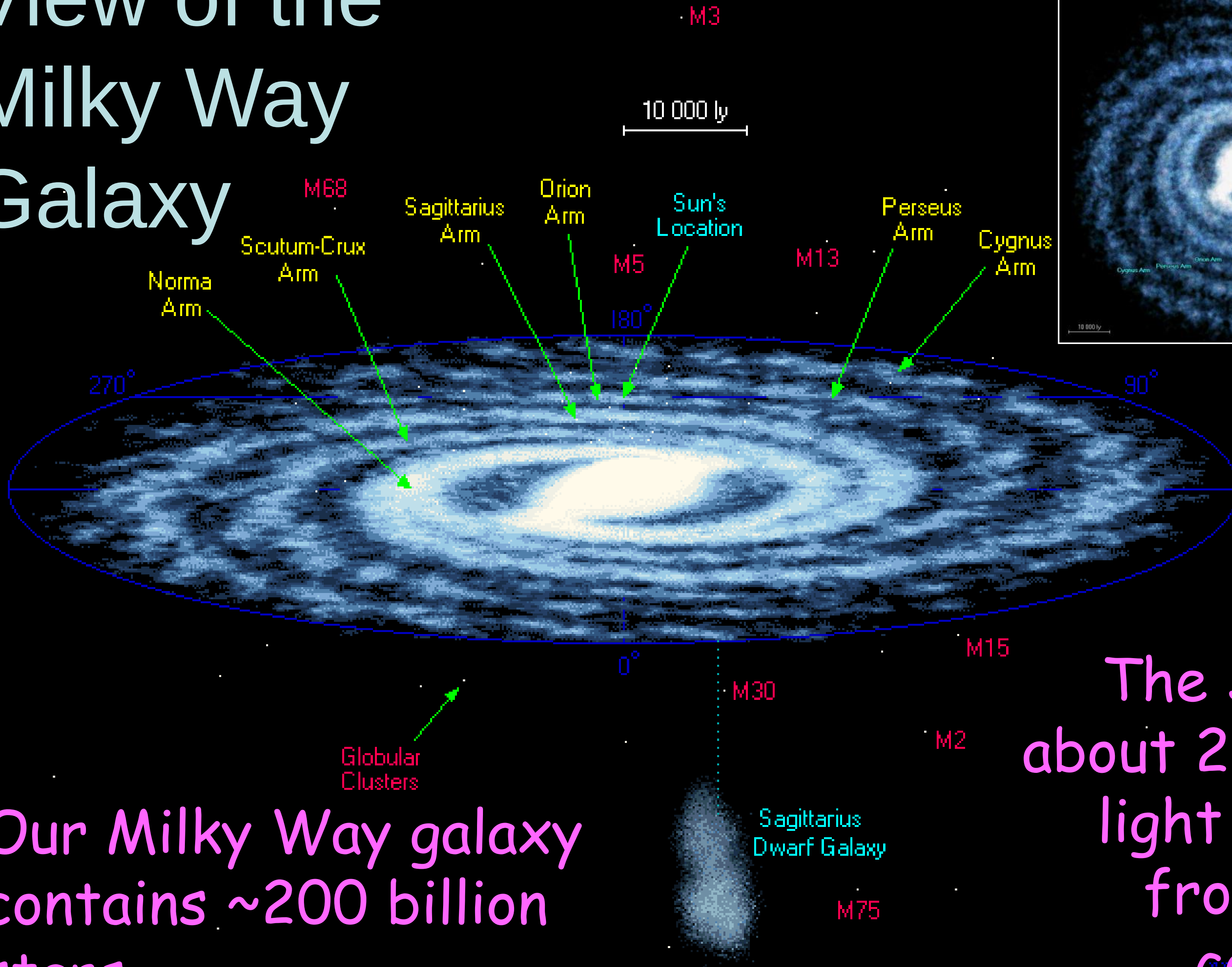


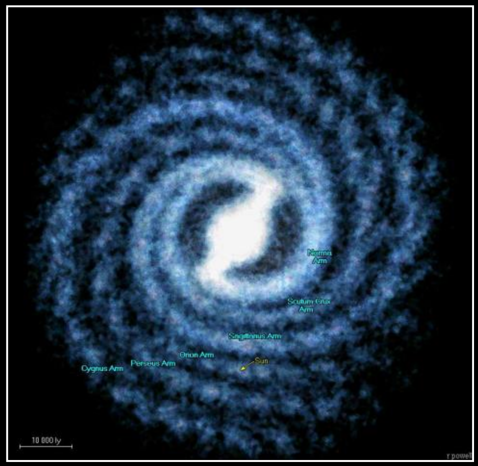
The closest star to our Sun is Proxima Centauri, about 4 light years distant.



Most of the stars we see unaided in the sky are within 250 light years

View of the Milky Way Galaxy

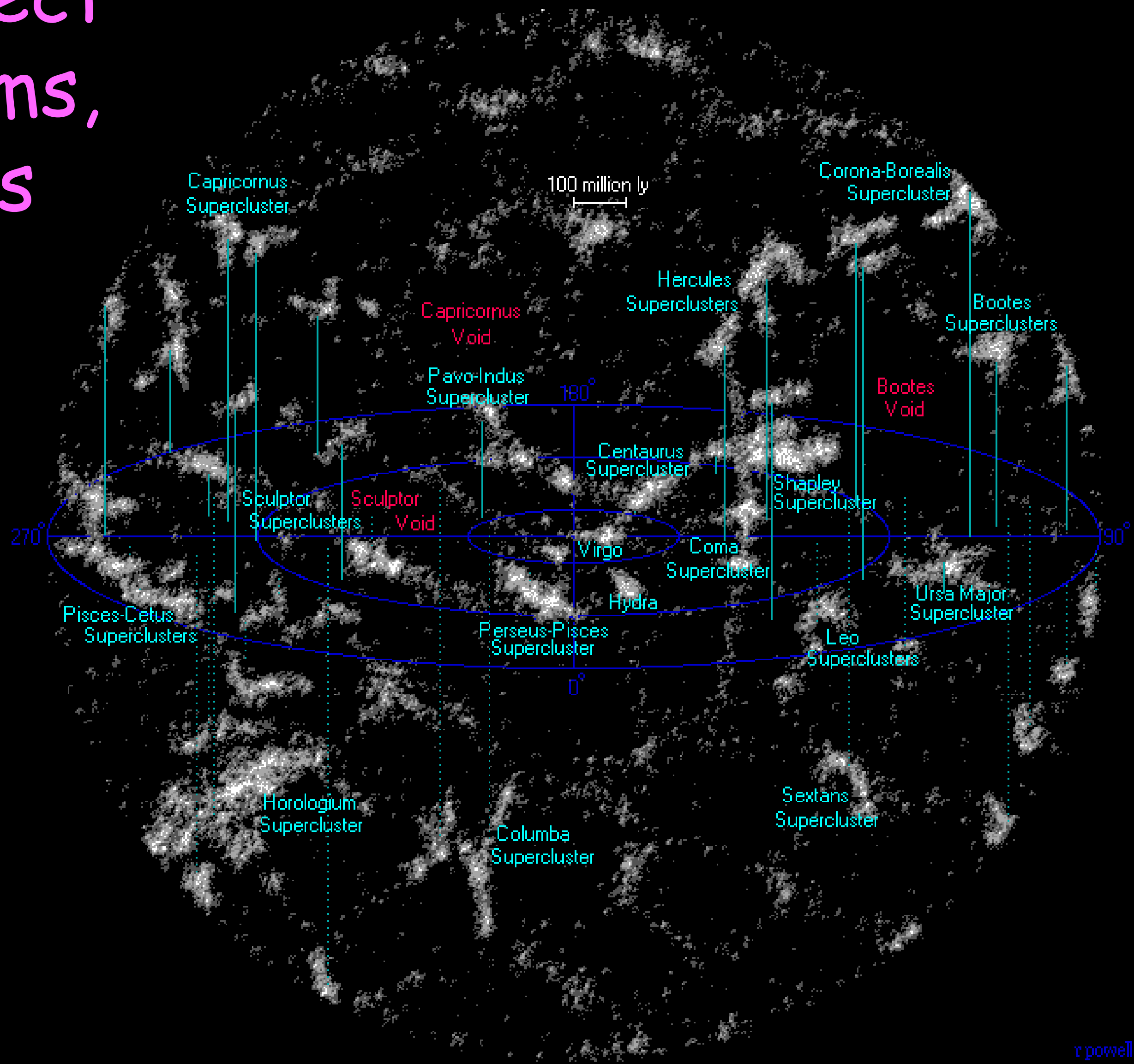




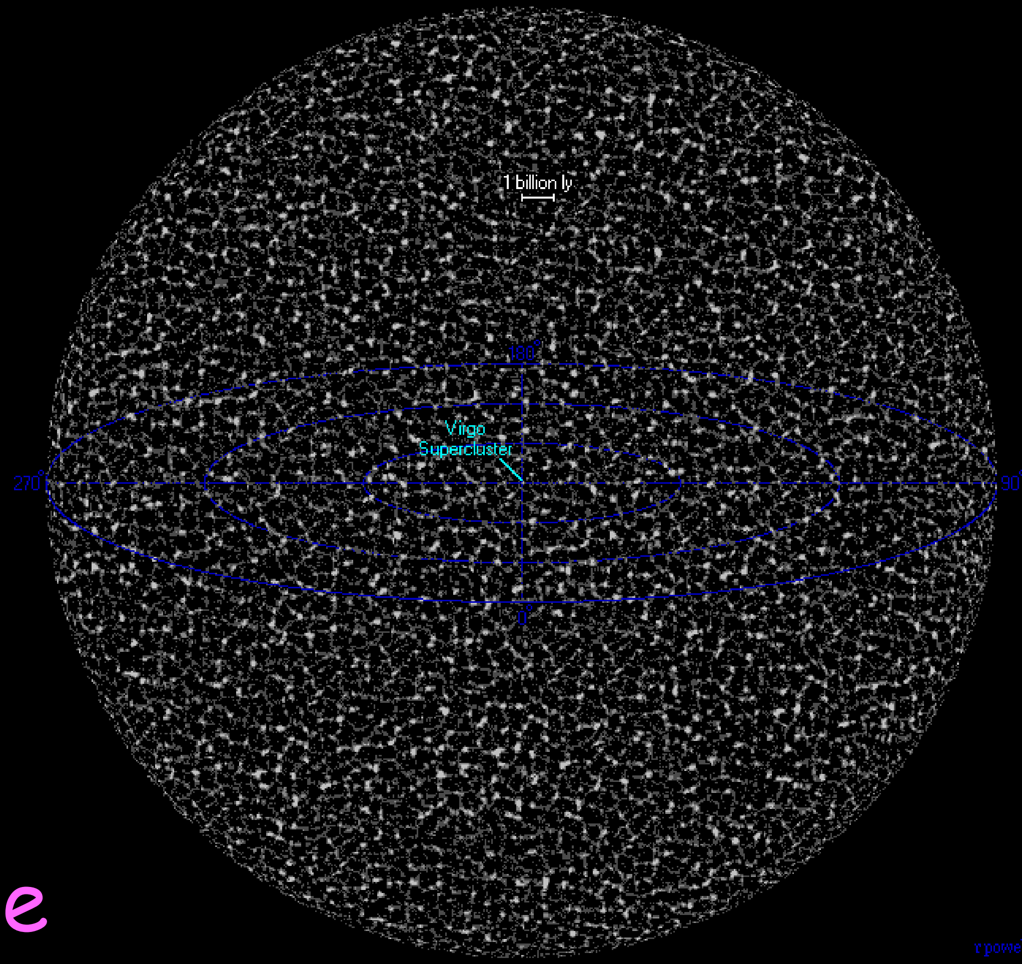
Our Milky Way galaxy contains ~200 billion stars.

The Sun is about 26,000 light years from the center.

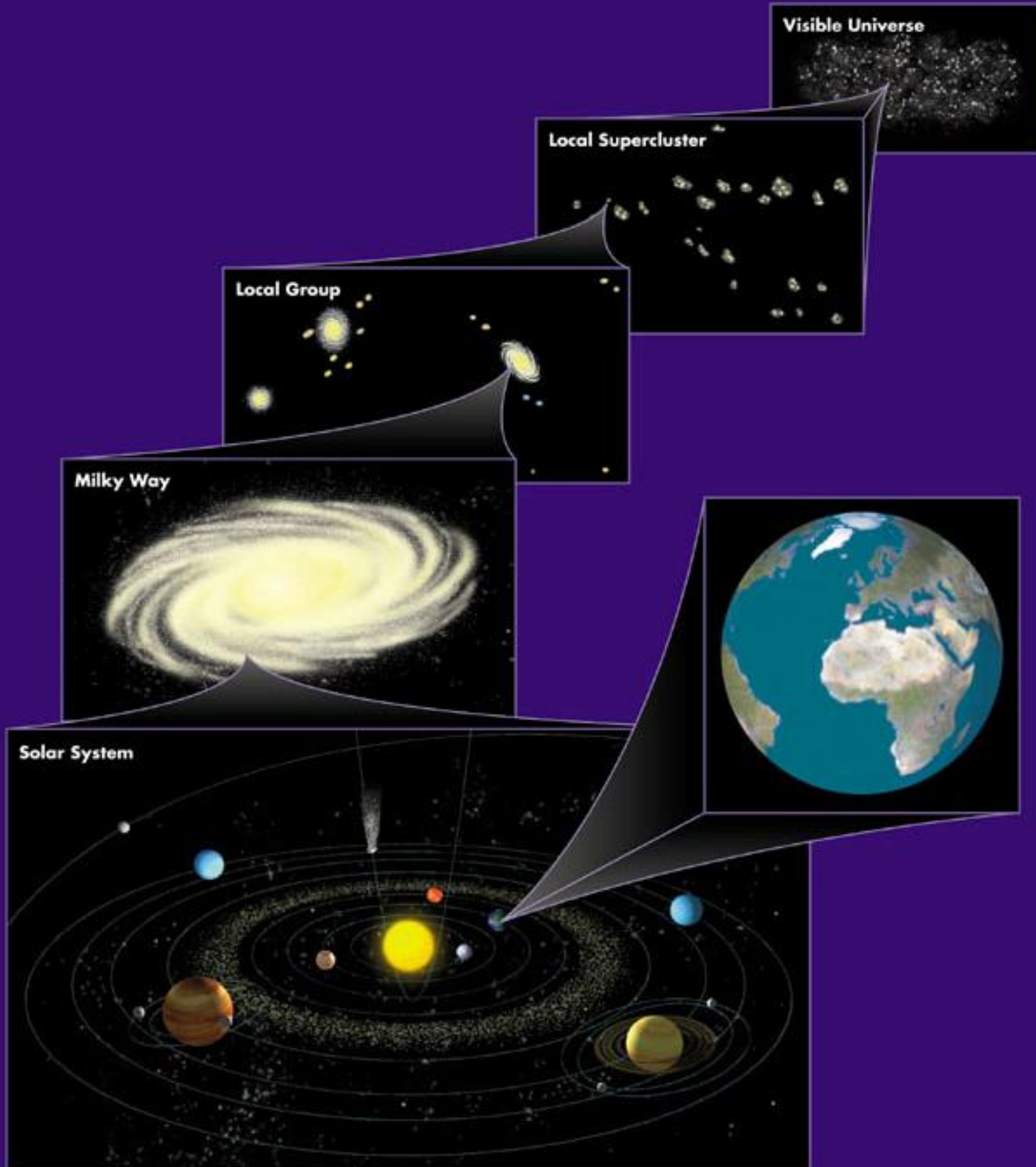
Galaxies and clusters of galaxies collect into vast streams, sheets and walls of galaxies



The Visible Universe



On the largest scales, the universe seems to be more or less uniform



Approximate numbers:

200 billion stars in our galaxy

100 billion galaxies in the visible universe

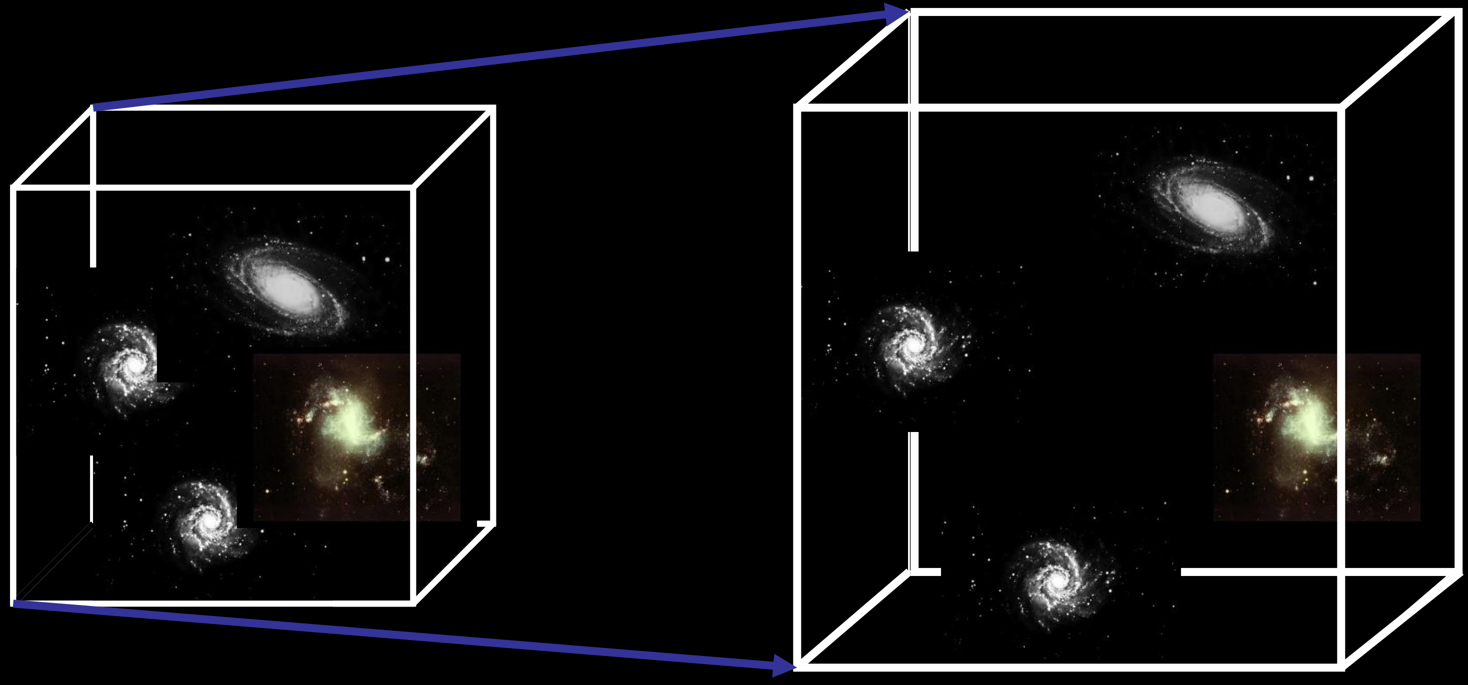
The Expanding Universe

On large scales, galaxies are moving apart, with velocity proportional to distance (Hubble's Law)

The Expanding Universe

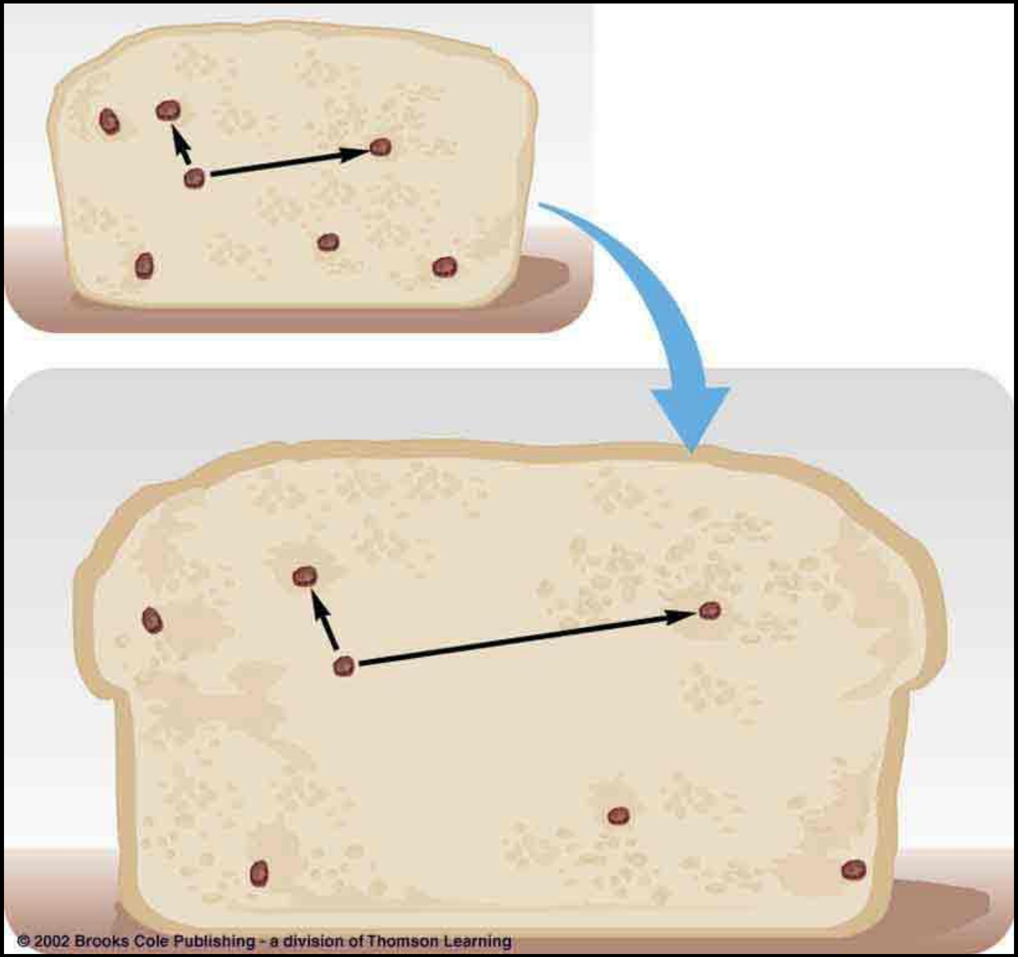
On large scales, galaxies are moving apart, with velocity proportional to distance (Hubble's Law)

It's not galaxies moving through space.
Space is expanding, carrying the galaxies along!



The galaxies themselves are not expanding

Expanding Space



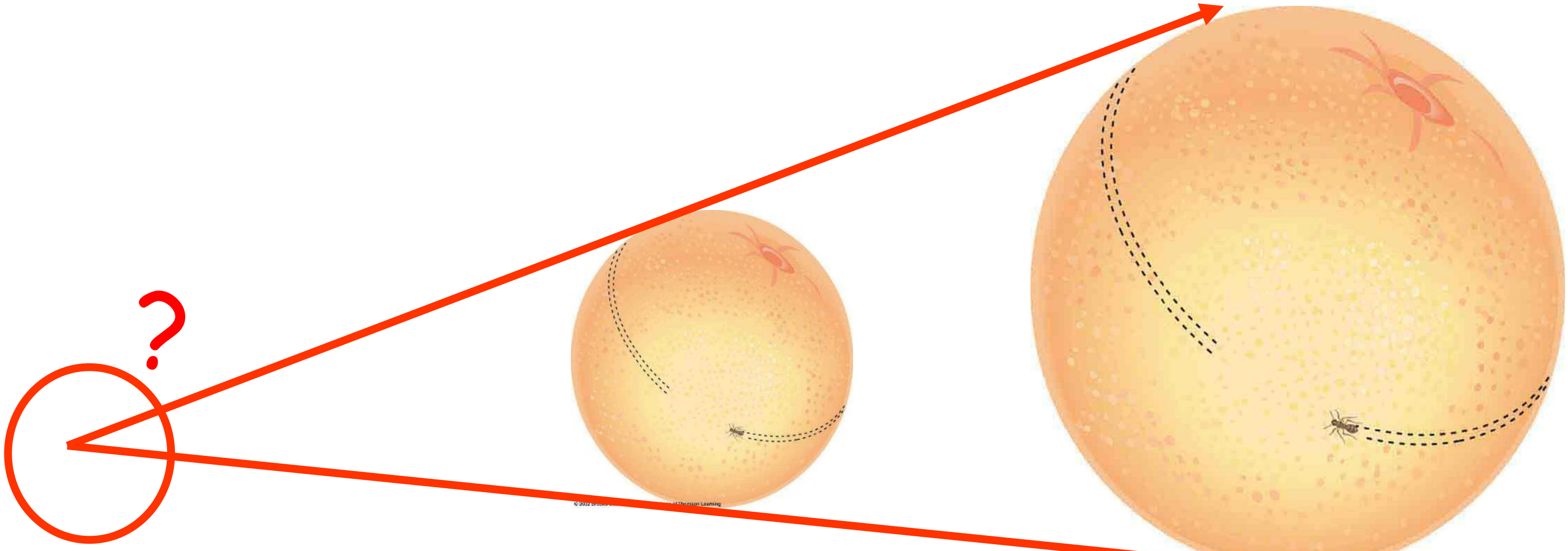
Analogy:

A loaf of raisin bread where the dough is rising and expanding, taking the raisins with it

The Necessity of a Big Bang

If galaxies are moving away from each other with a speed proportional to distance, there must have been a beginning, when everything was concentrated in one single point:

The Big Bang!



The Age of the Universe

Knowing the current rate of expansion of the universe, we can estimate the time it took for galaxies to move as far apart as they are today:

Hubble found Velocity is proportional to Distance

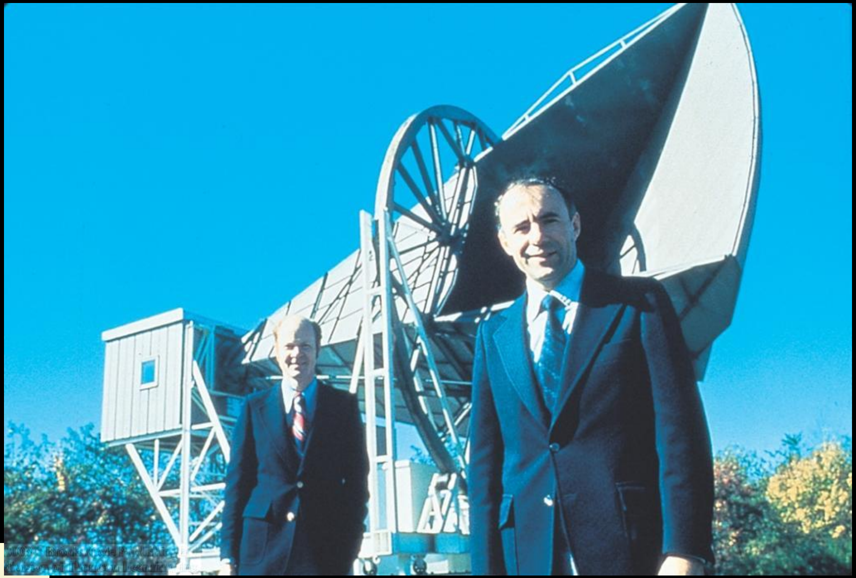
i.e. Velocity = H * Distance

But Time = Distance / Velocity

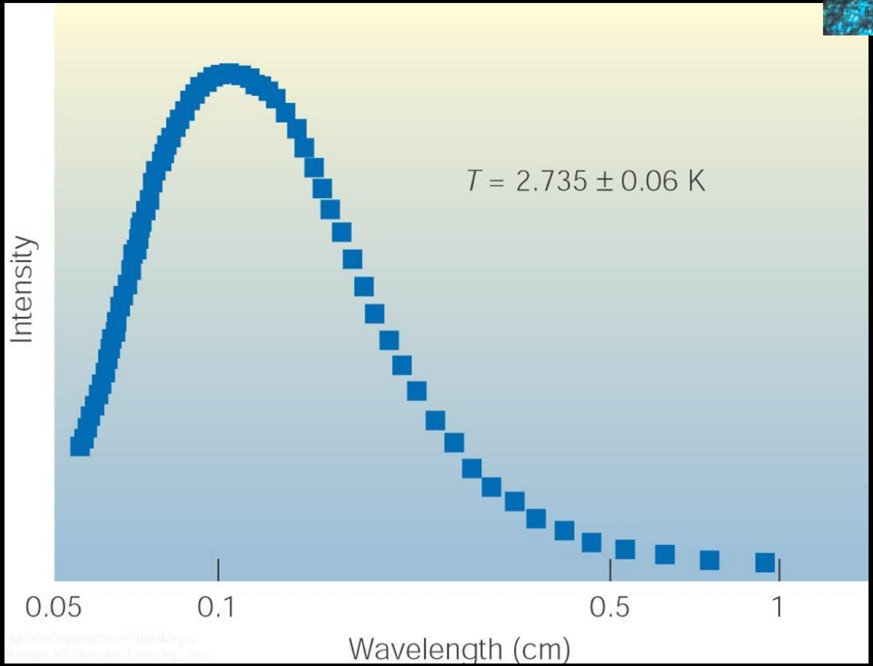
So Time = 1/H ~ 13.7 Billion Years

The Cosmic Background Radiation

The radiation from the very early phase of the universe is detectable today



R. Wilson & A. Penzias

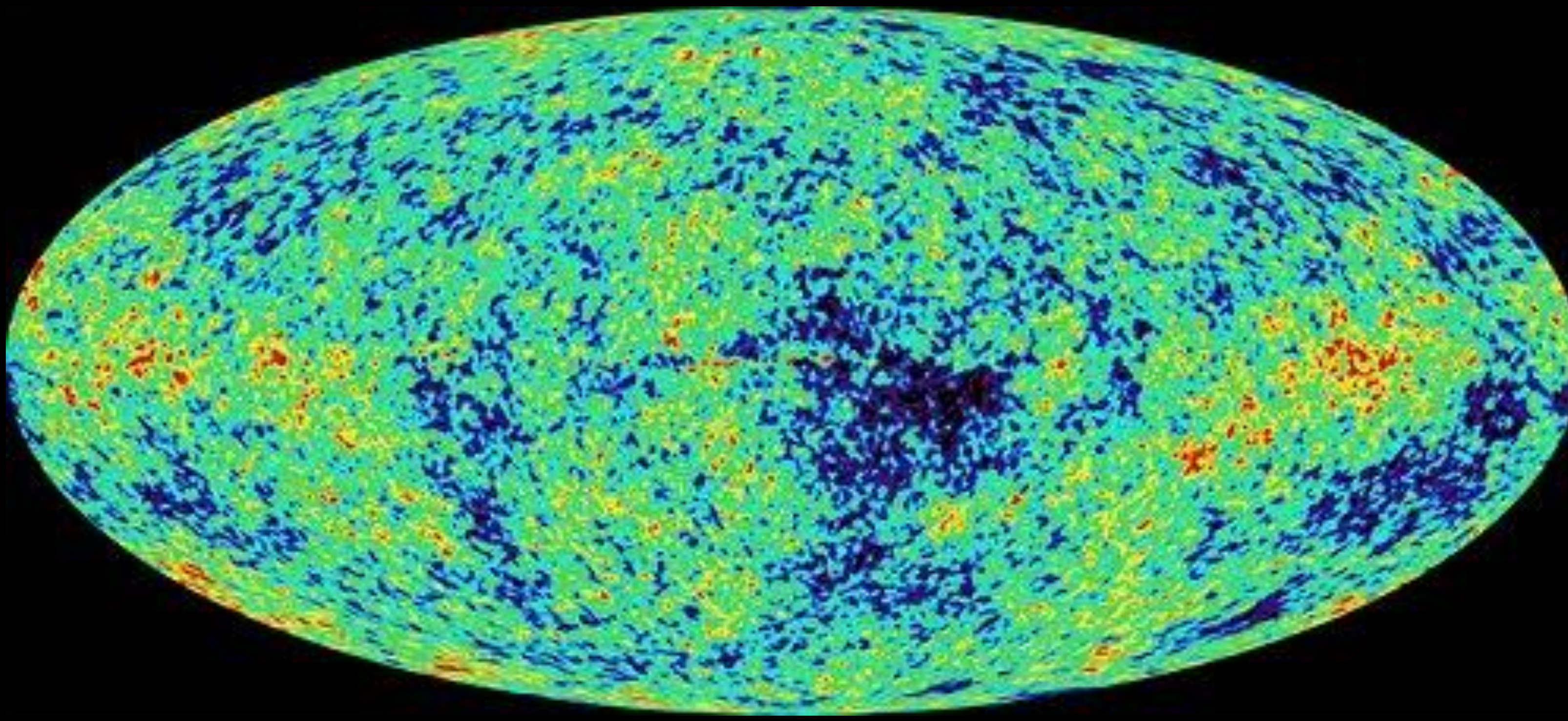


Discovered in mid-1960s as the **Cosmic Microwave Background:**

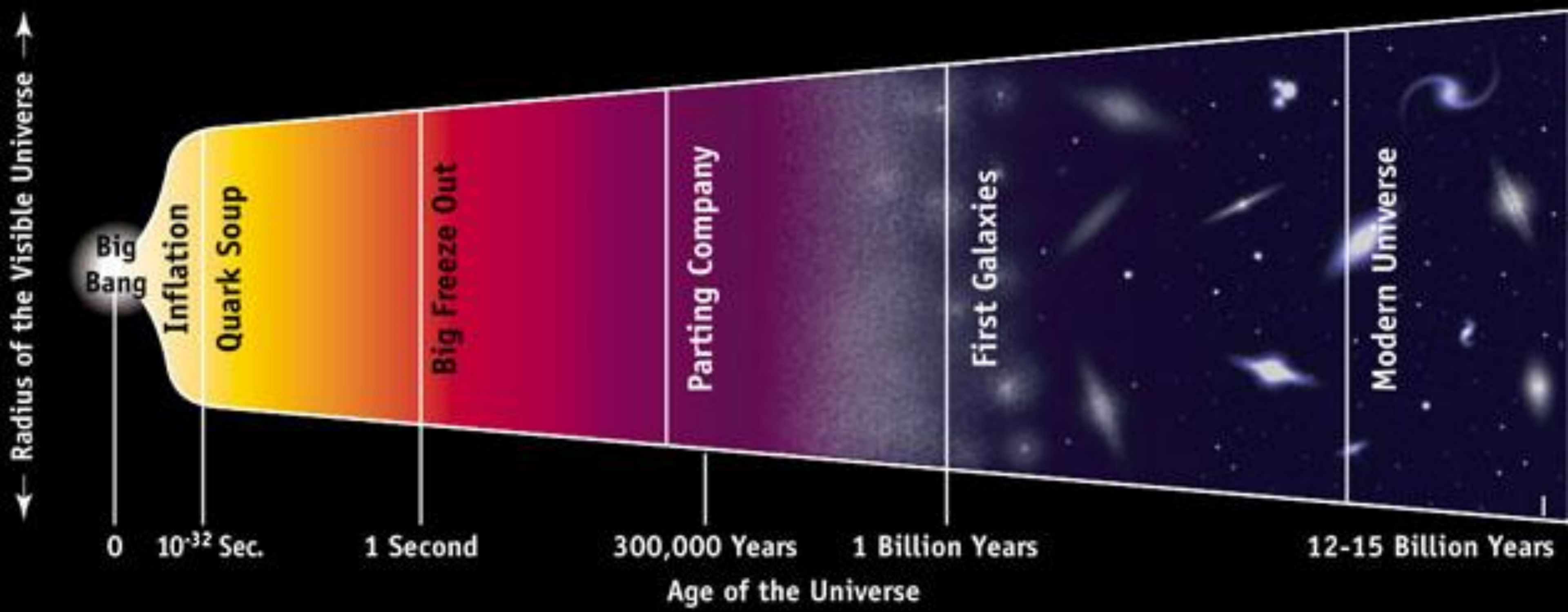
Blackbody radiation with a temperature of T = 2.73 K

Cosmic Microwave Background

CMB has small variations in temperature in different directions of only about 1 part in 10,000 indicating early 'inflation' of the universe

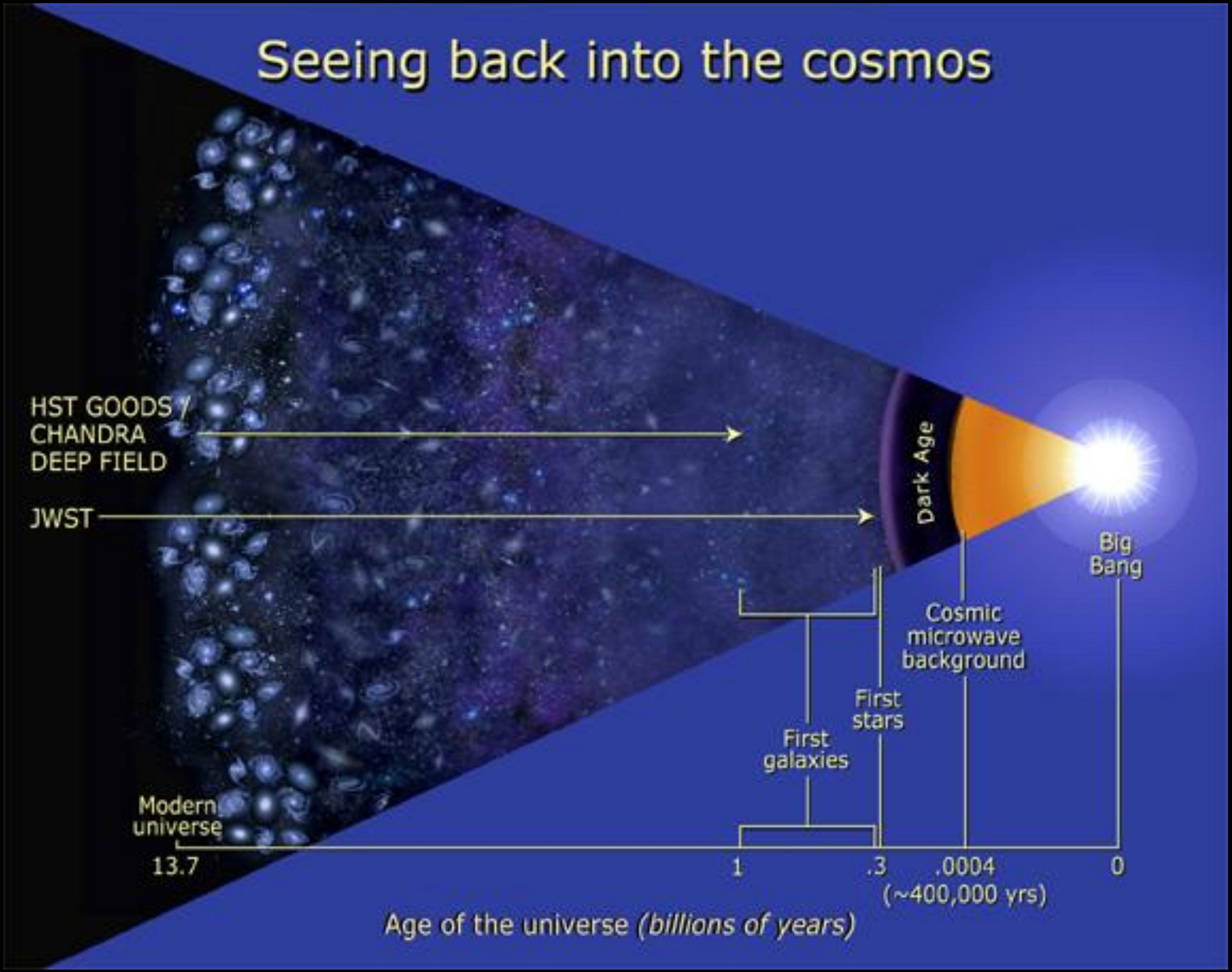


Inflation



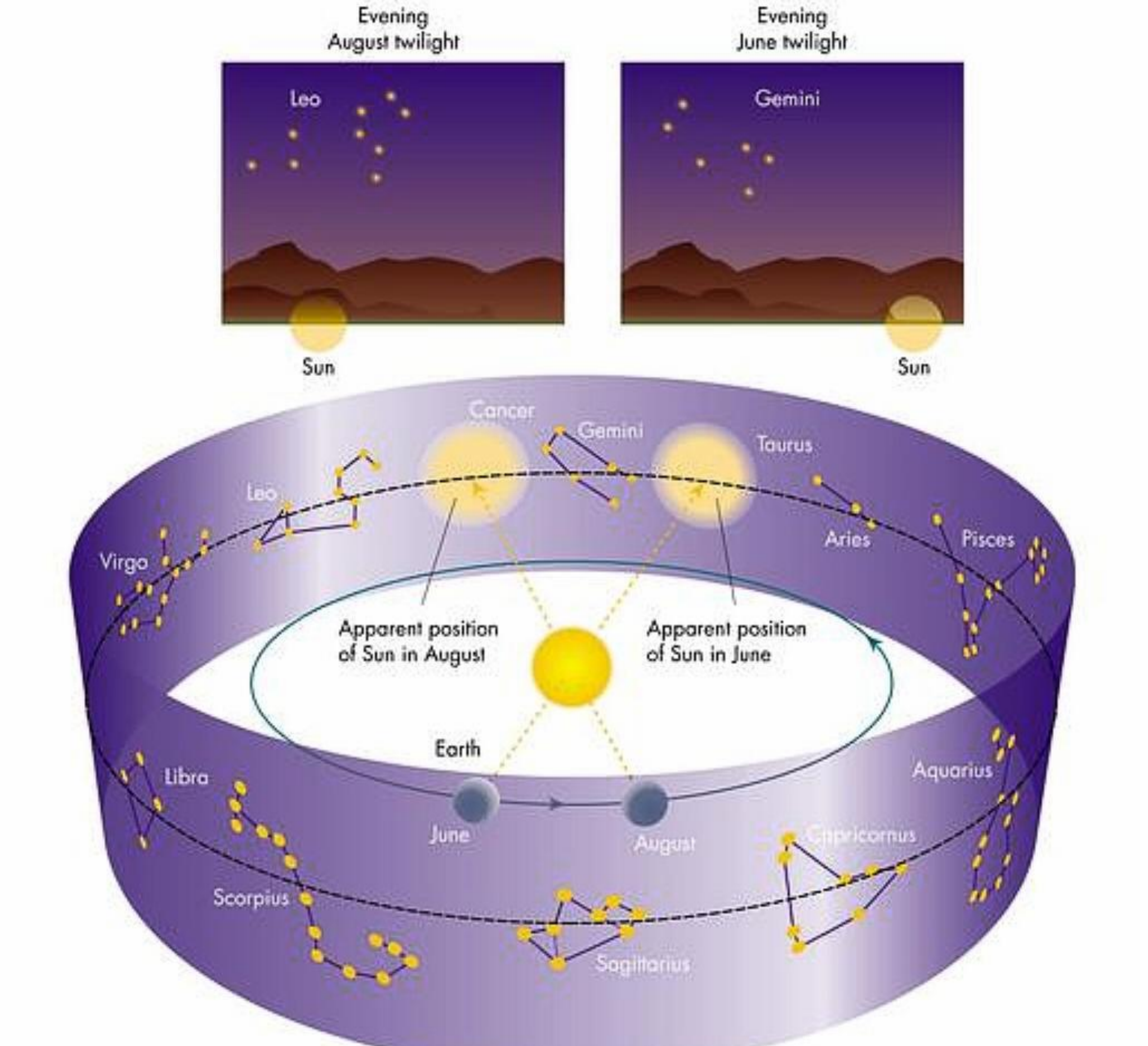
← Radius of the Visible Universe →
Big Bang
Inflation
Quark Soup
Big Freeze Out
Parting Company
First Galaxies
Modern Universe
0
10^{-32} Sec.
1 Second
300,000 Years
1 Billion Years
12-15 Billion Years
Age of the Universe

Inflation


Seeing back into the cosmos
HST GOODS / CHANDRA DEEP FIELD
JWST
Dark Age
Big Bang
Cosmic microwave background
First stars
First galaxies
Modern universe
13.7
1
.3
.0004
(~400,000 yrs)
0
Age of the universe (billions of years)

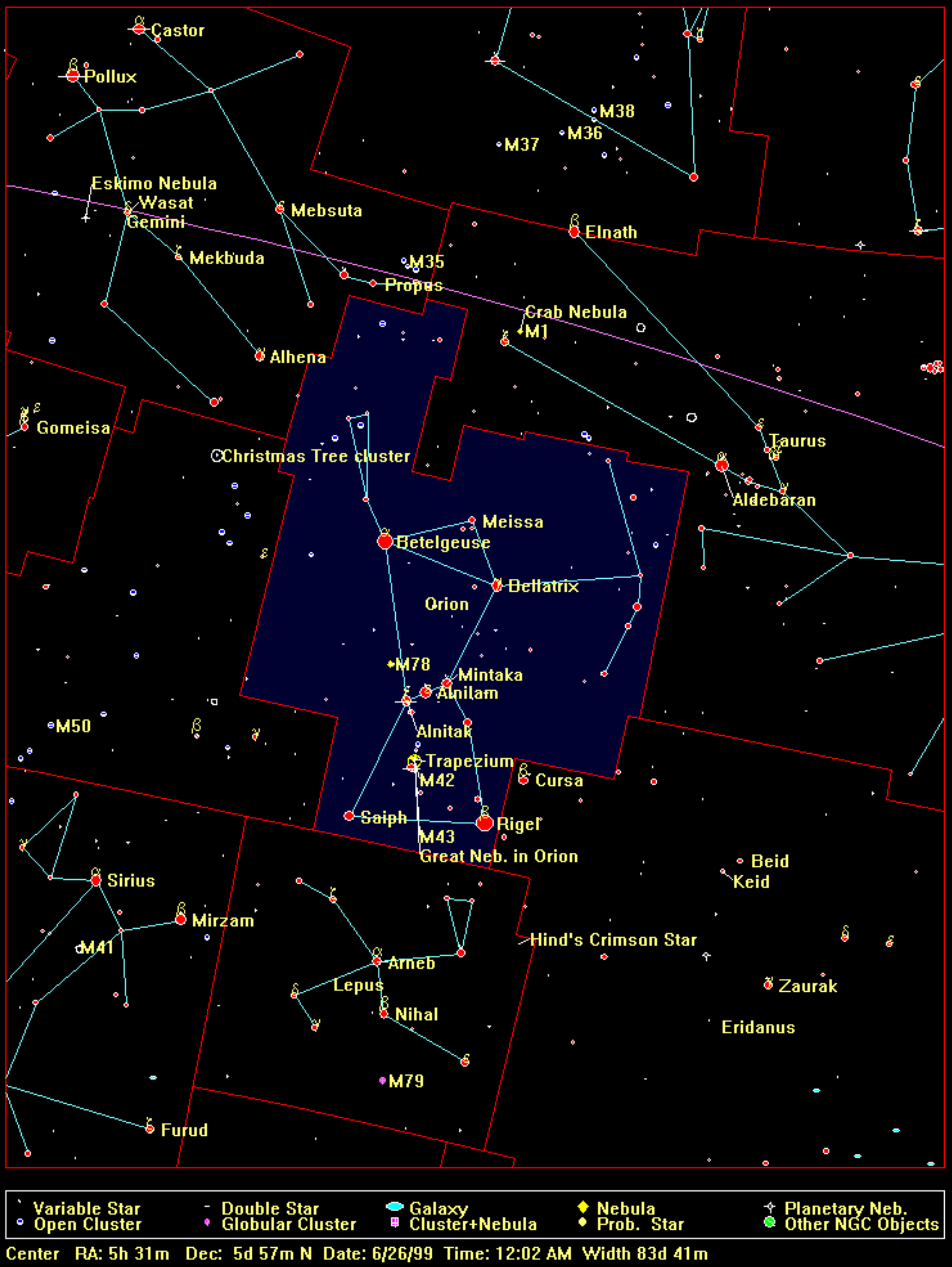
Observing

- Constellations
- Planets
- The Moon
- Stars (doubles etc.)
- Star Clusters
- Nebulae
- Galaxies
- Comets
- The Sun
- Eclipses (solar & lunar)
- Occultations
- Aurora
- Noctilucent clouds
- Satellites
- Spectra

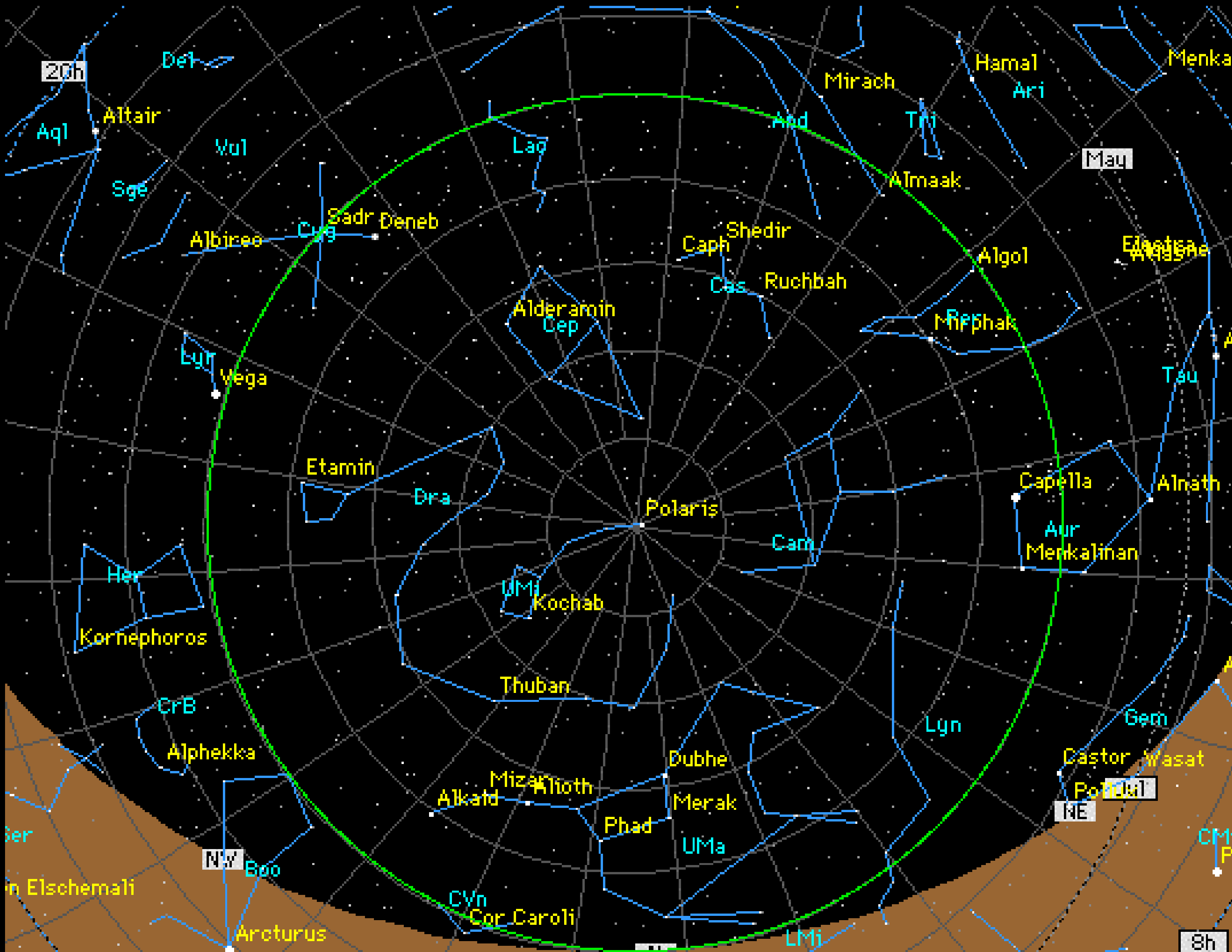


Evening
August twilight
Evening
June twilight
Leo
Gemini
Sun
Sun
Cancer
Gemini
Taurus
Leo
Aries
Pisces
Virgo
Apparent position
of Sun in August
Apparent position
of Sun in June
Earth
Libra
Aquarius
June
August
Capricornus
Scorpius
Sagittarius

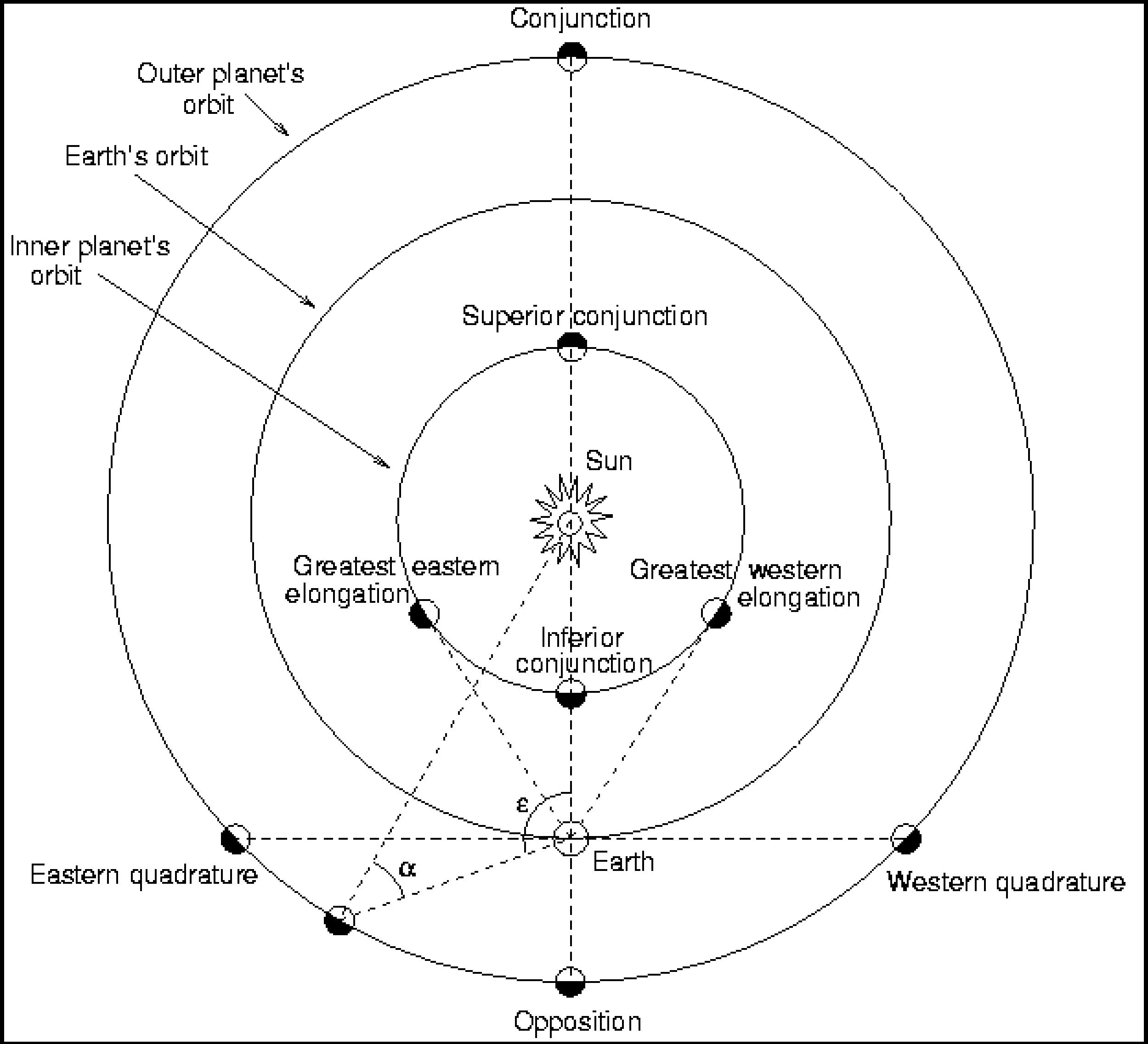
A **constellation** is one of 88 listed regions in the sky: like **Orion**.



Circumpolar Constellations

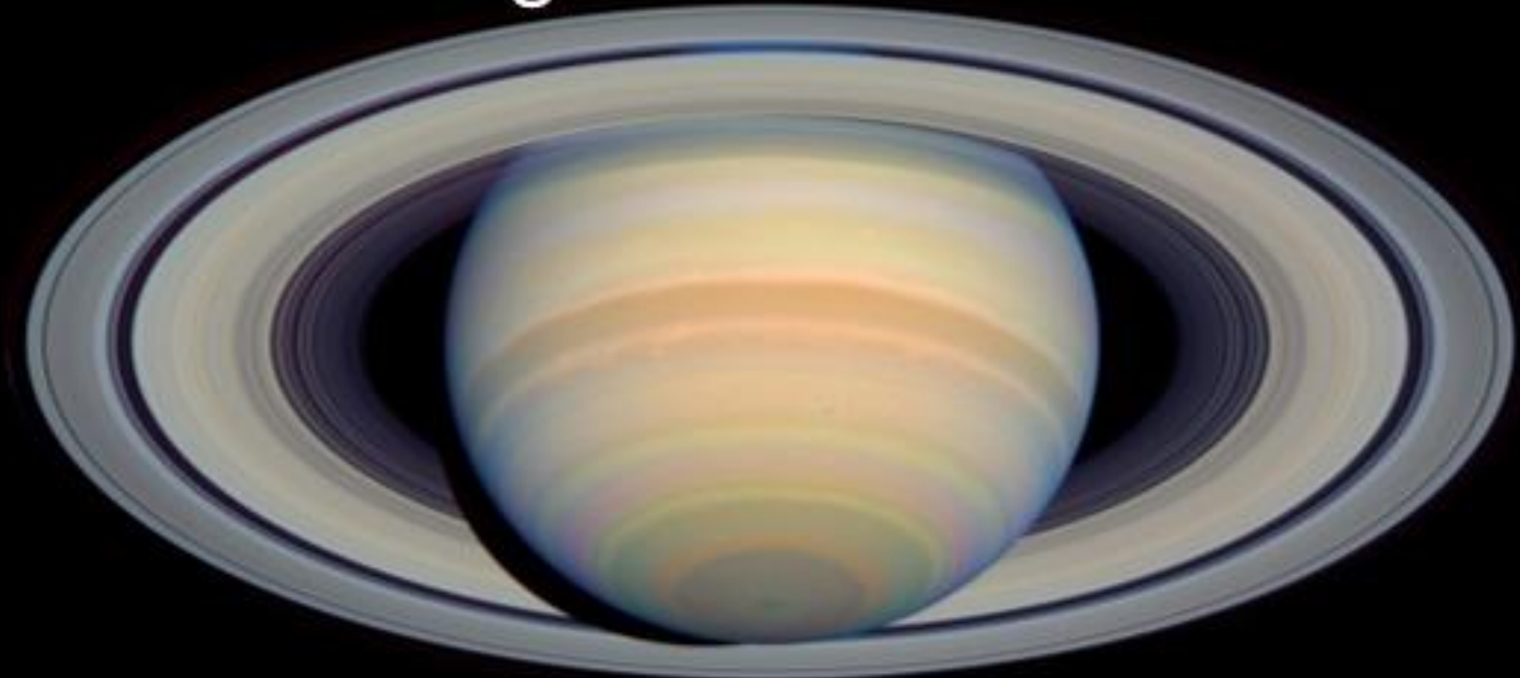


Planets - Inner and Outer



The four Galilean moons of Jupiter.

Magnificent Saturn



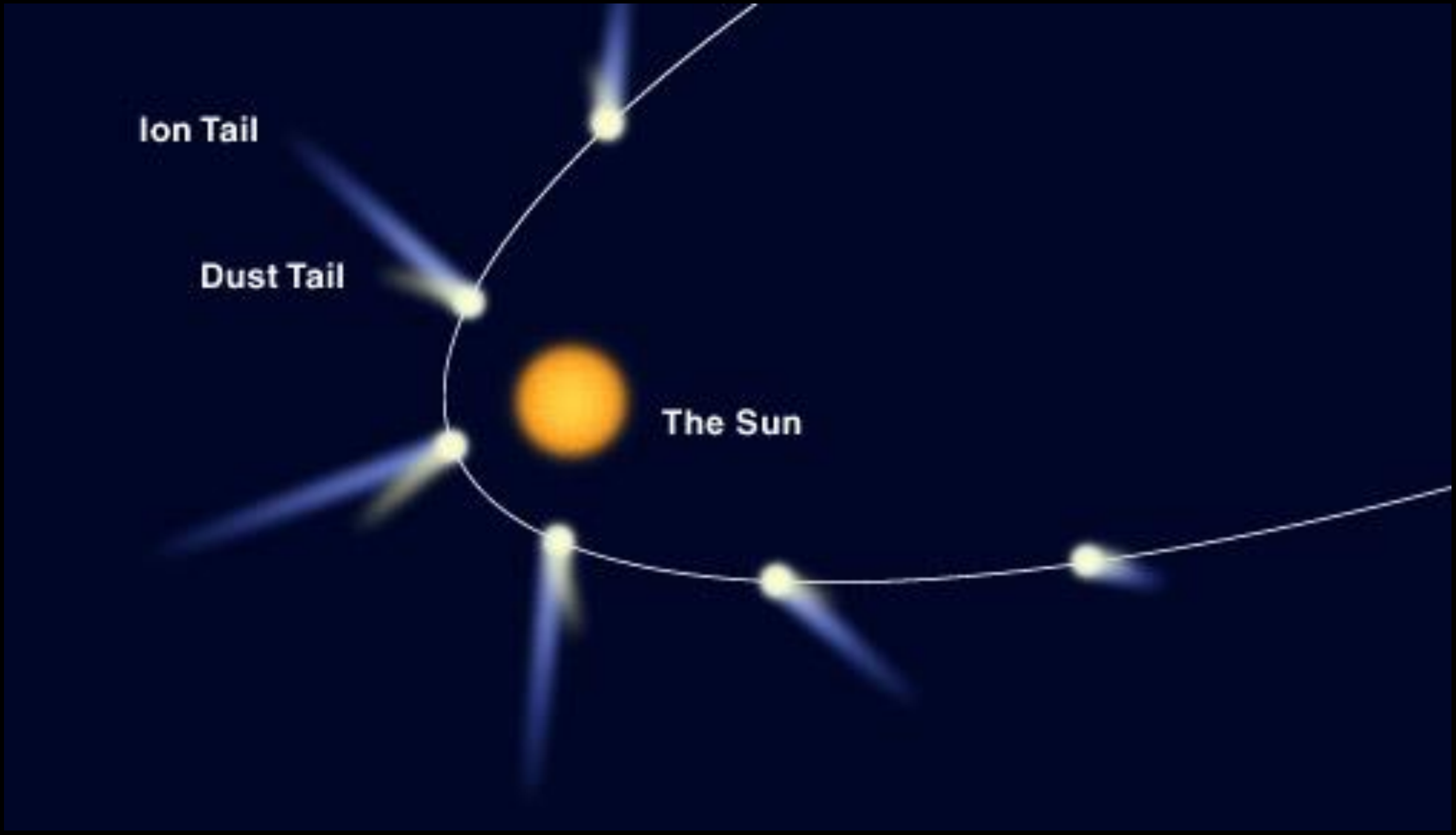
Hubble Space Telescope

‘Our’ Moon

Galileo found mountains on the moon and calculated their height from the shadows they cast.

Comets

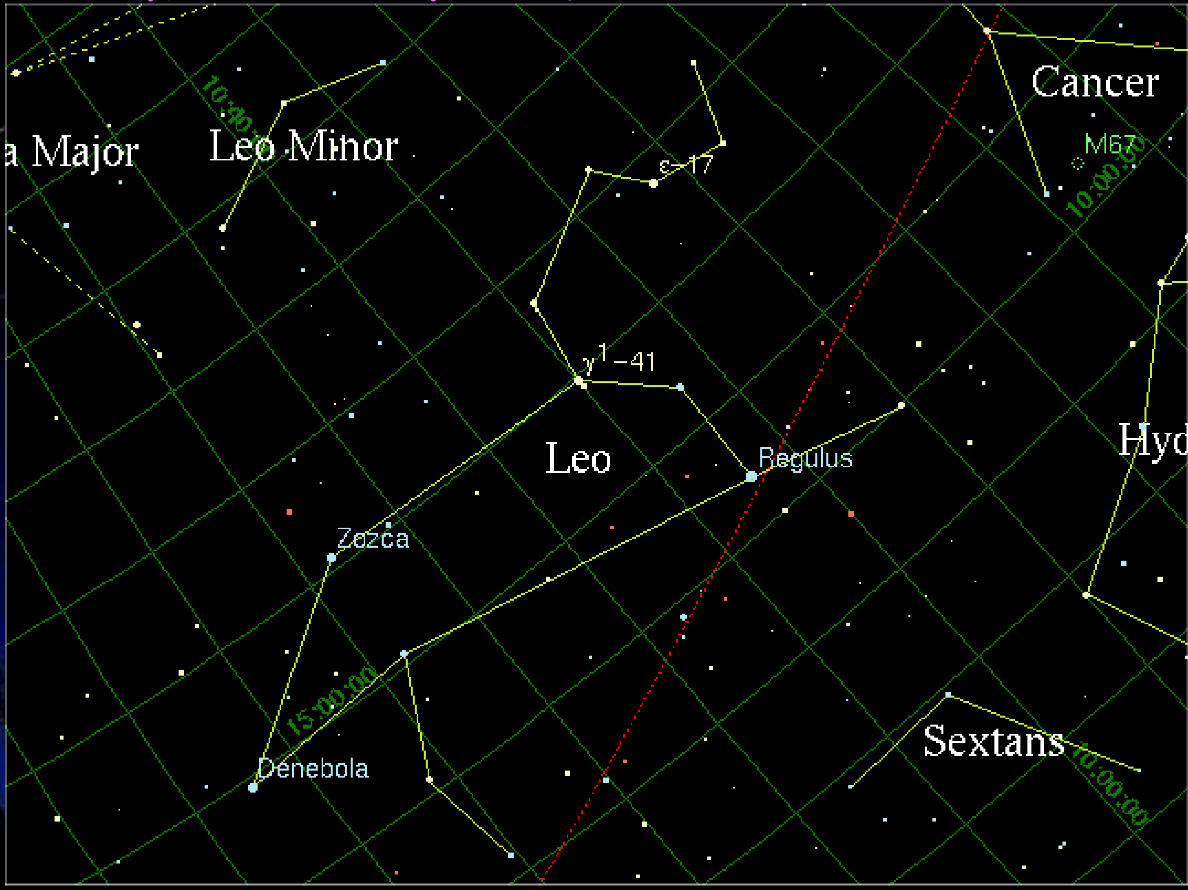
We see the **ion tail**, a veil of evaporated ions swept back by the solar wind - always pointing away from the sun.
A **dust tail**, visible mainly in the infrared, is left in its wake.



Comet Hale-Bopp

Comet debris left in the path of earth's orbit creates a **meteor shower** at a regular time each year

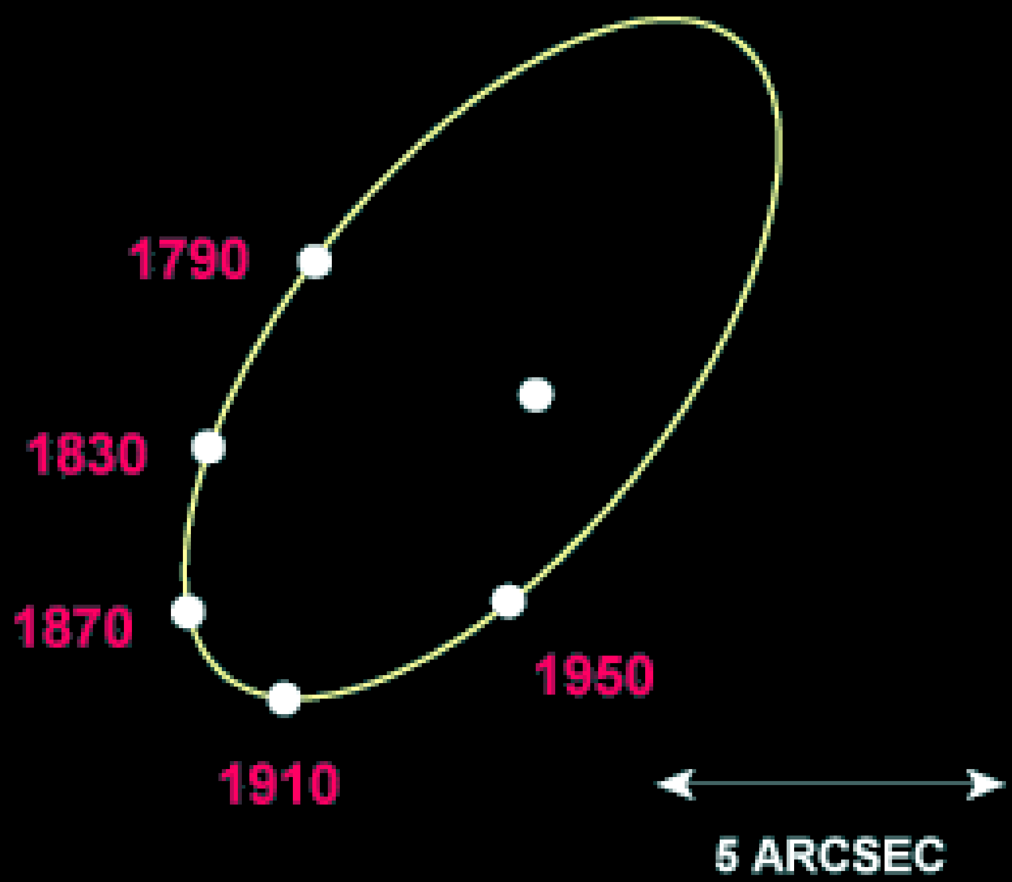
E.g. The comet Tempel-Tuttle creates the Leonids shower- from constellation Leo in mid-November.



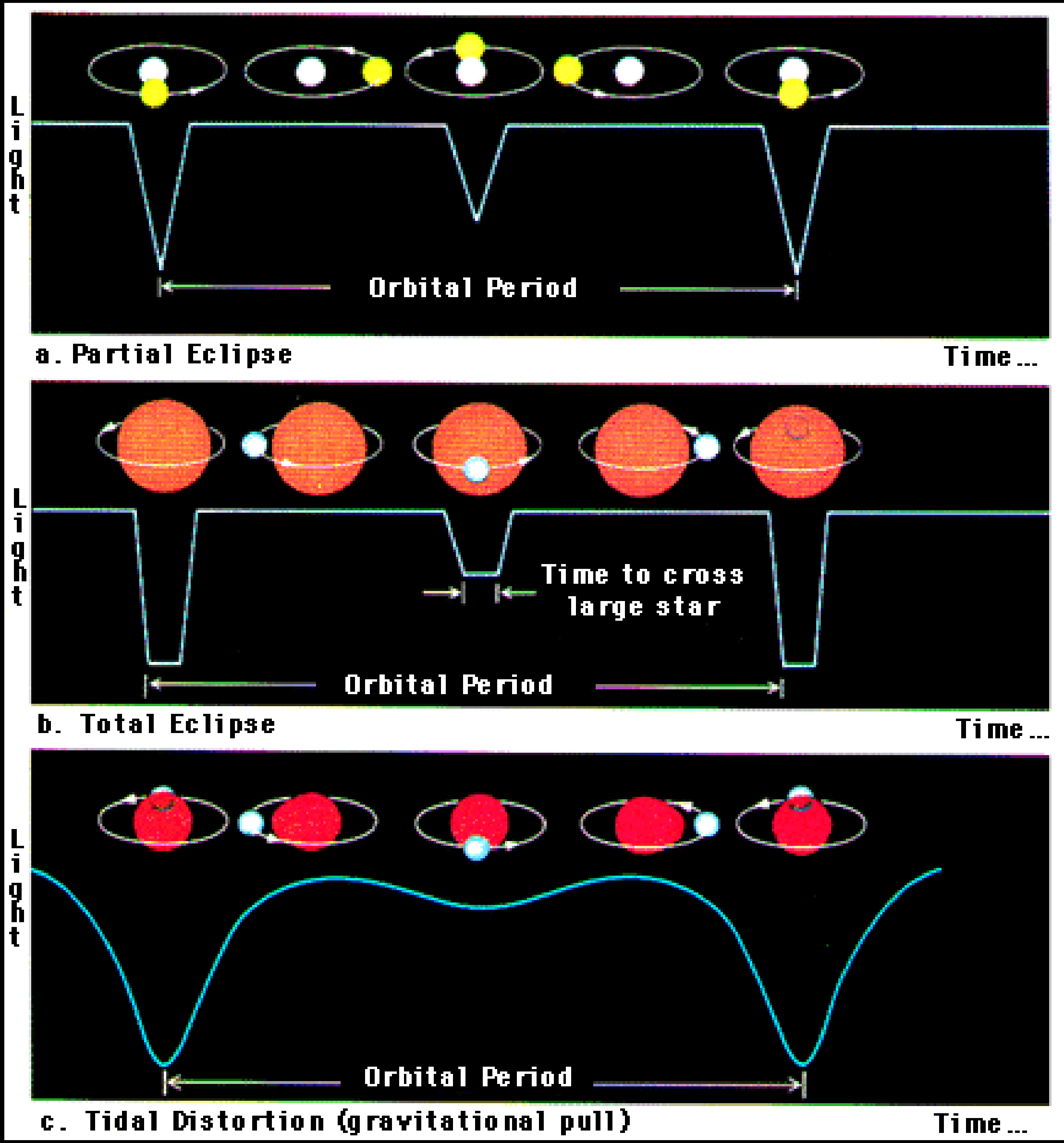
Albireo, an optical double star

Optical double - a false binary - two stars not bound together; one at a greater distance.

Visual binary star



Castor in Gemini: a visual binary



Eclipsing Binary Star

One star eclipses another - two dips in the light curve.

Open Star Cluster

Open Clusters: less than 1,000 young stars, composed of recycled material with heavy elements.
Not gravitationally bound.

E.g The Pleiades and The Hyades.

Globular Cluster

Thousands to millions of stars in a spherical bound group.

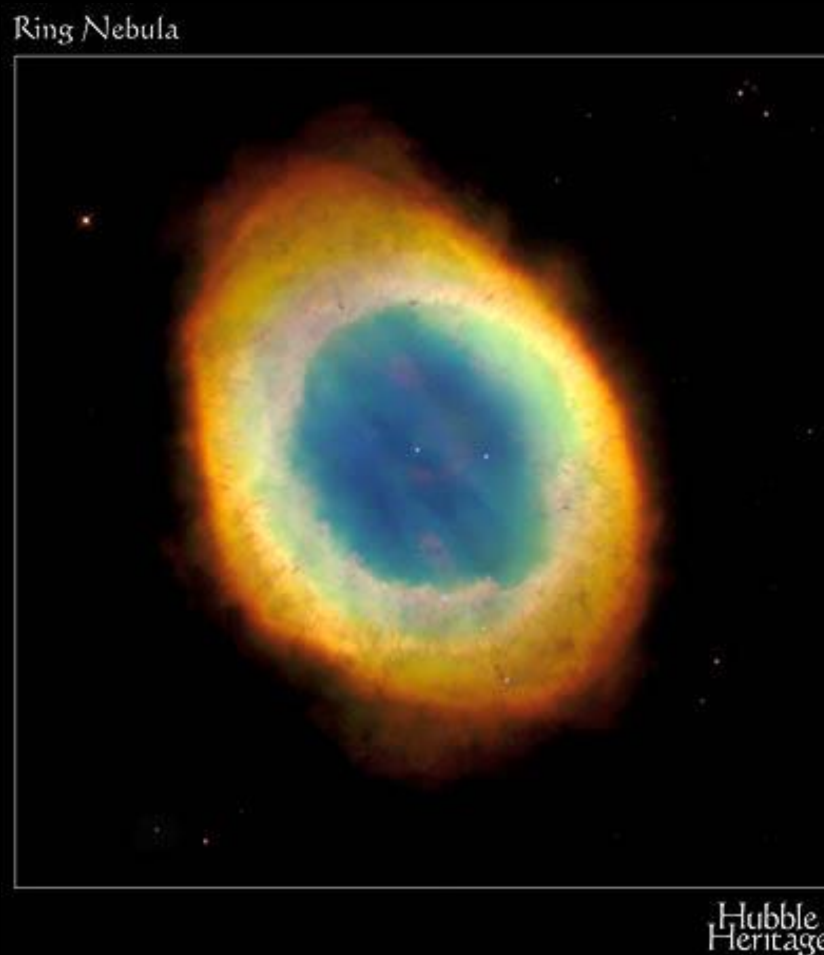
Stars made of primordial H and He.
Over 12 billion years old.
Stars have small mass.

E.g. Globular cluster in Hercules, M13

Orion Nebula - a stellar nursery

Planetary Nebula

Stars starting with less than about 2 M_{sun} finish burning to carbon, become unstable as they burn H and He in a shell and blow off 10-20% of their mass, becoming a **planetary nebula**, glowing because they are ionized by the hot UV core.



Andromeda Galaxy

Observing

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- The Sun
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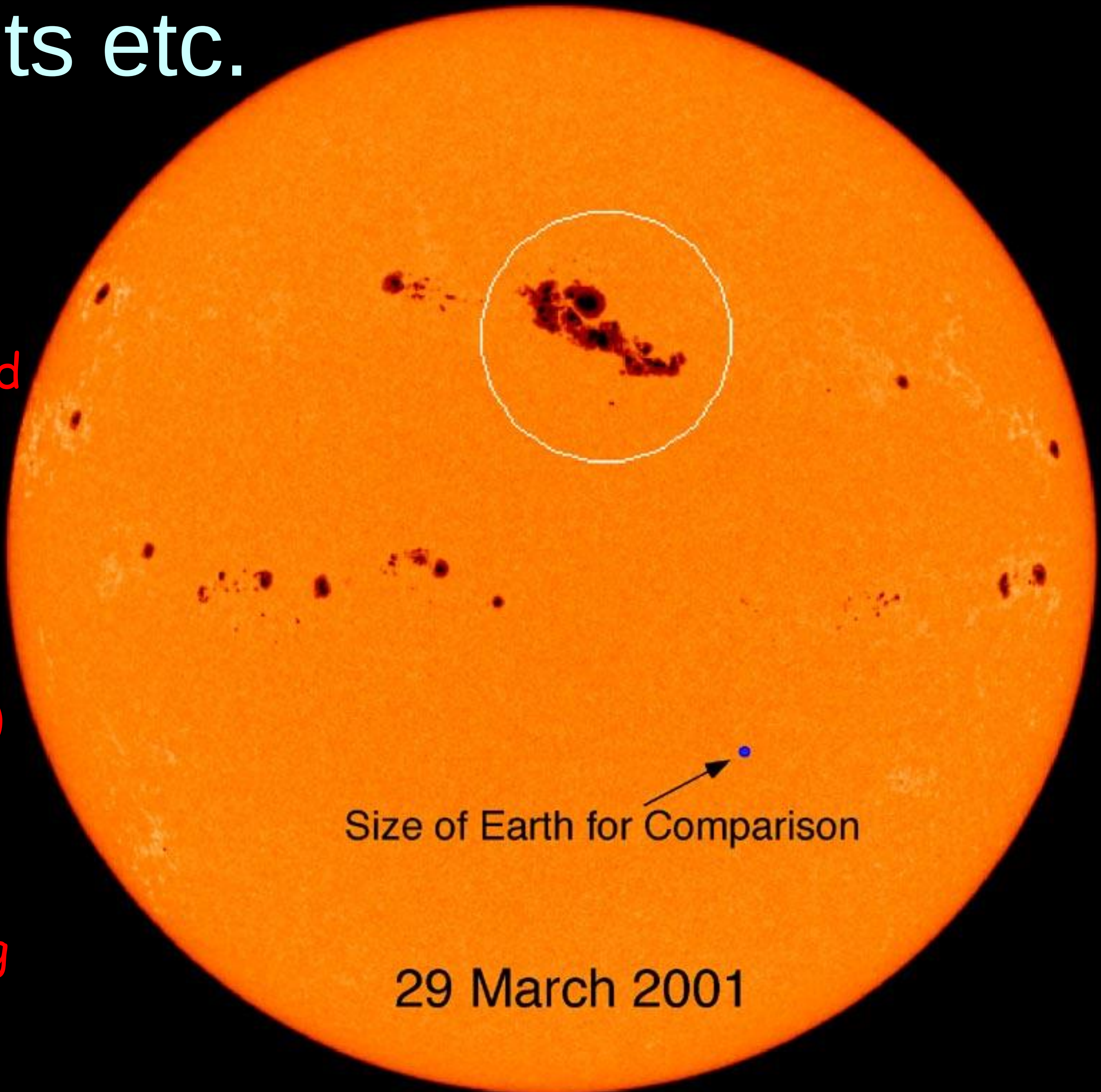
- Spectra

Sunspots etc.

NEVER try observing the sun directly with a standard telescope, binoculars etc. (Blindness and/or equipment damage result)

ONLY use specialised solar observing equipment



Lunar Eclipse

Solar Eclipse

Aurora

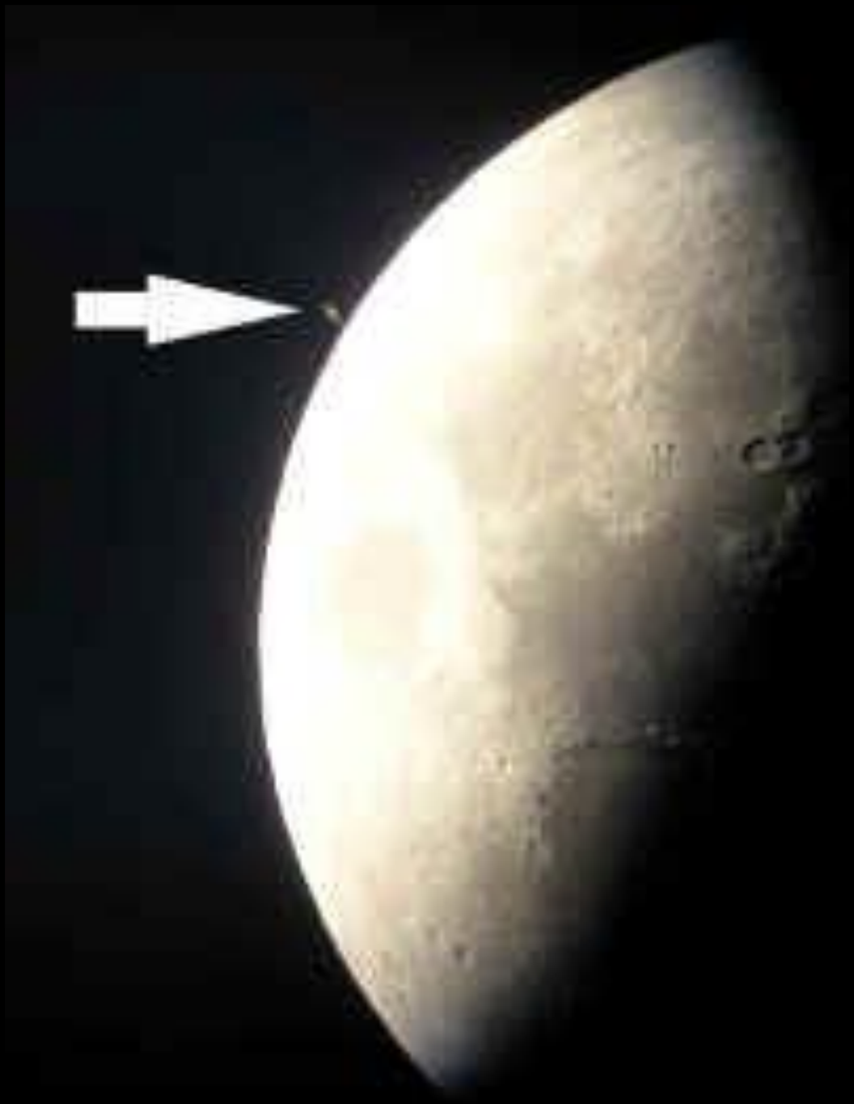
©1995 Dick Hutchinson

Aurora: Northern and Southern lights:
  Aurora Borealis and Australialis (Australis)
Caused by solar wind hitting earth's magnetic field

Occultations

Lunar Occultation Of Saturn, 22 May 2007

Martin Cook



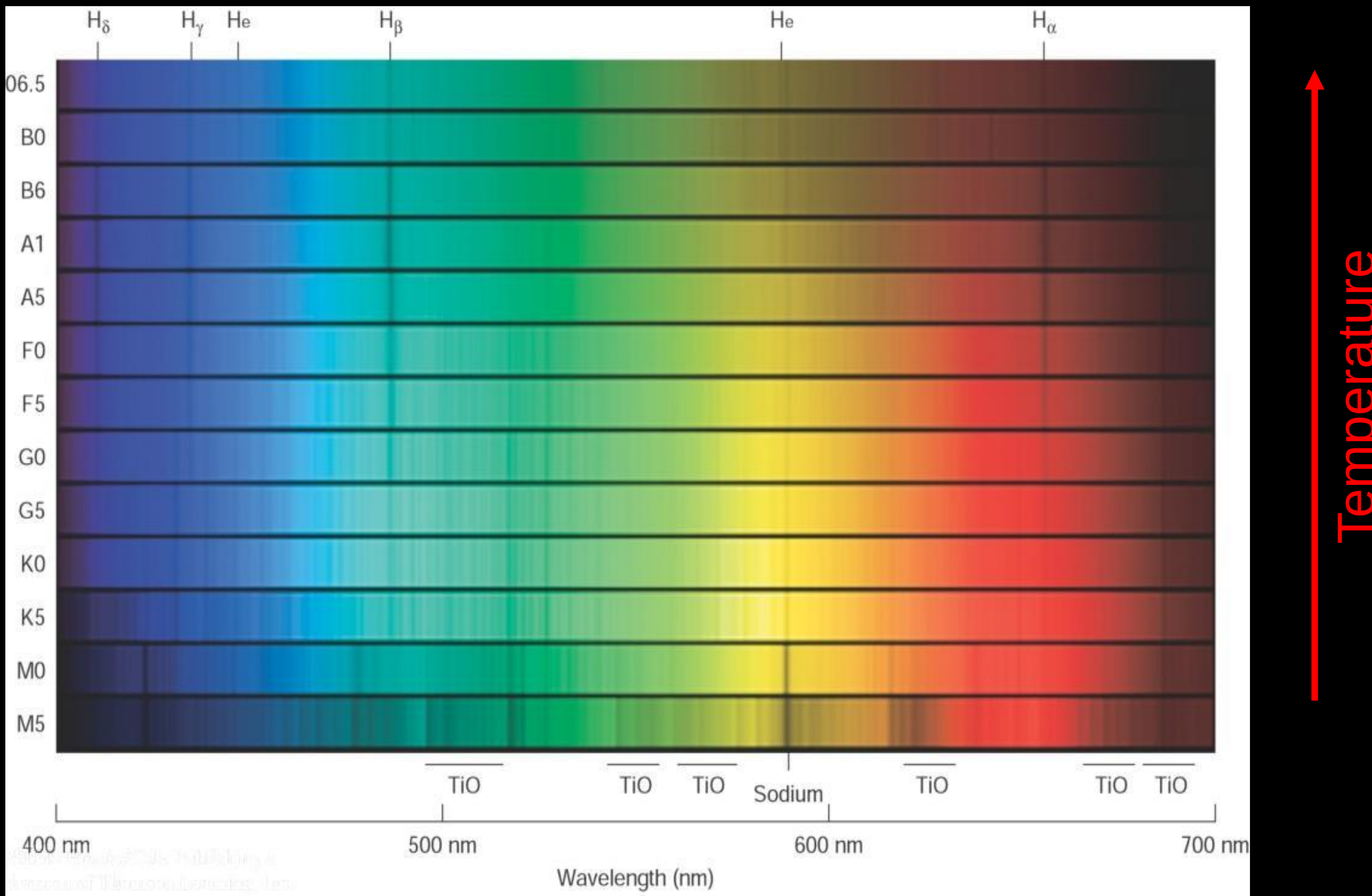
Noctilucent Clouds

Mike Harlow observing from Newbourne

08 July 1997

Spectra of Stars

Different types of stars show different characteristic sets of absorption lines.

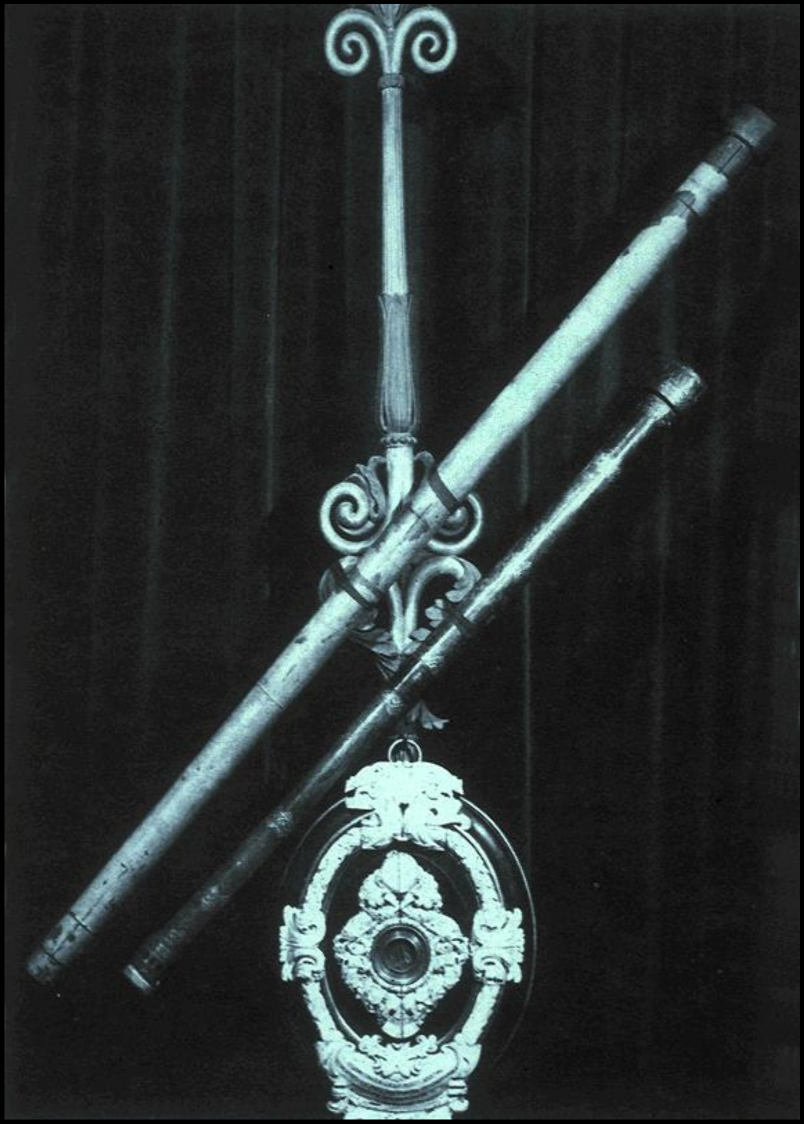


Telescopes

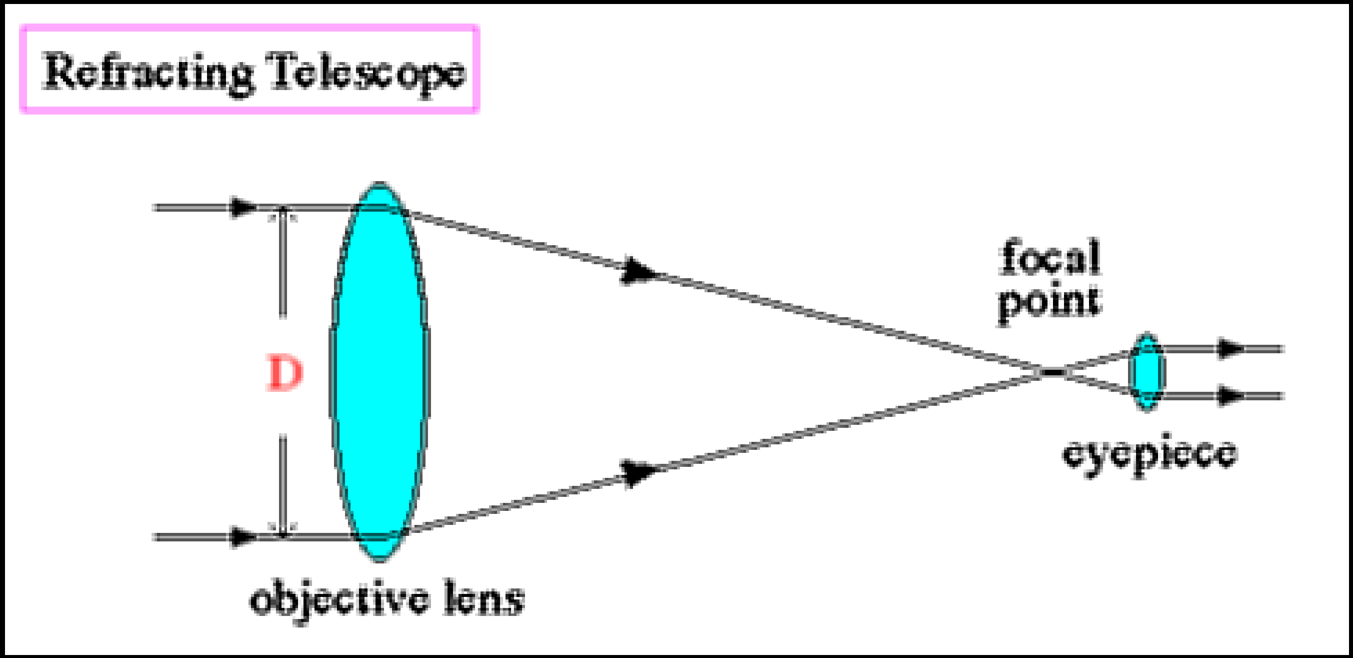
- Types of telescopes:
  - Refractors and Reflectors
- How good is your telescope?
  - Light gathering power
  - Resolving power
  - Magnifying power
- Choosing a telescope

Refracting Telescope

Galileo’s Refractor 1609



Refracting telescope: A large **objective** lens focuses an image and a small **eyepiece** lens magnifies it. The final image is inverted.

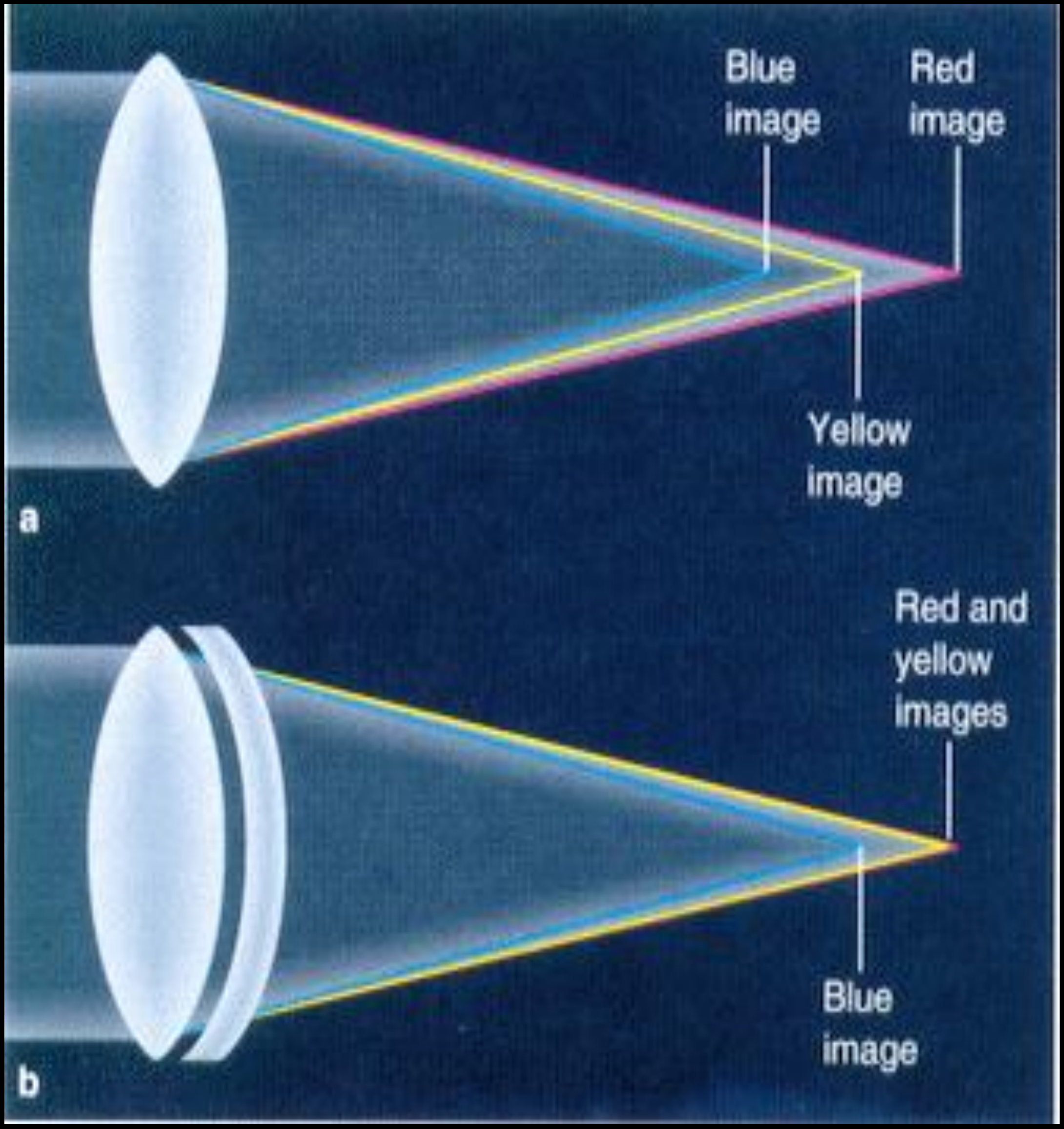


Distance between lenses is a the sum of the two focal lengths.

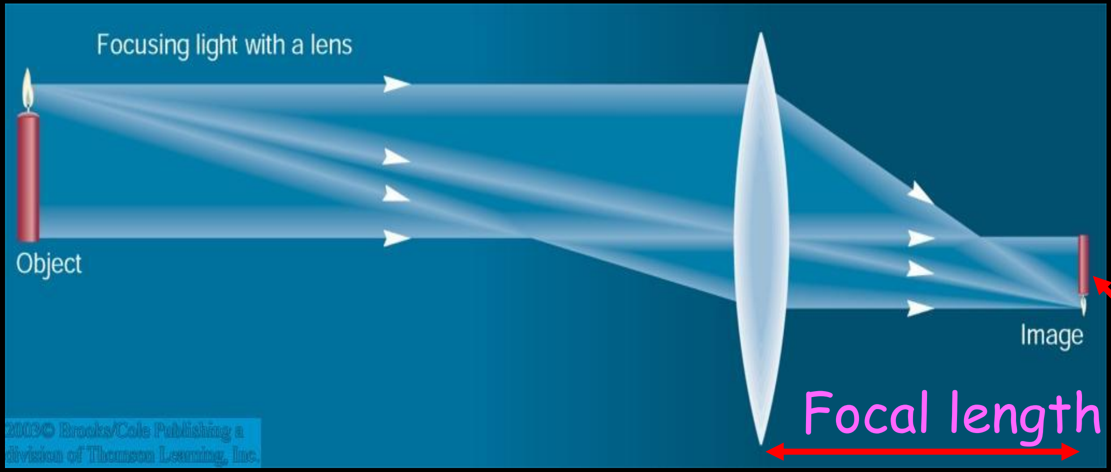
Magnification is the ratio of the focal lengths: F1/F2

Problem:
Different colors refract by different angles:
lenses suffer from **chromatic aberration**.

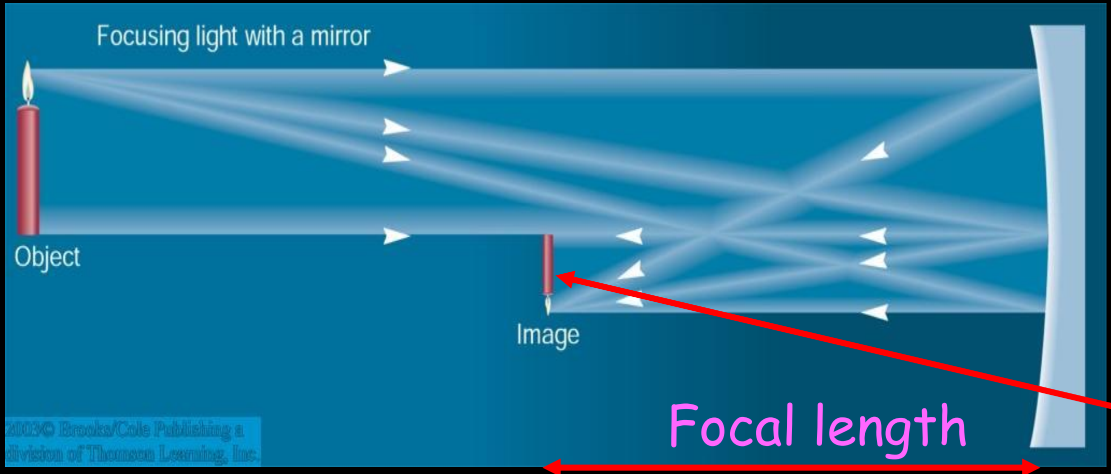
Solution:
Combine two types of glass:
Reduces chromatic aberration
(but only exactly cancels for two colours)



Refracting/Reflecting Telescopes



Refracting Telescope: *Lens* focuses light onto the focal plane



Reflecting Telescope: Concave *Mirror* focuses light onto the focal plane

Almost all big (professional) modern telescopes are reflecting telescopes.

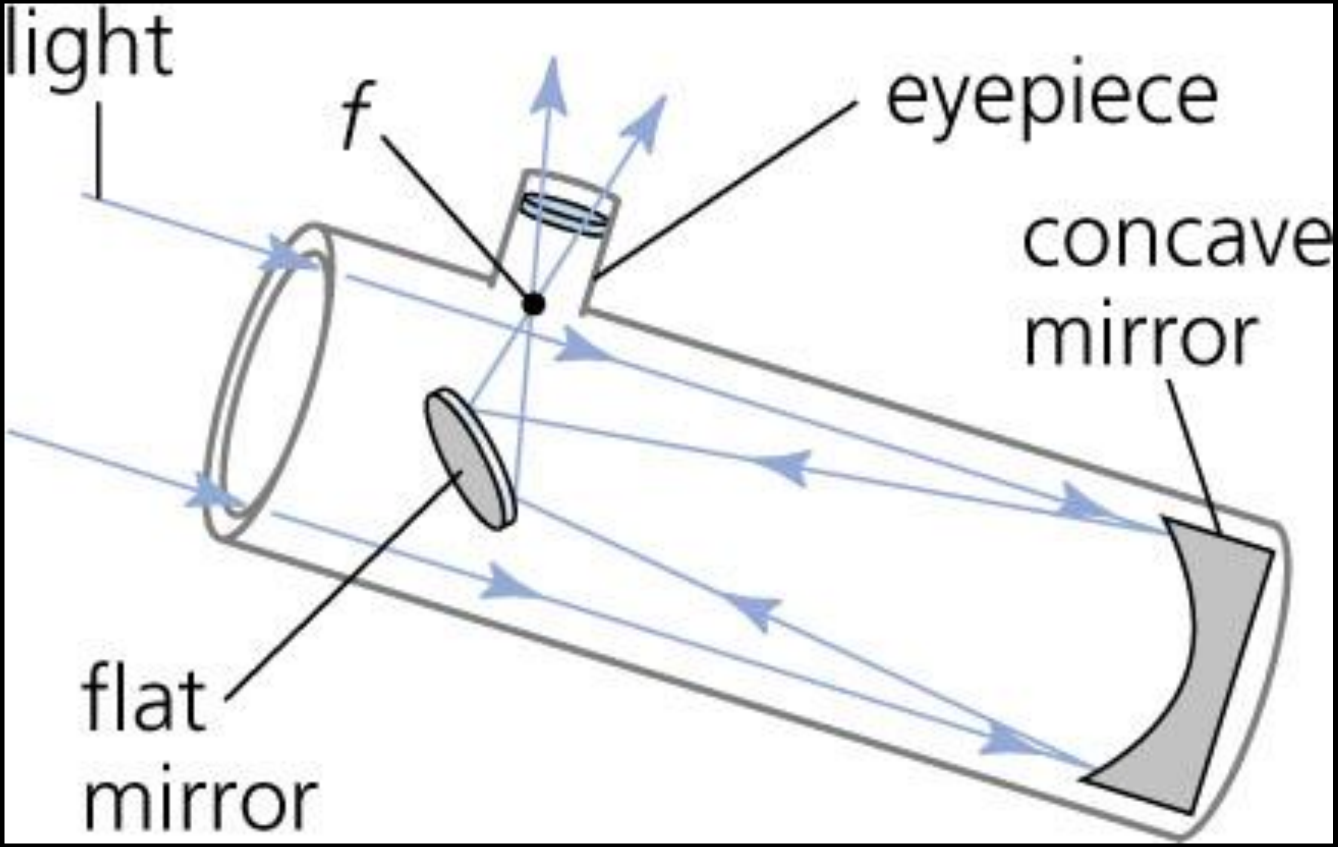
Isaac Newton's Reflecting Telescope

Reflecting Telescope:

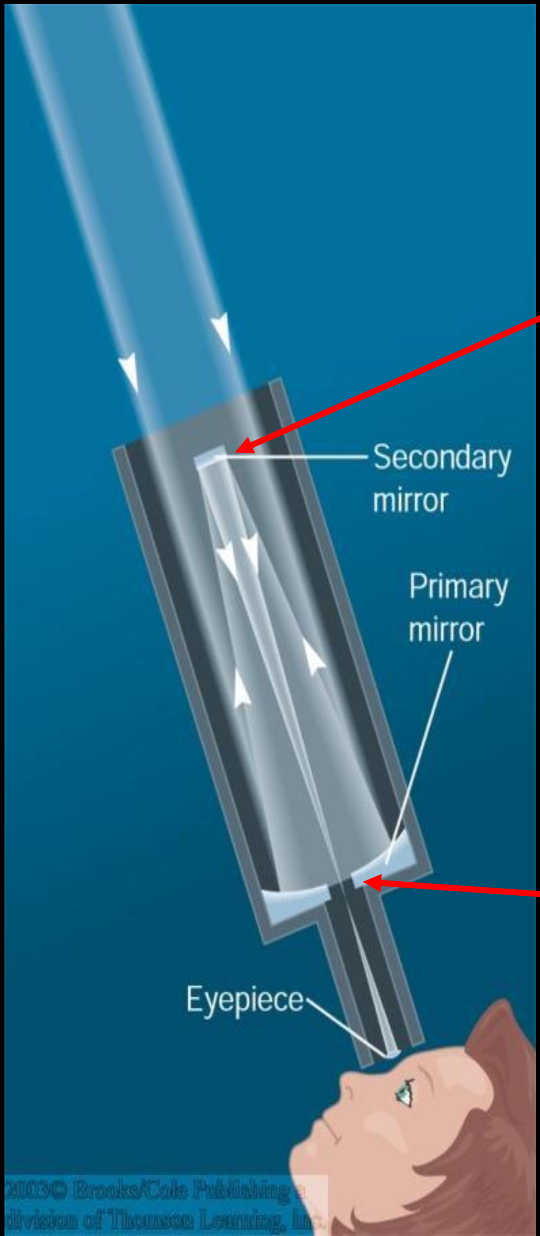
A large curved **objective** mirror focuses an image, a small **eyepiece** lens magnifies it.

The image is inverted.

Example: Newtonian telescope:



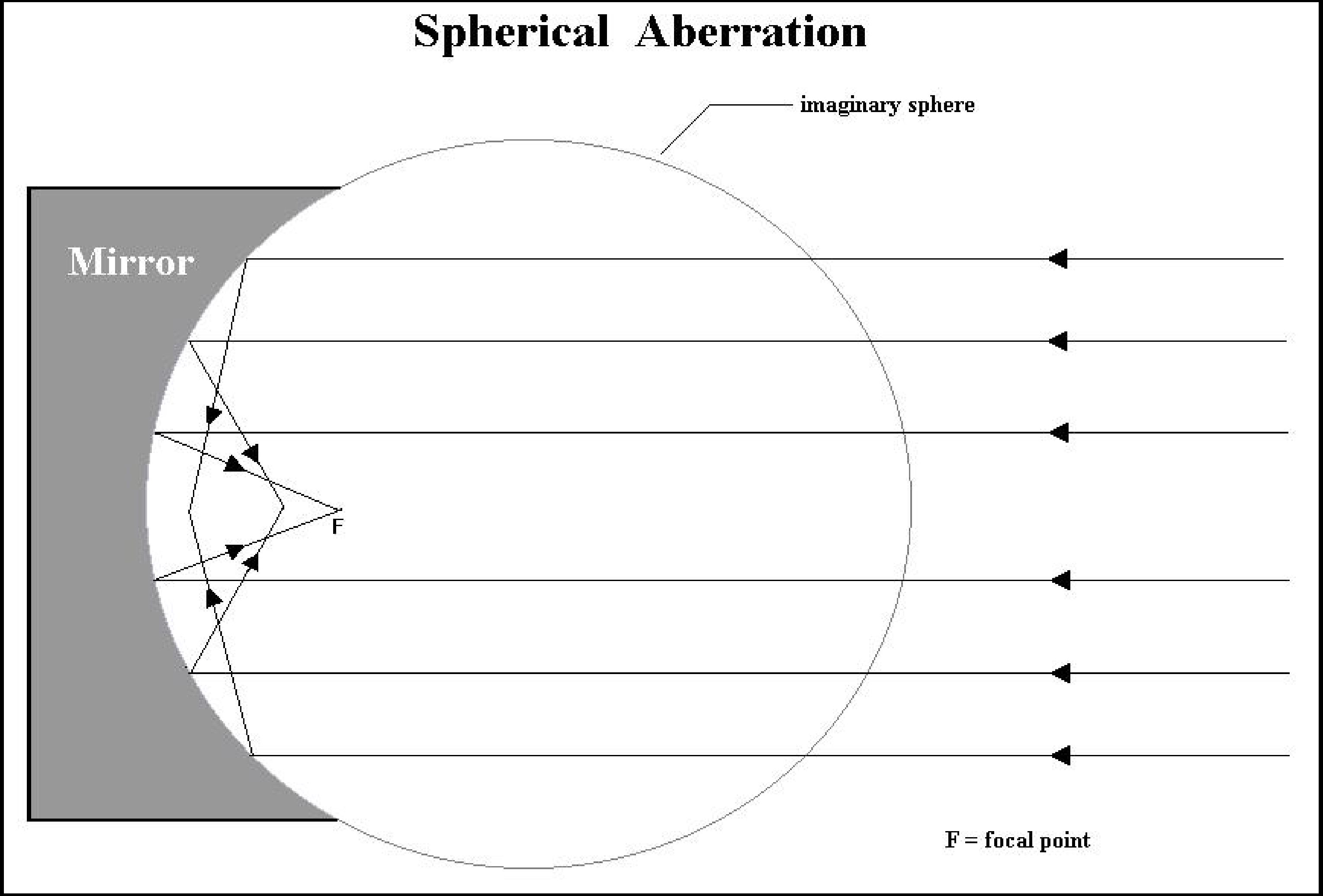
Cassegrain reflector



Secondary mirror, to re-direct light path towards back of telescope

Hole in primary mirror

Mirrors do not suffer chromatic abberation, but a spherical mirror does suffer **spherical abberation.**
There are various solutions to this.



Reflecting Telescope with a correction plate to correct spherical abberation (Schmidt-Newtonian)

Meade Model SN-8 - 8" f/4 Schmidt-Newtonian Telescope. The telescope is supplied as standard equipment with all of the features shown, including optical tube assembly, equatorial mounting, Autostar control system, Super Plössl 26mm eyepiece, and 6 x 30mm viewfinder.

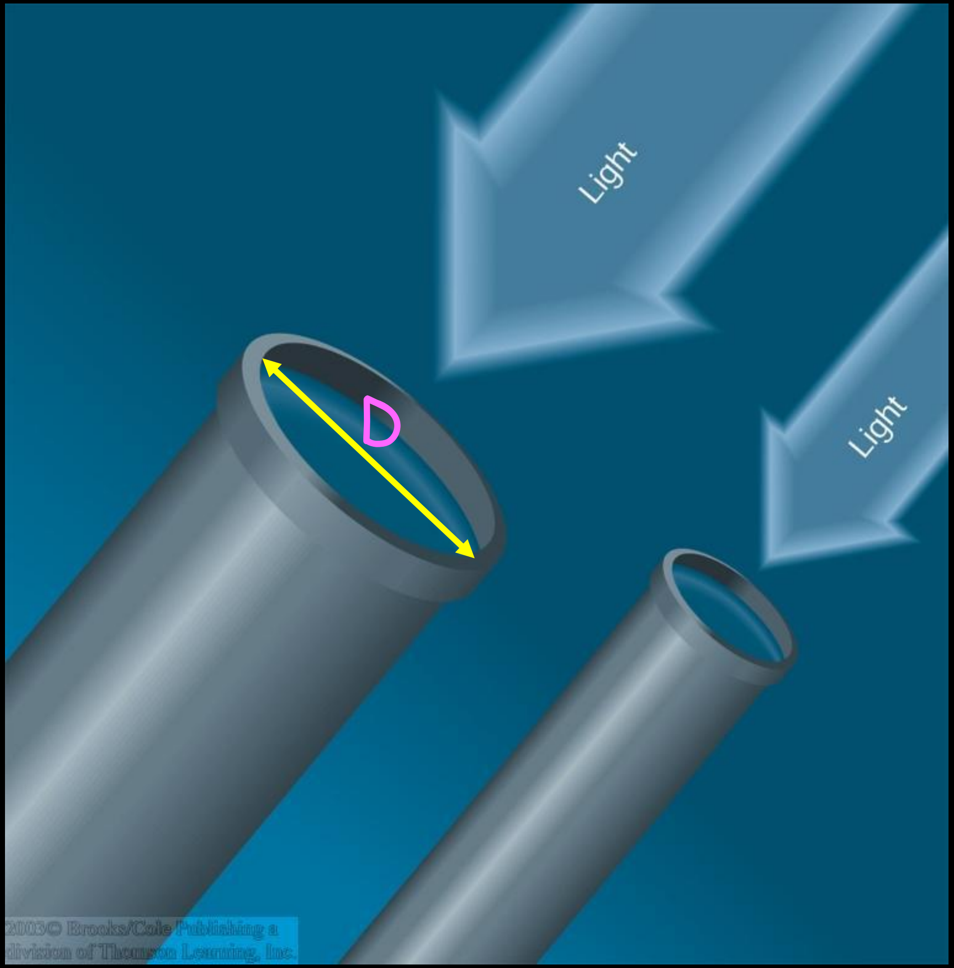
SPECIFICATIONS: Models SN-6, SN-8, and SN-10 Schmidt-Newtonian Telescopes - Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with MgF2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally); quick-release cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXD55 German-type equatorial mount with worm gear drives and electric slow- motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. #497 Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12v DC auto cigarette lighter plug or from 115v AC home outlet; operating instructions.

Light-Gathering Power

Light-gathering power:

Depends on the surface area A of the primary lens / mirror, proportional to diameter squared:

$$A = \pi D^2/4$$



Resolving Power

Resolving power:

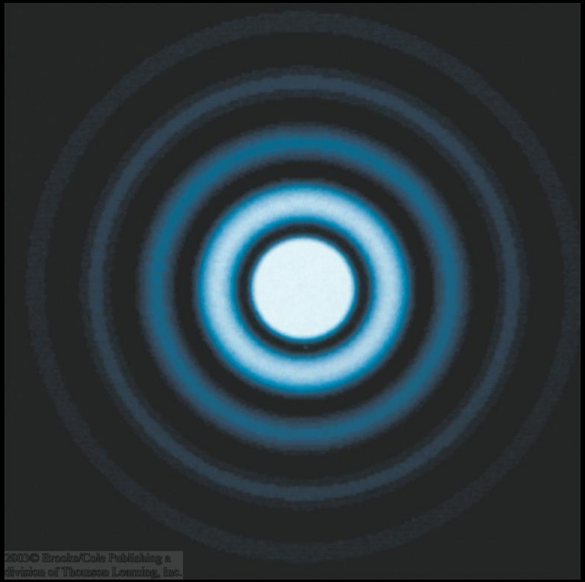
Wave nature of light => The telescope aperture produces fringe rings that set a limit to the resolution of the telescope.

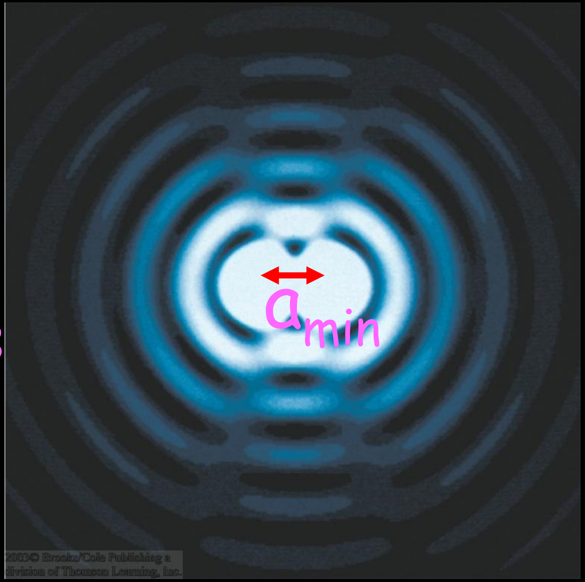
Resolving power = minimum angular distance a_{min} between two objects that can be separated.

$$a_{min} = 1.22\ (l/D)$$

For optical wavelengths, this gives

$$a_{min} = 11.6\ \text{arcsec} / D[\text{cm}]$$





Magnifying Power

Magnifying Power = ability of the telescope to make the image appear bigger.

The magnification is the ratio of focal lengths of the primary mirror/lens and the eyepiece:

$$M = F_{objective}/F_{eyepiece}$$

A larger magnification does not improve the resolving power of the telescope! Things just get bigger, blurrier and dimmer!

Seeing

Weather conditions and turbulence in the atmosphere set further limits to the quality of astronomical images

Acknowledgements

- Most of these slides are adapted from ones downloaded from the Internet. My grateful thanks to those who so generously put them up there, particularly:

- Astronomy Lectures on Power Point: Perspectives on the Universe Dr. Philip Petersen, Solano College professor: http://www.empyreanquest.com/perspectives.htm
- Ken Broun Jr., Associate Professor Math, Physics and Astronomy, Tidewater Community College, Virginia Beach Campus: http://www.tcc.edu/faculty/webpages/KBroun/PowerPoint%20Slides%20Contents.htm
- and http://science.pppst.com/telescope.html

Choosing a telescope

- Telescopes 101