Beginners Workshop Part 2

Mike Whybray

- The Big Bang (again)
- The Solar System
- Motions of the Earth and Planets
- Constellations and Naming of Stars
- Magnitudes (Apparent Brightness)
- Stellar Evolution (overview!)
- The Celestial Sphere
- Choosing a Telescope

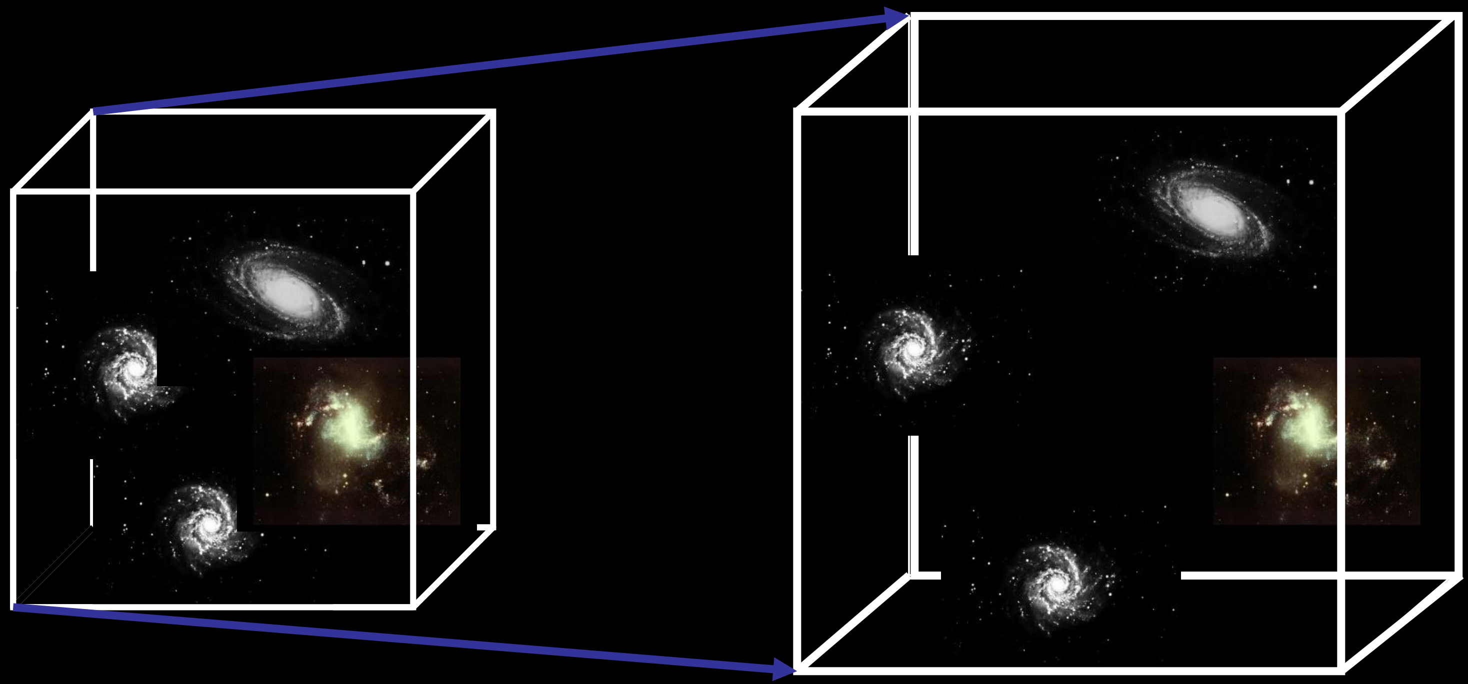
Big Bang or Steady State?

- Fred Hoyle championed the Steady State theory: that the universe has always existed and has no beginning or end.
- He coined the disparaging term 'Big Bang' for the alternative theory: that the universe began at a fixed time in the past

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!

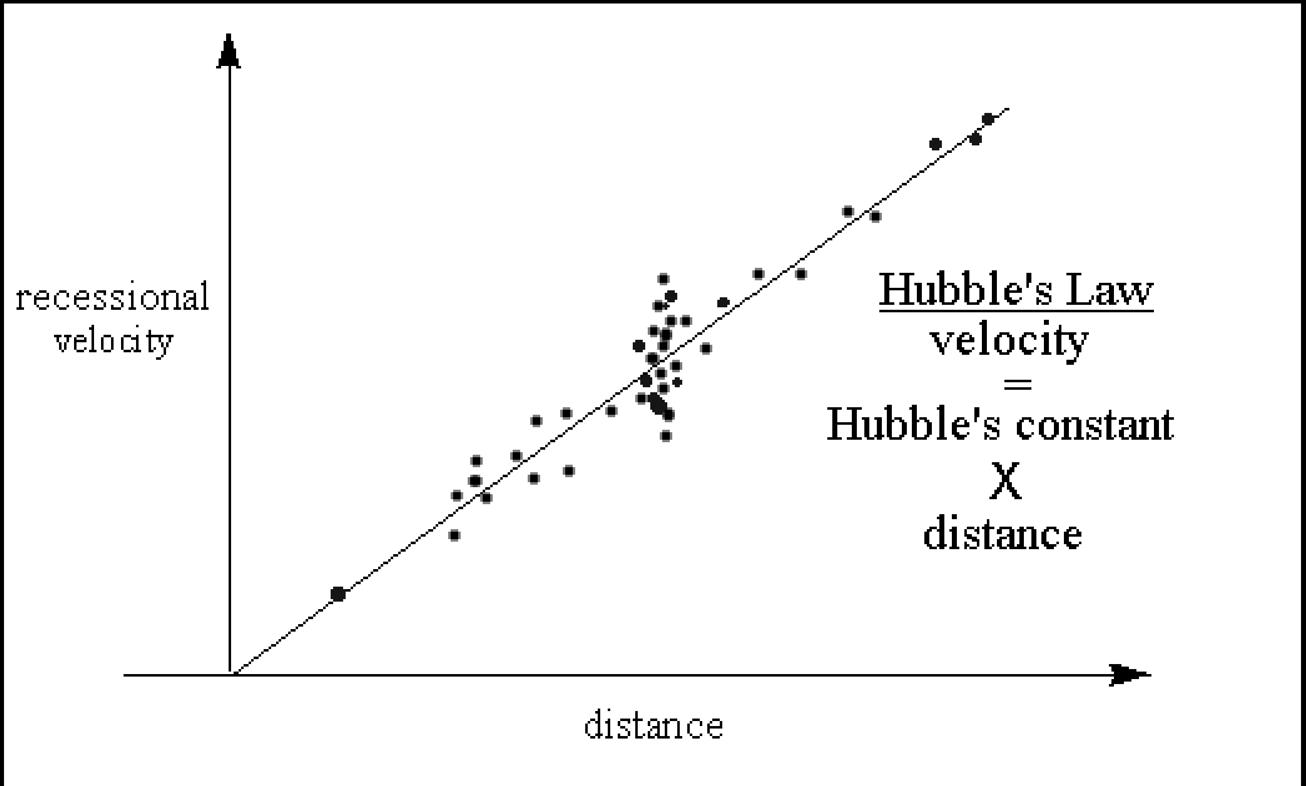


The galaxies themselves are not expanding

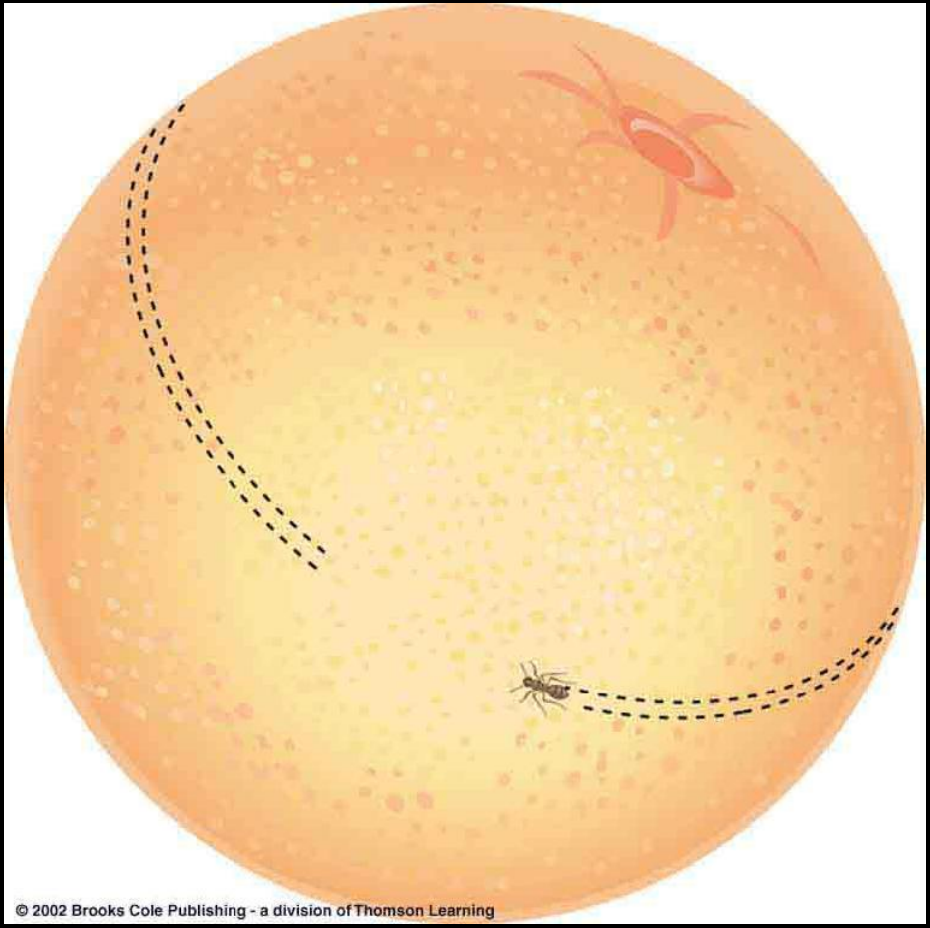
Hubble's Law

(At the present time) the velocity of receding galaxies is given by **Hubble's Law**:
Velocity = H * Distance where H is the Hubble constant.

(This holds only for galaxies at moderately low distances)



Finite, But Without Edge



<u>2-dimensional analogy:</u>
<u>Surface of a sphere:</u>

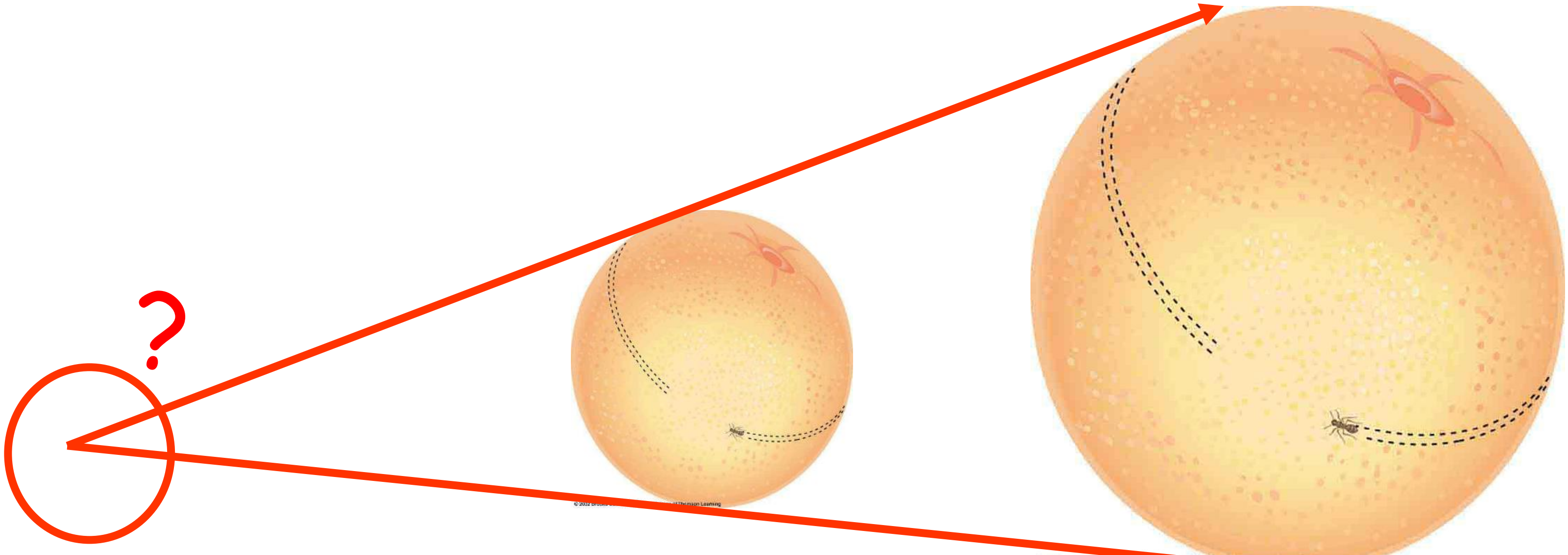
Surface is finite, but has no edge.

For a creature living on the sphere, having no sense of the third dimension, there's no 'centre'. All points are equal.

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

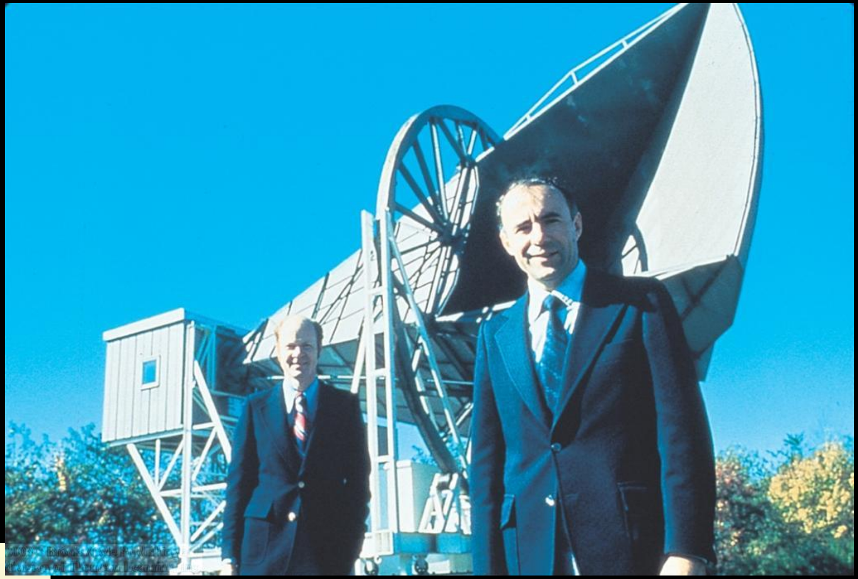
i.e. Velocity = H * Distance

But Time = Distance / Velocity

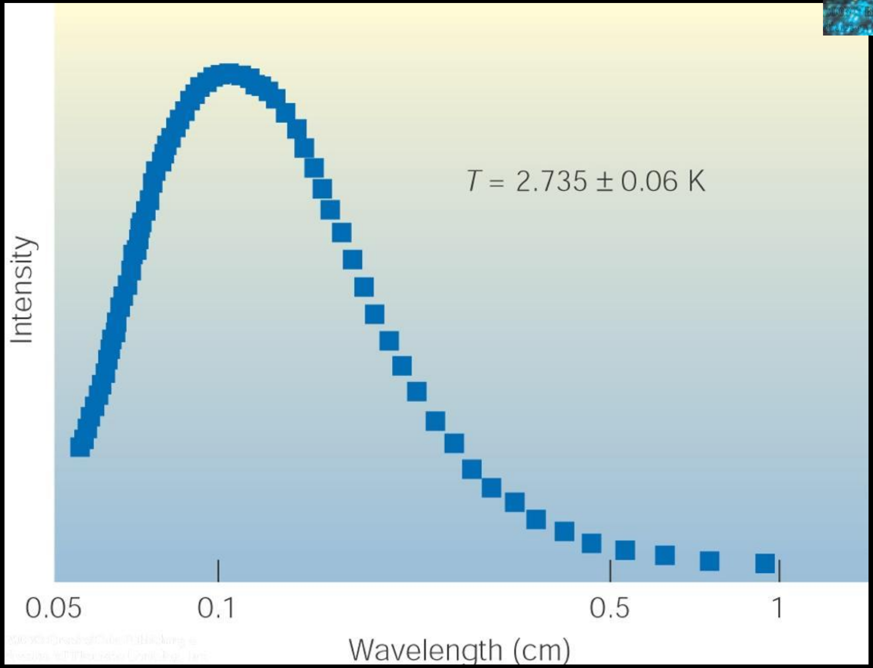
So Time = 1/H ~ 13.7 Billion Years

The Cosmic Background Radiation

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



R. Wilson & A. Penzias

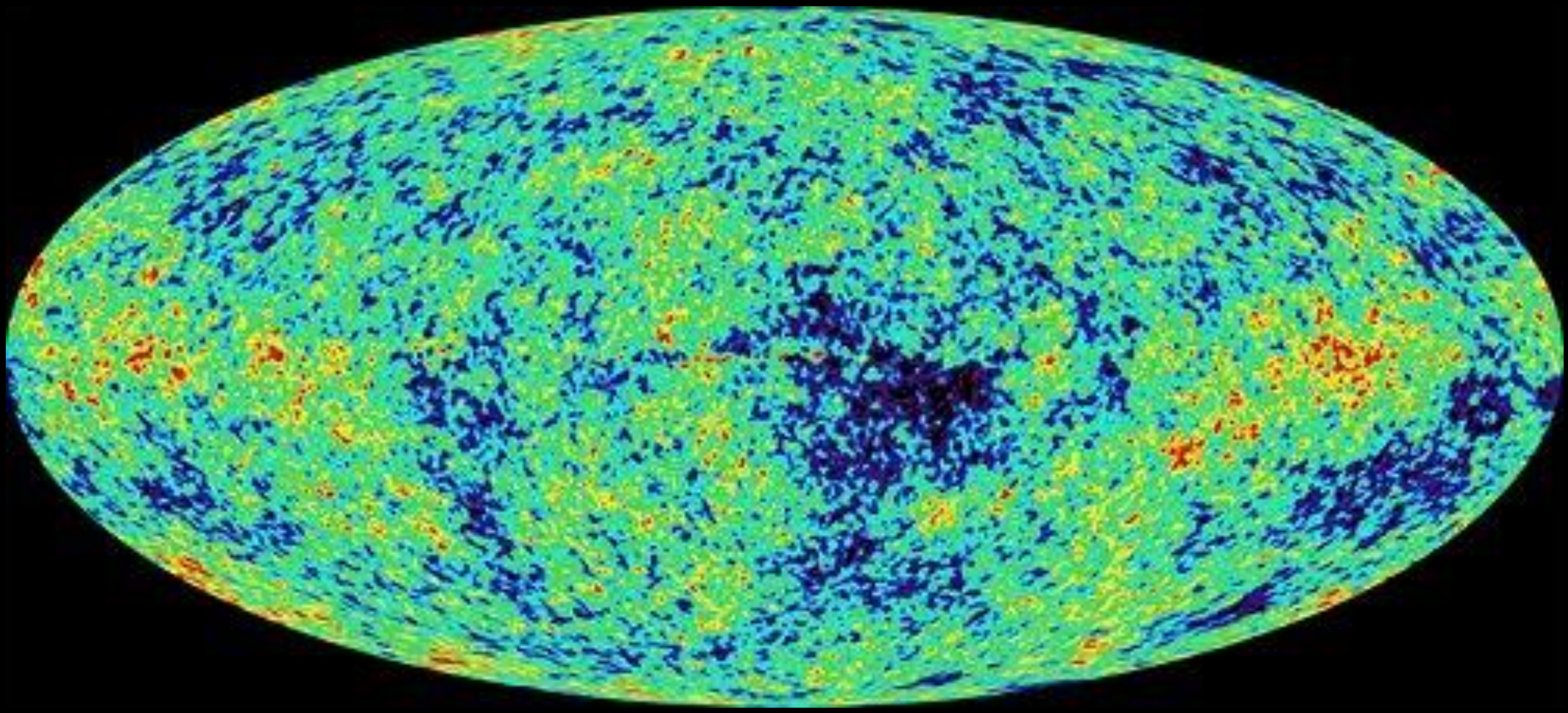


Discovered in mid-1960s as the **Cosmic Microwave Background:**

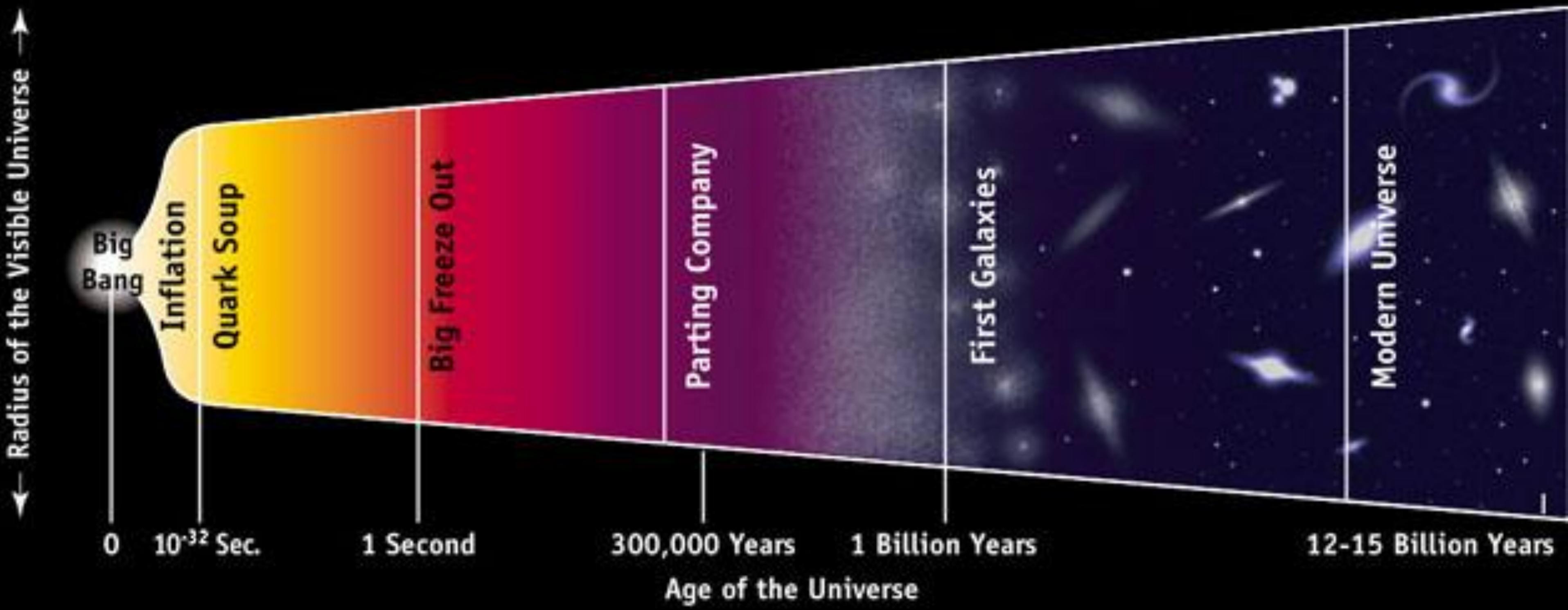
Blackbody radiation with a temperature of T = 2.73 K

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

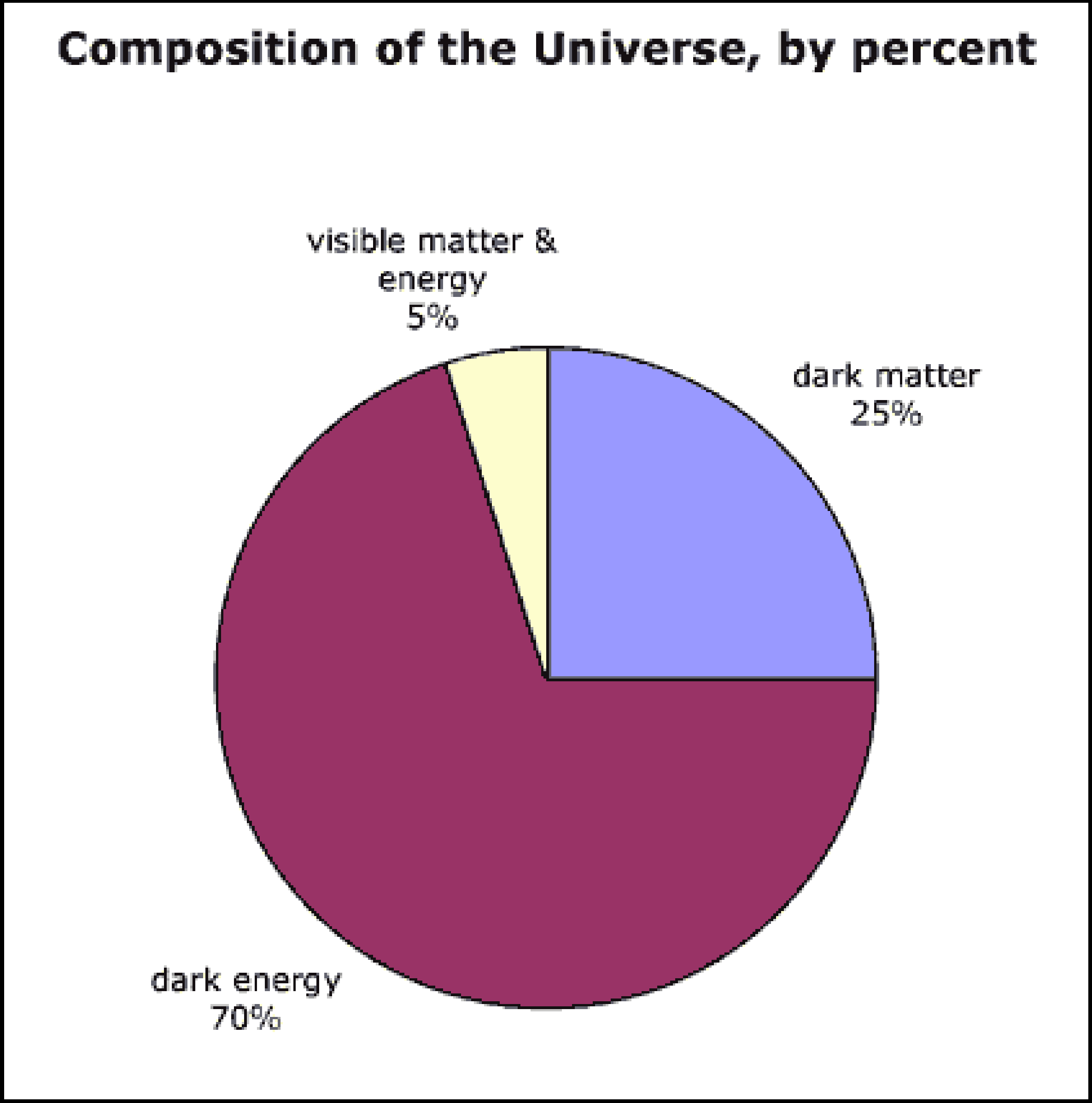

Radius of the Visible Universe
Big Bang
Inflation
Quark Soup
Big Freeze Out
Parting Company
First Galaxies
Modern Universe
0
10^{-32} Sec.
1 Second
300,000 Years
1 Billion Years
12-15 Billion Years
Age of the Universe

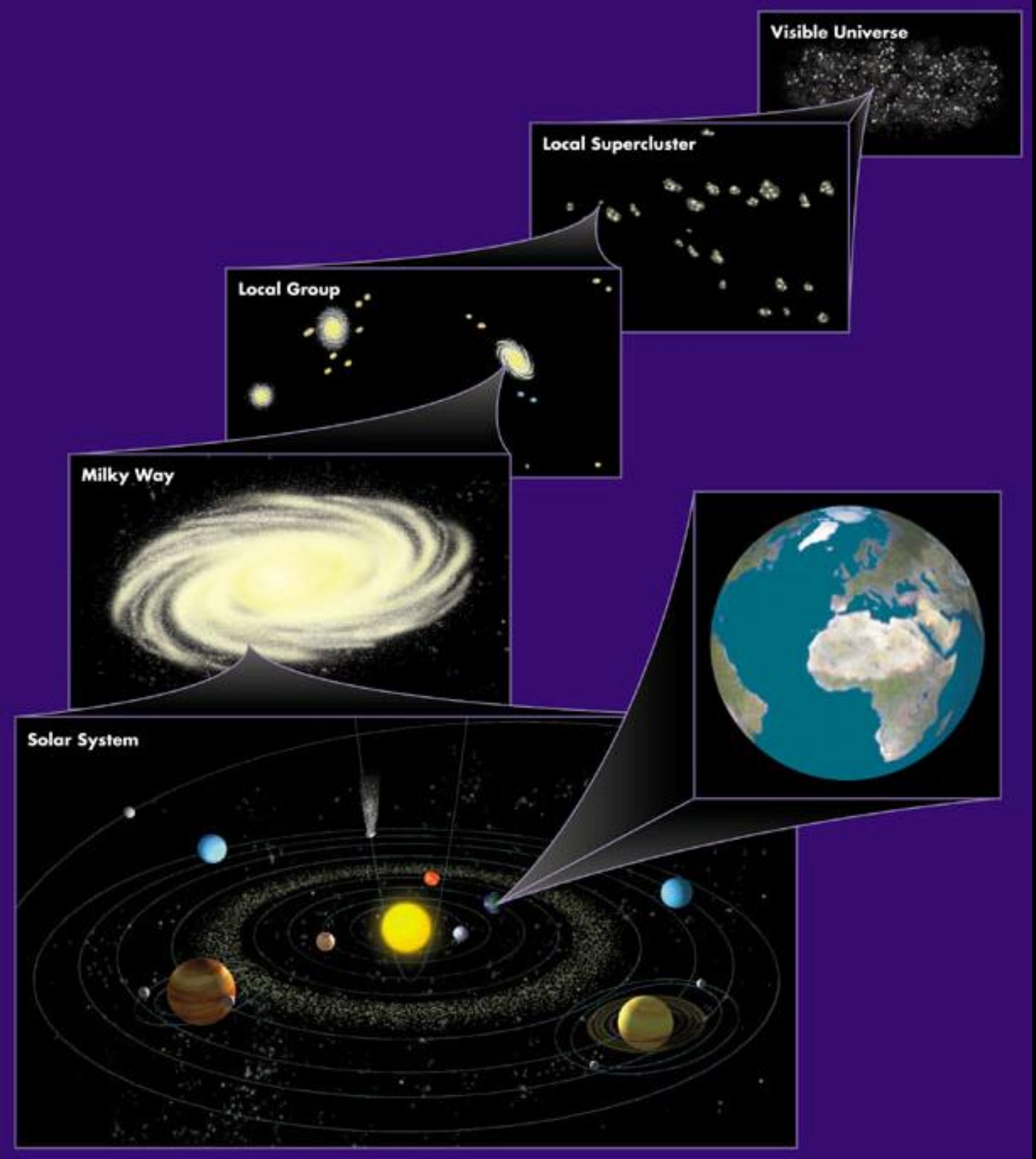
Dark Matter!

Combined mass of all “visible” matter (i.e. emitting any kind of radiation) in the universe adds up to much less than the ‘critical density’.

Gravitational lensing shows that some clusters contain 10 times as much mass as is directly visible.

Dark Energy!

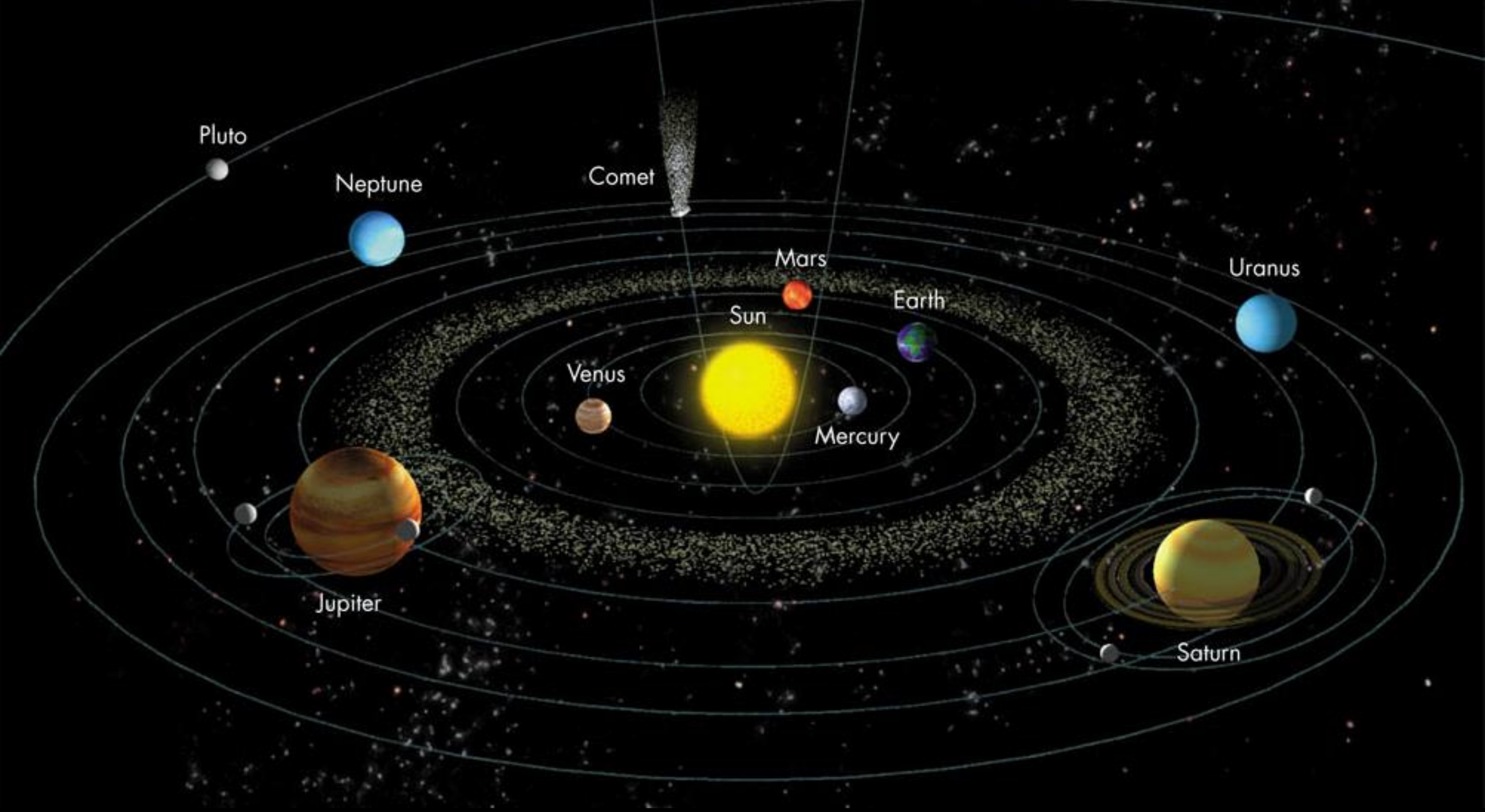

Composition of the Universe, by percent
visible matter & energy 5%
dark matter 25%
dark energy 70%



Approximate numbers:

200 billion stars in our galaxy

100 billion galaxies in the visible universe



Solar System

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

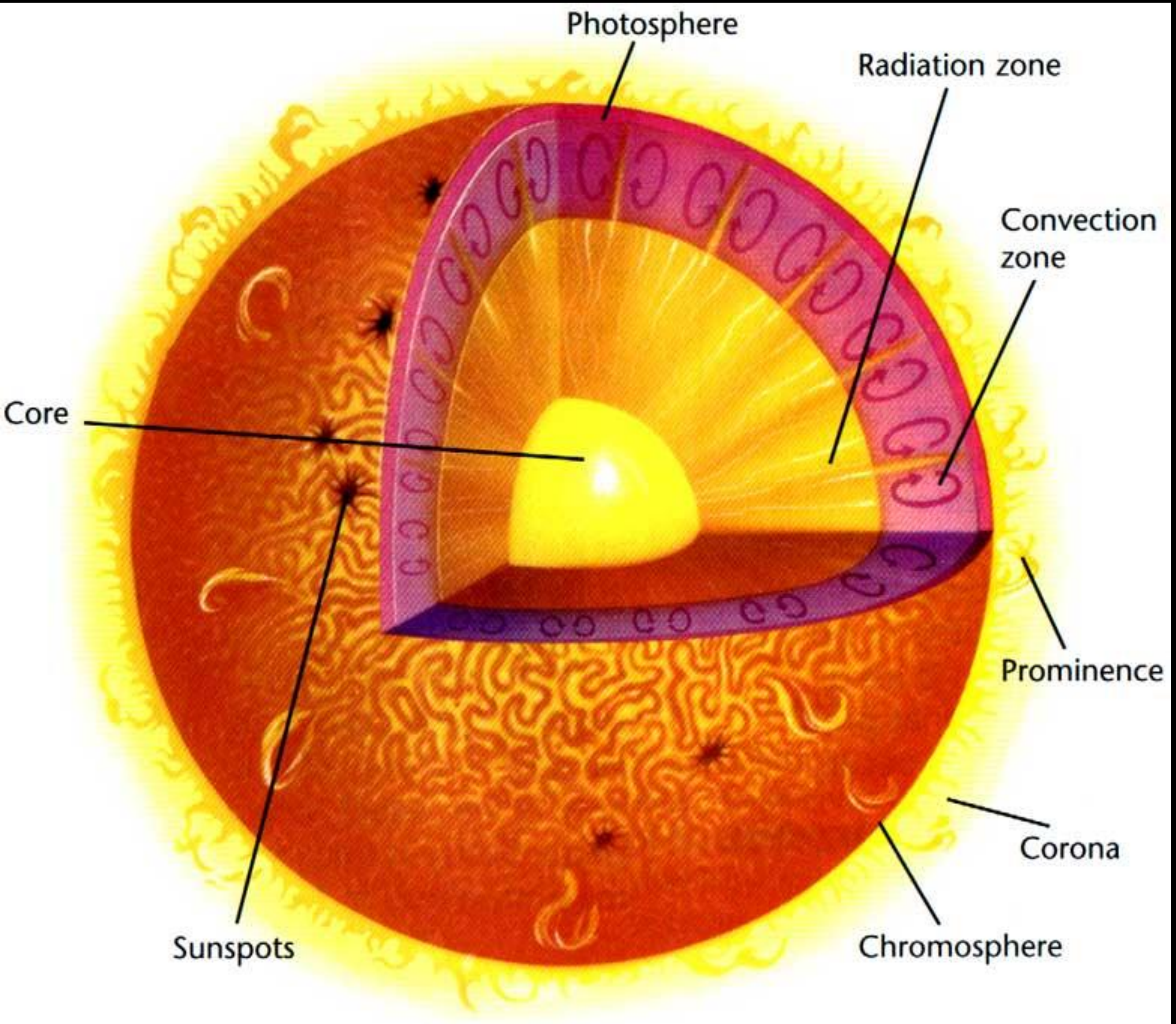
Solar system objects to scale

Layers of the sun:
Three means of energy transfer:
Conduction (throughout), Convection, and Radiation.

Photosphere:
T= 5700 K

Chromosphere
T = 15,000 K

Corona
T = 2 million K



Mass	1.00
Distance	1.00
Diameter	1.00
Moons	1
Day	1d
Year	1y

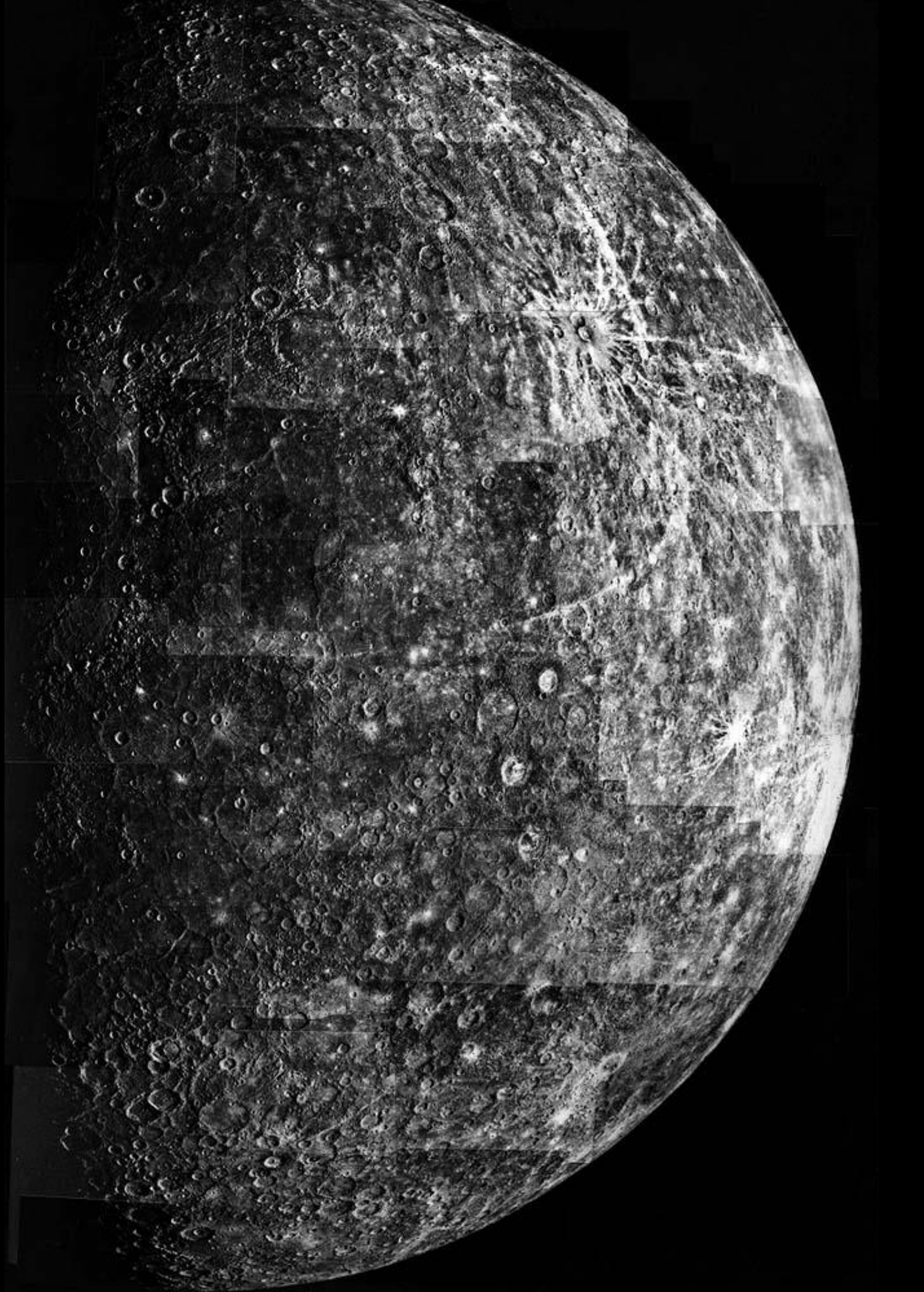
Earth

Mass	0.38
Distance	0.39
Diameter	0.38
Moons	0
Day	58.6d
Year	88d

Mercury

Mercury

photographic
mosaic



Mass	0.82
Distance	0.72
Diameter	0.95
Moons	0
Day	-243d
Year	226d

Venus

Venus

Venus -- ultraviolet photograph

Mass	1.00
Distance	1.00
Diameter	1.00
Moons	1
Day	1d
Year	1y

Earth

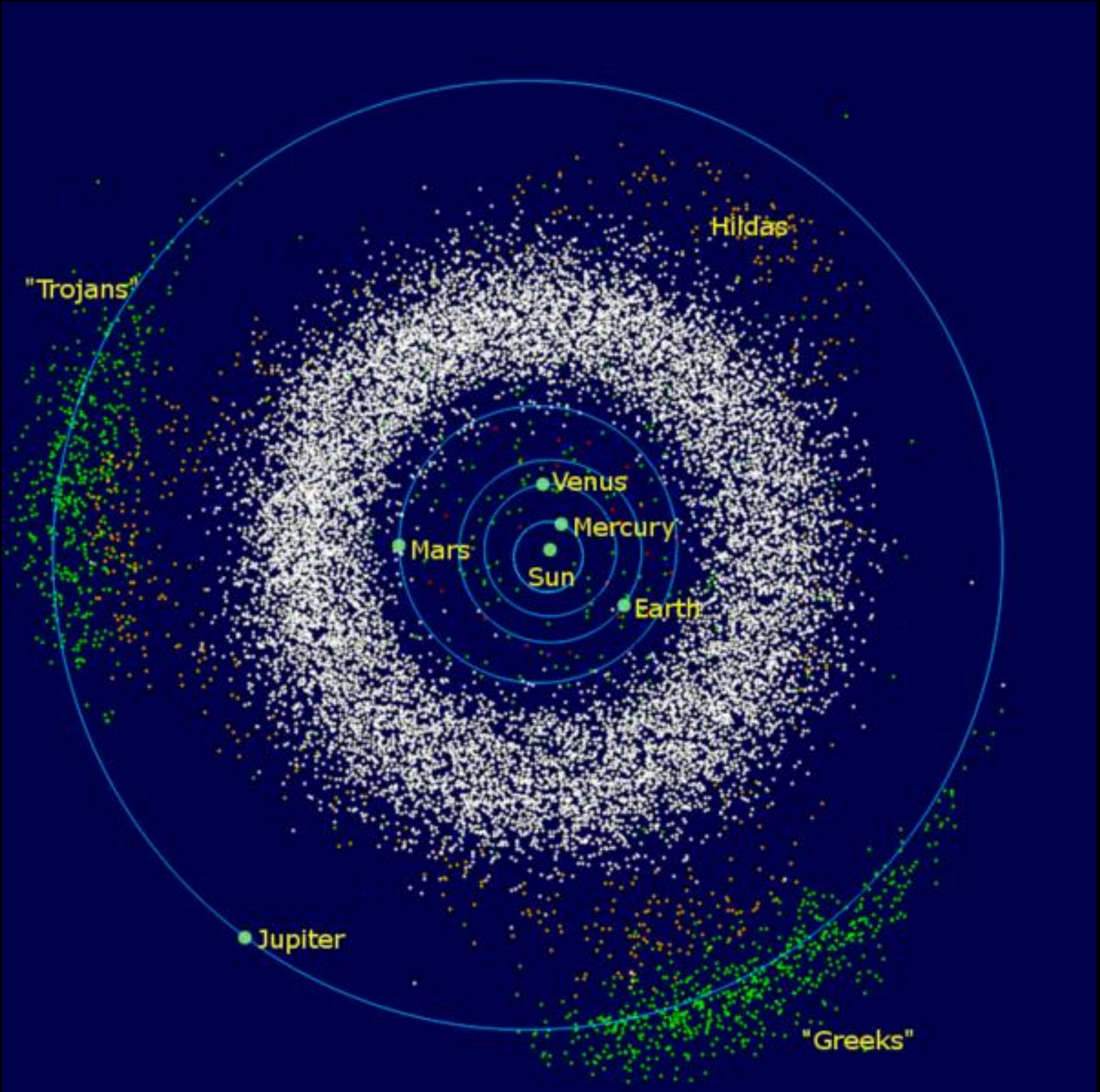
Mass	0.11
Distance	1.52
Diameter	0.53
Moons	2
Day	1.03y
Year	1.88y

Mars

Mars – 20th October 2005

Orwell Park Observatory

Paul Whiting *FRAS*

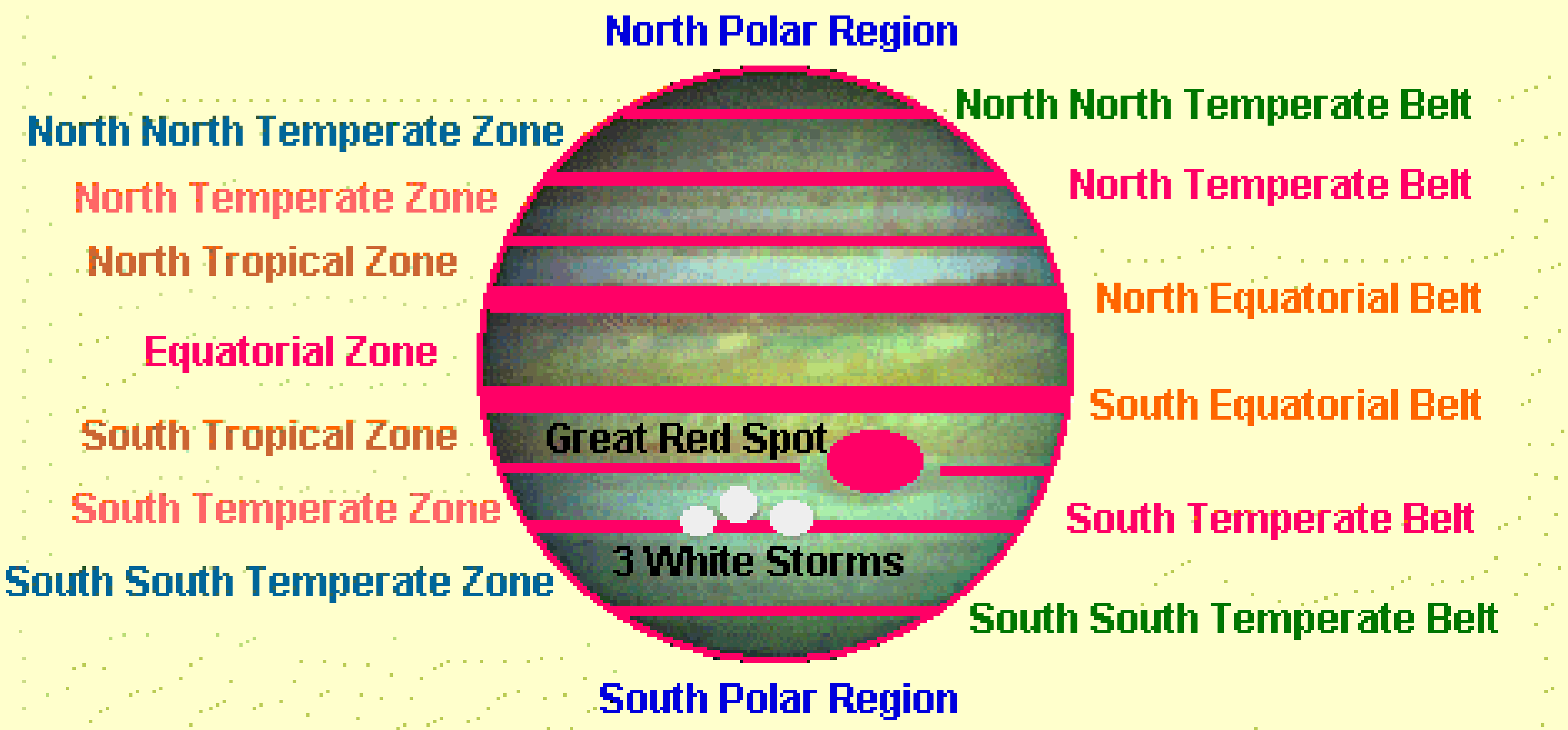


Hildas
"Trojans"
Venus
Mercury
Mars
Sun
Earth
Jupiter
"Greeks"

Mass	318
Distance	5.20
Diameter	11.2
Moons	49
Day	0.4d
Year	11.9y

Jupiter

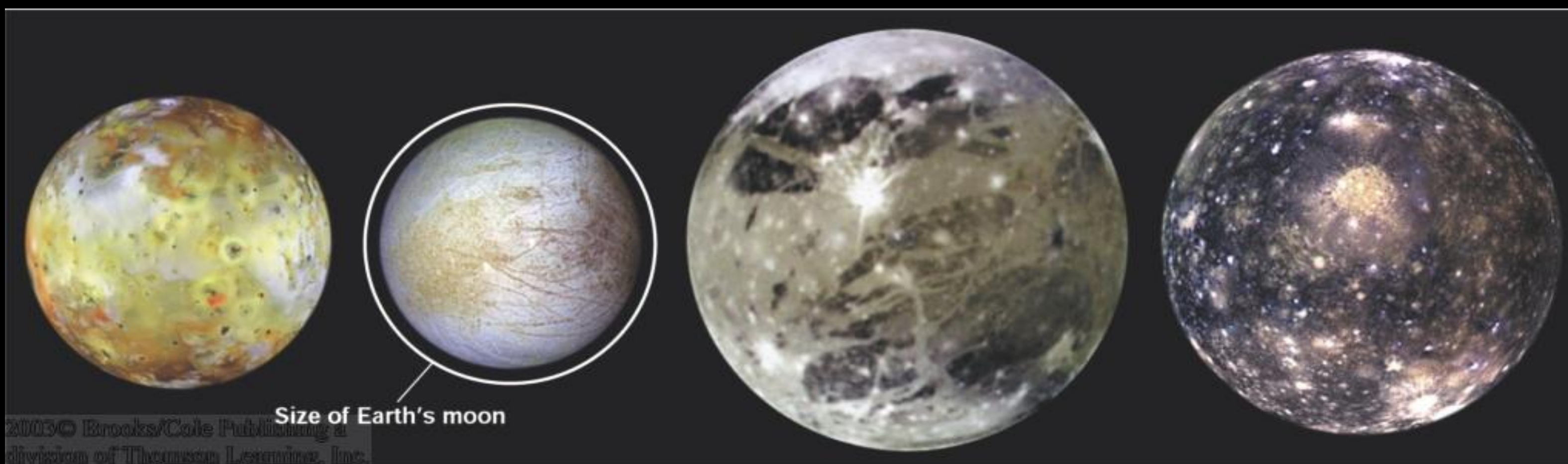
Jupiter's Major Atmospheric Belts, Zones, and Storms



Jupiter's Family of Moons

Over two dozen moons known now;
new ones are still being discovered.

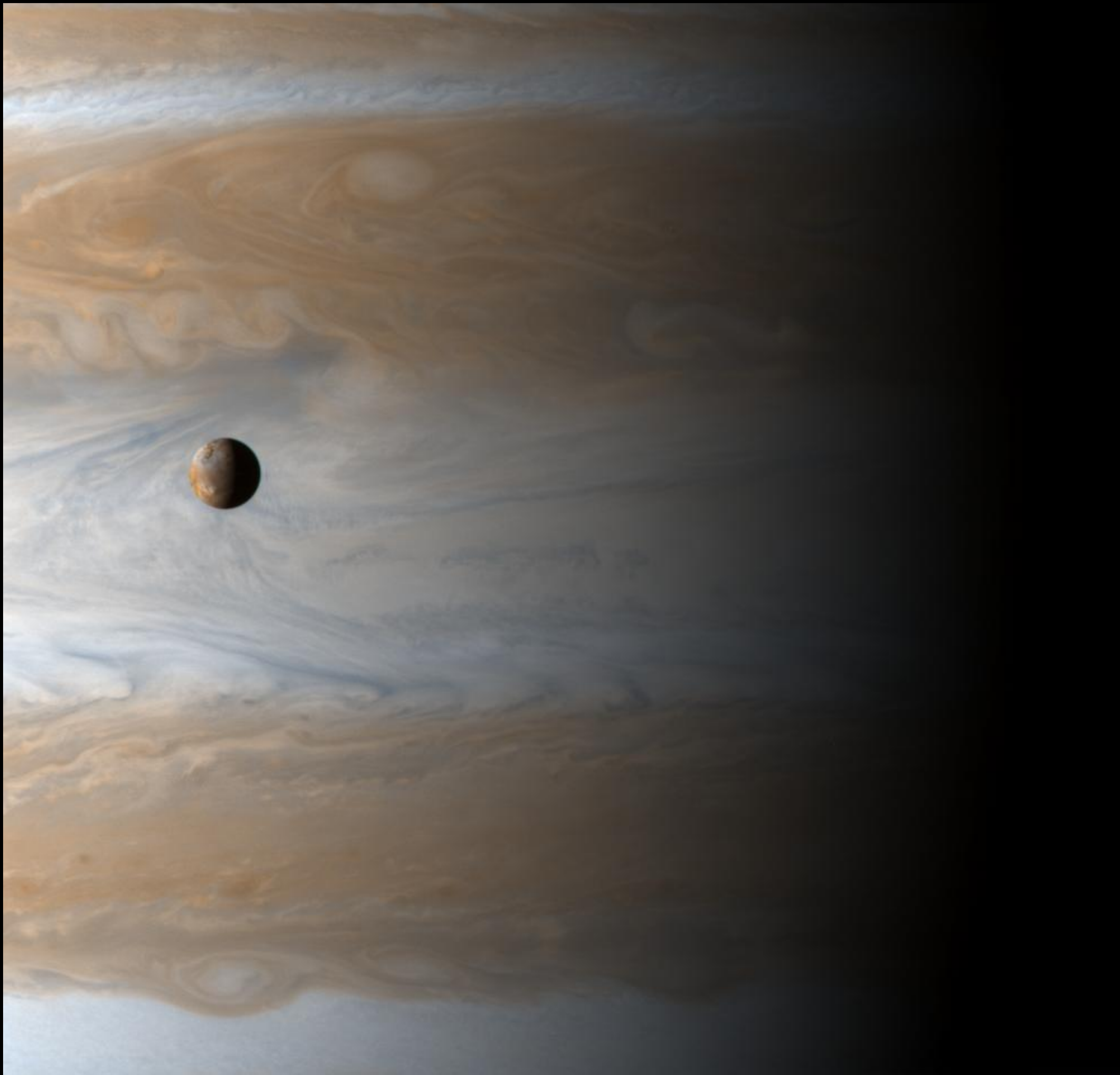
Four largest moons already discovered by
Galileo: The Galilean moons



Io Europa Ganymede Callisto

Interesting and diverse individual geologies.

Jupiter
and its
moon, Io



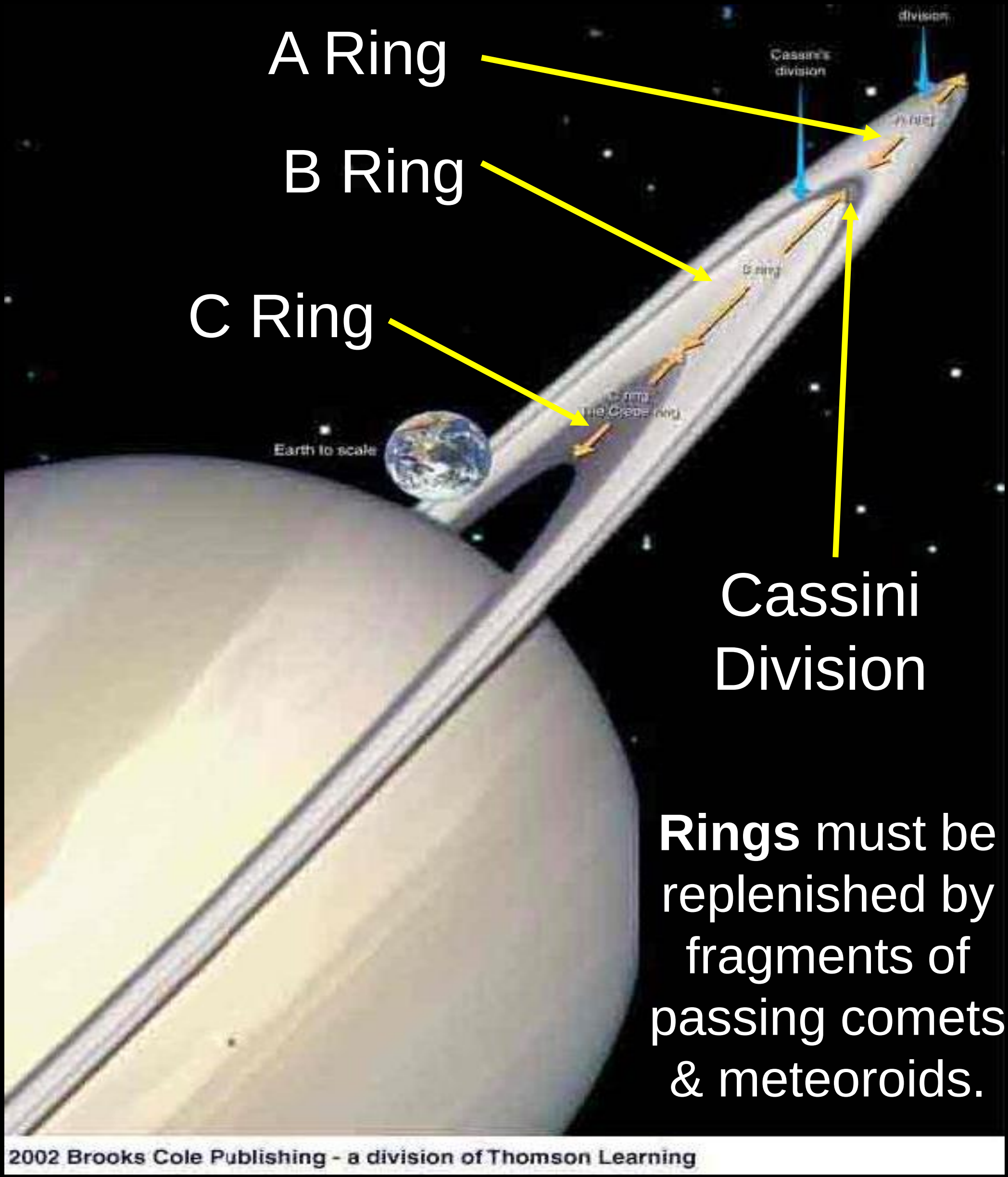
Mass	95.2
Distance	9.54
Diameter	9.5
Moons	52
Day	0.4d
Year	29.4y

Saturn

Saturn's Rings

Ring consists of 3 main segments: A, B, and C Ring separated by empty regions: divisions

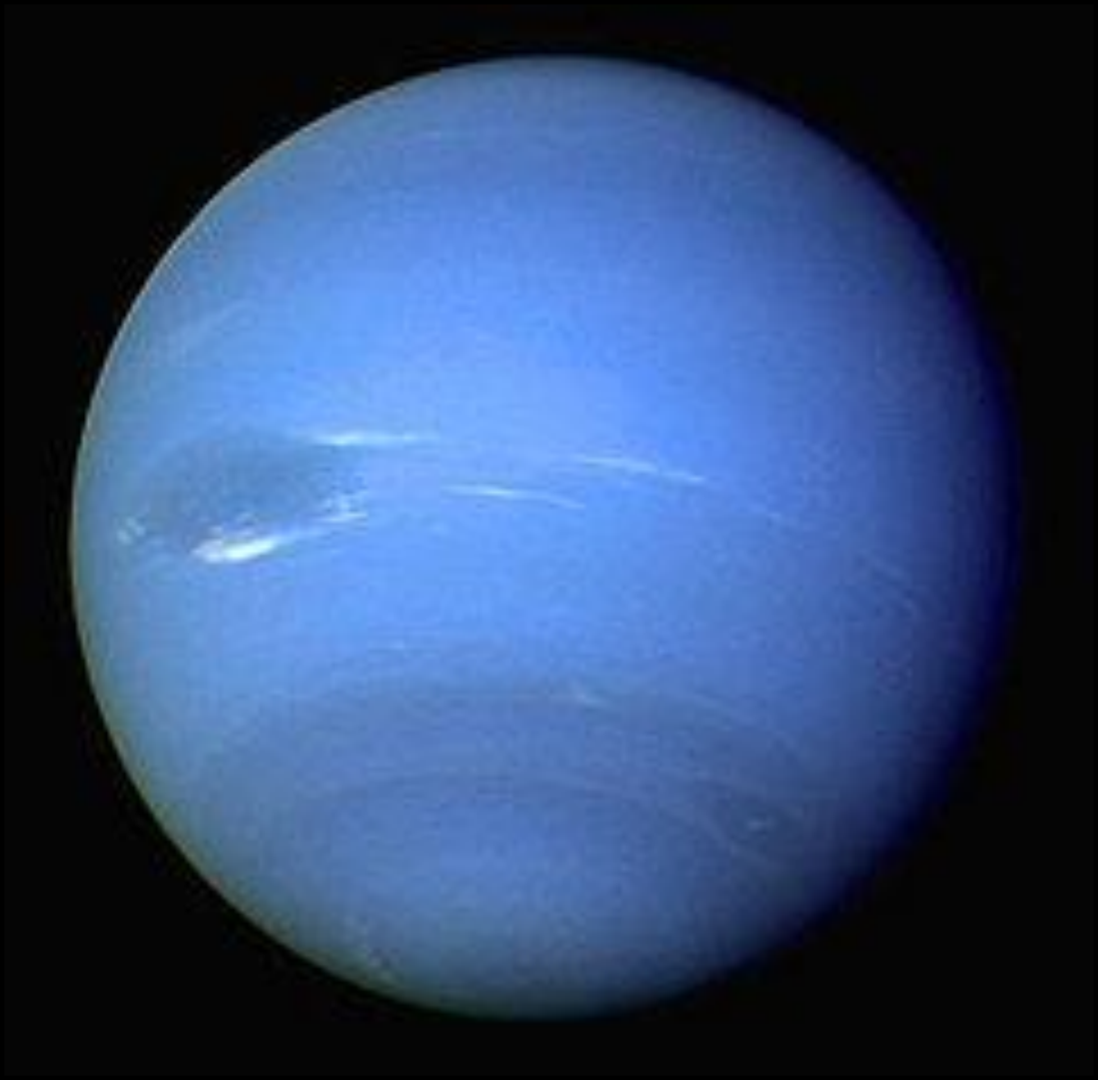
Rings can't have been formed together with Saturn because material would have been blown away by particle stream from hot Saturn at time of formation.



Rings must be replenished by fragments of passing comets & meteoroids.

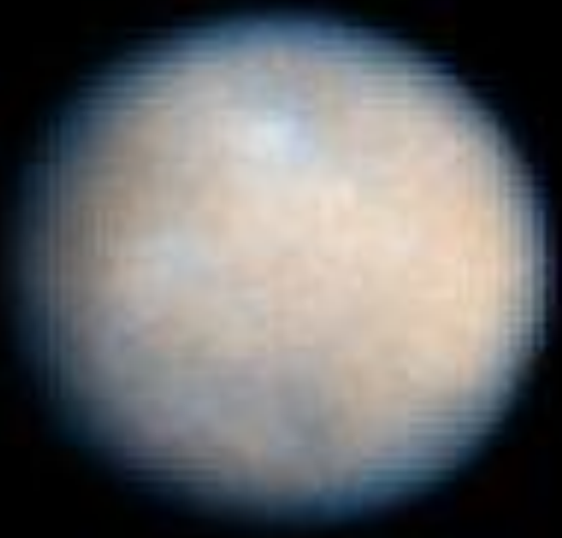
Mass	14.6
Distance	19.2
Diameter	4.0
Moons	27
Day	-0.72d
Year	84.0y

Uranus



Mass	17.2
Distance	30.0
Diameter	3.88
Moons	13
Day	0.67d
Year	164.8y

Neptune



Eris

Makemake

Ceres

Pluto

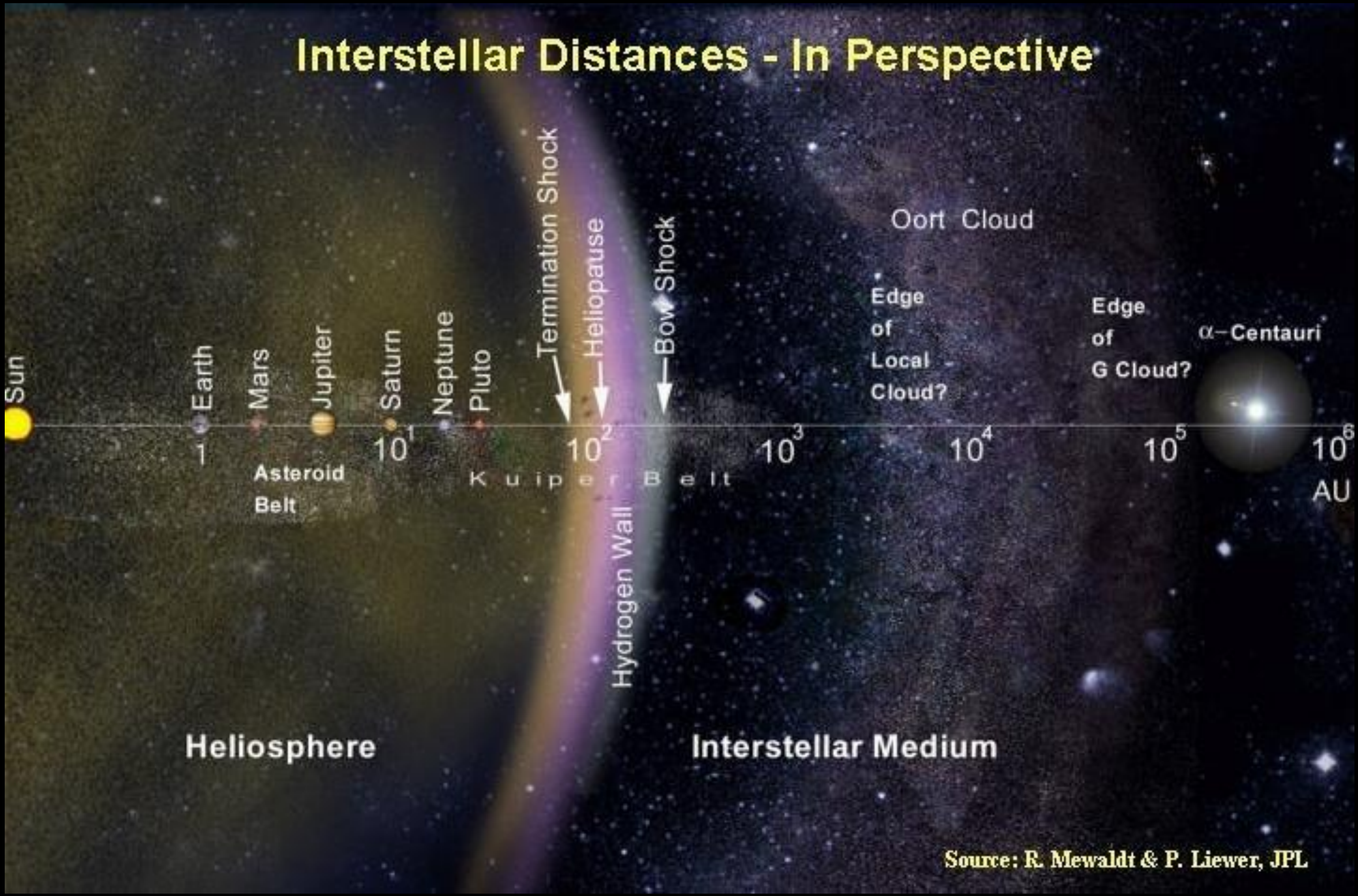
Haumea

The Dwarf Planets

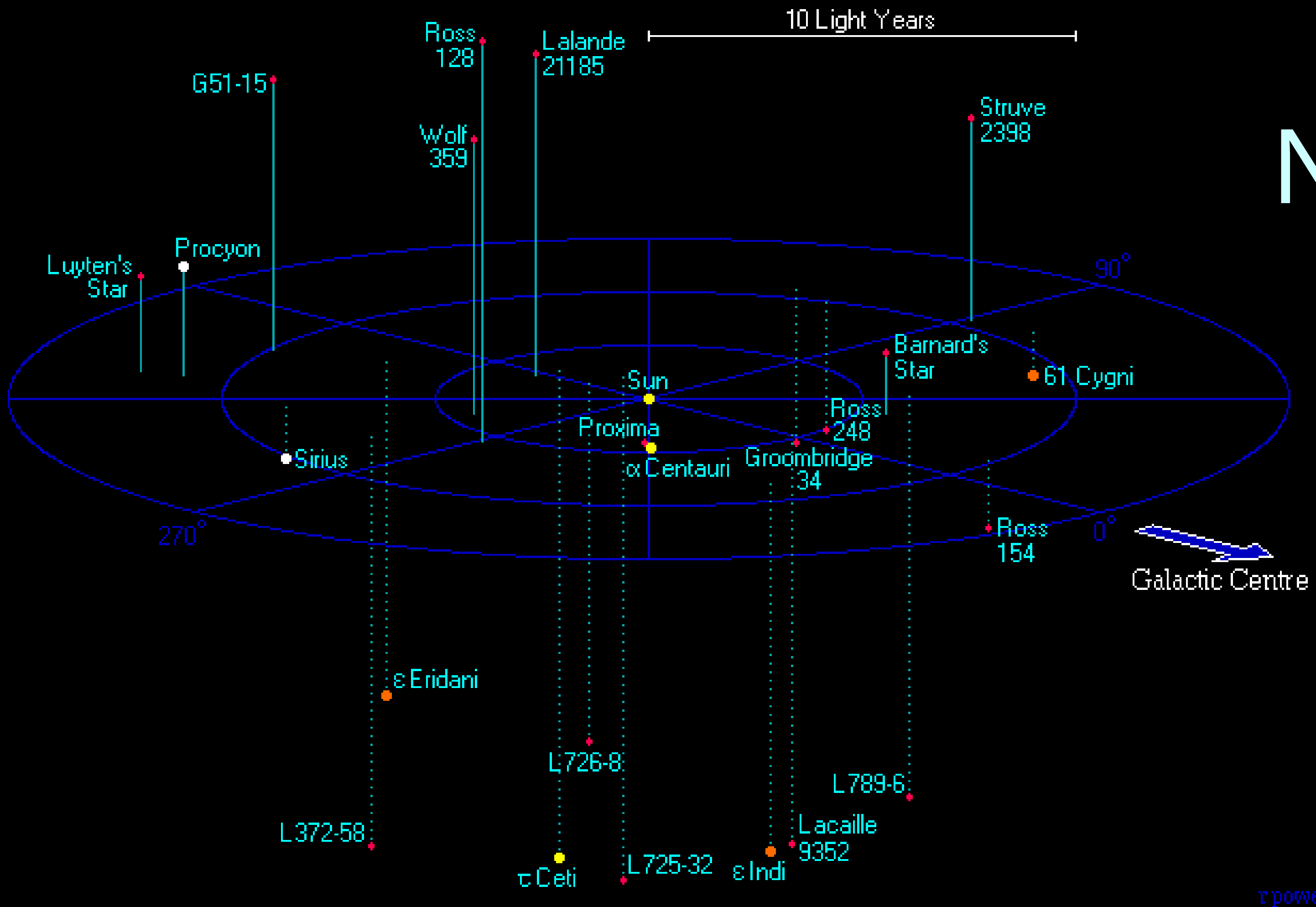
How far to a star?

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

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



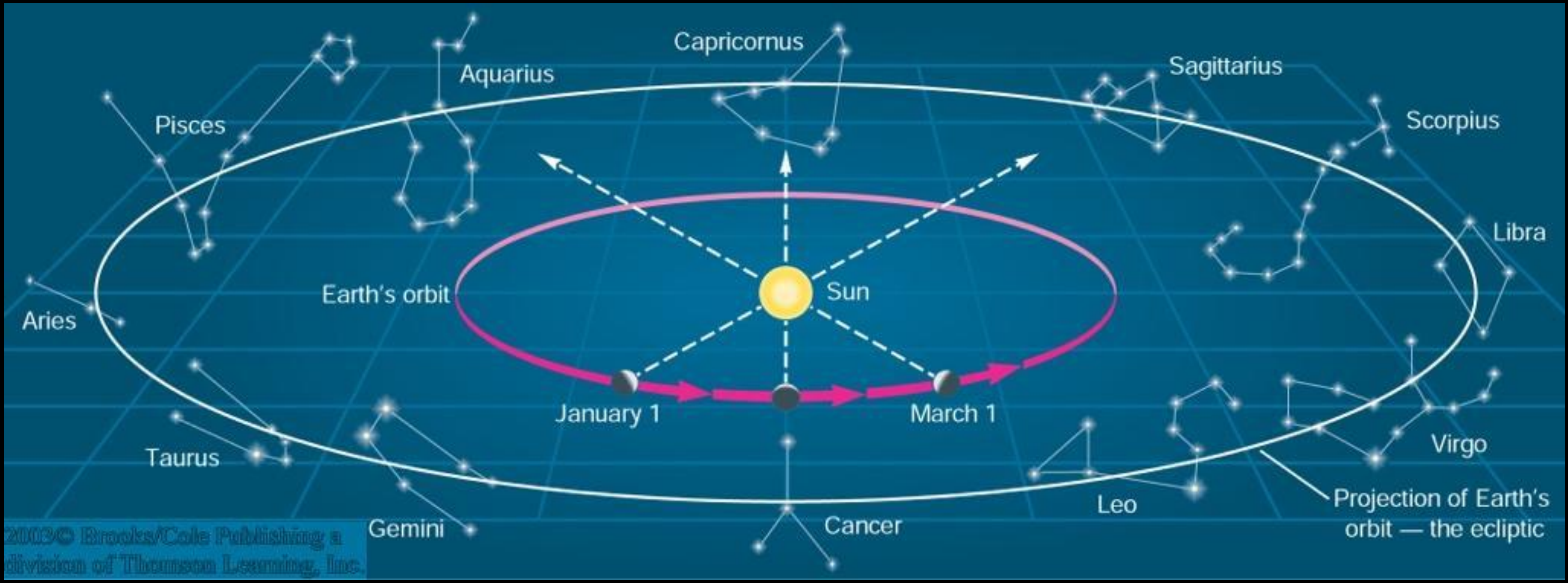
The Nearest Stars



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

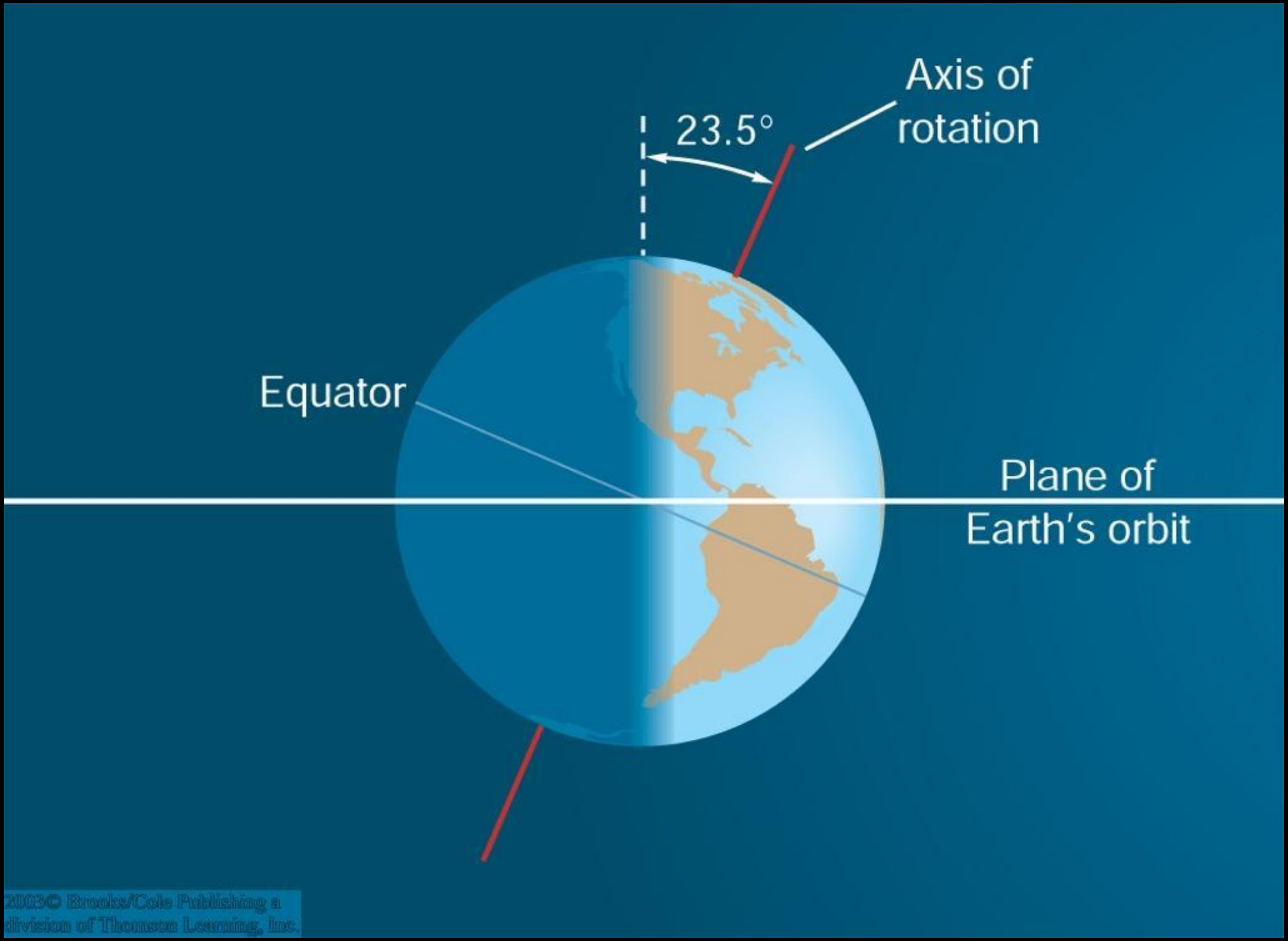
The Sun and Its Apparent Motion

Due to Earth's revolution around the sun, the sun appears to move through the zodiacal constellations.



The Sun's apparent path on the sky is called the **Ecliptic**.

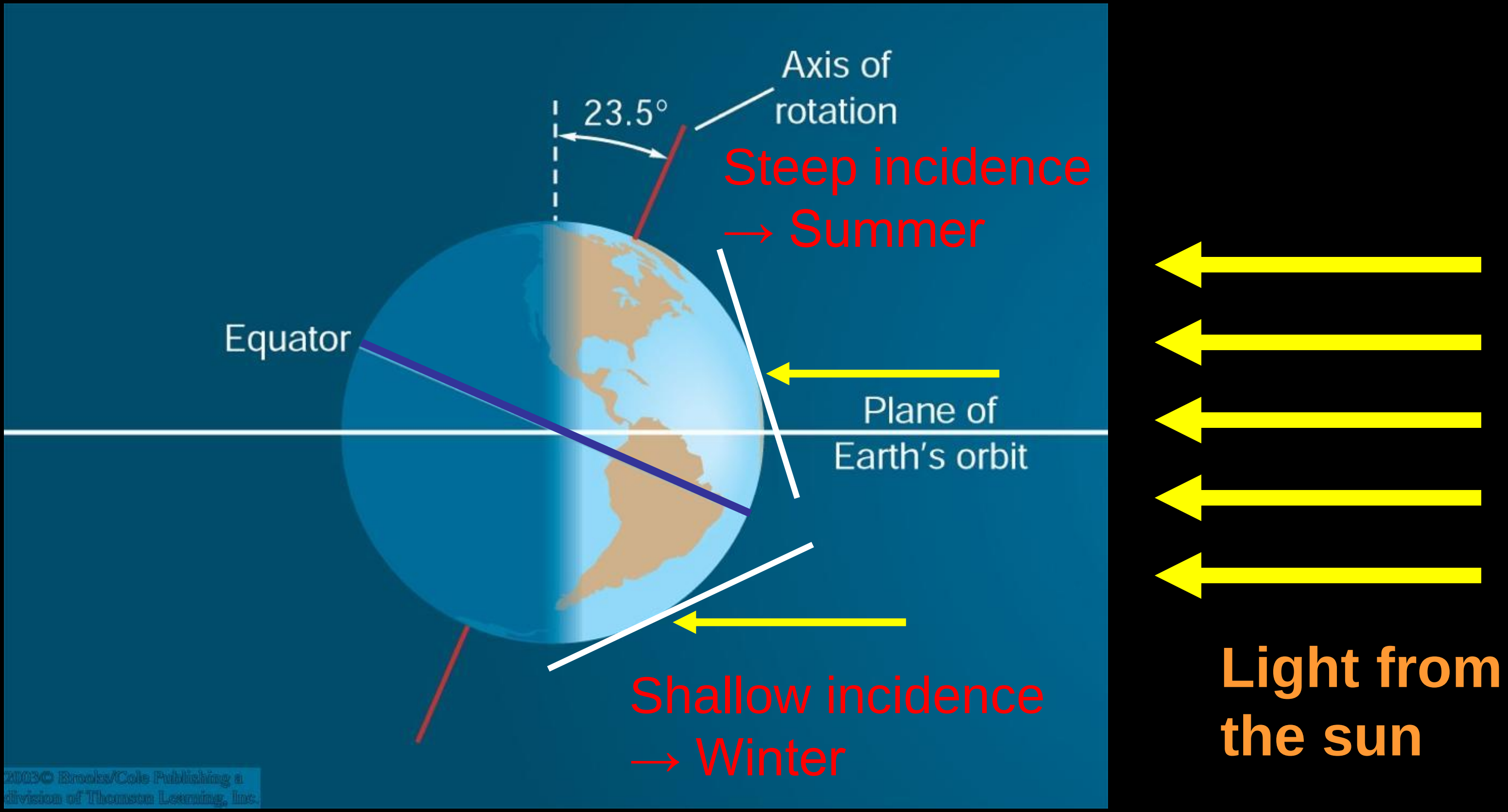
The Seasons



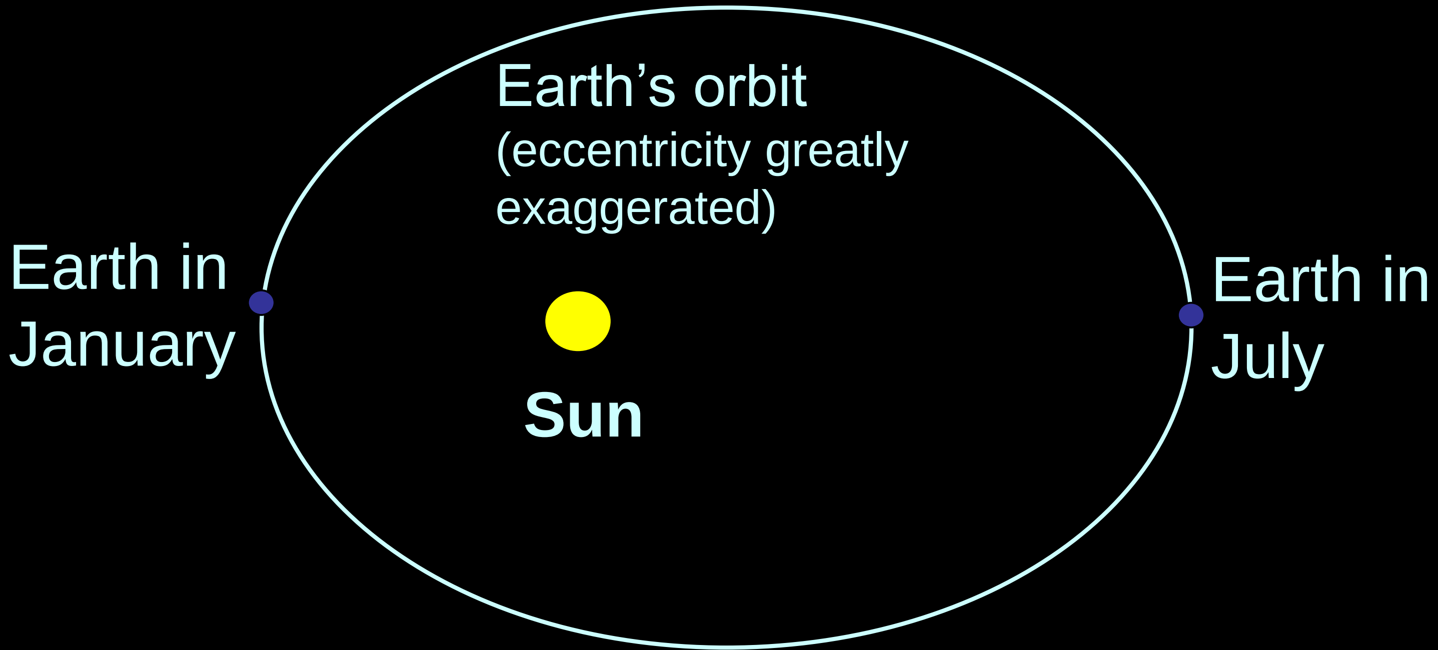
Earth's axis of rotation is inclined vs. the normal to its orbital plane by 23.5°, which causes the **seasons**.

The Seasons

The Seasons are caused by a varying angle of incidence of the sun's rays.



Earth's Orbit



Seasons are **not** related to Earth's distance from the sun. In fact, Earth is slightly closer to the sun in (northern-hemisphere) winter than in summer.

Johannes Kepler (1571 – 1630)

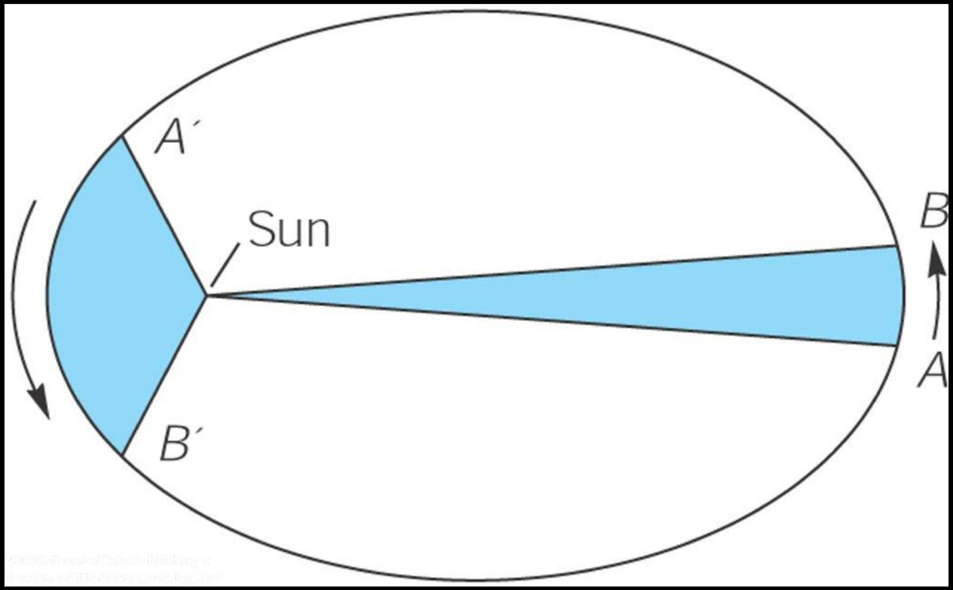
Used the precise observational tables of Tycho Brahe (1546 – 1601) to study planetary motion mathematically

Found a consistent description by abandoning both circular motion and uniform motion

Planets move around the sun on elliptical paths, with non-uniform velocities

Planetary Orbits (Kepler)

A line from a planet to the sun sweeps over equal areas in equal intervals of time.



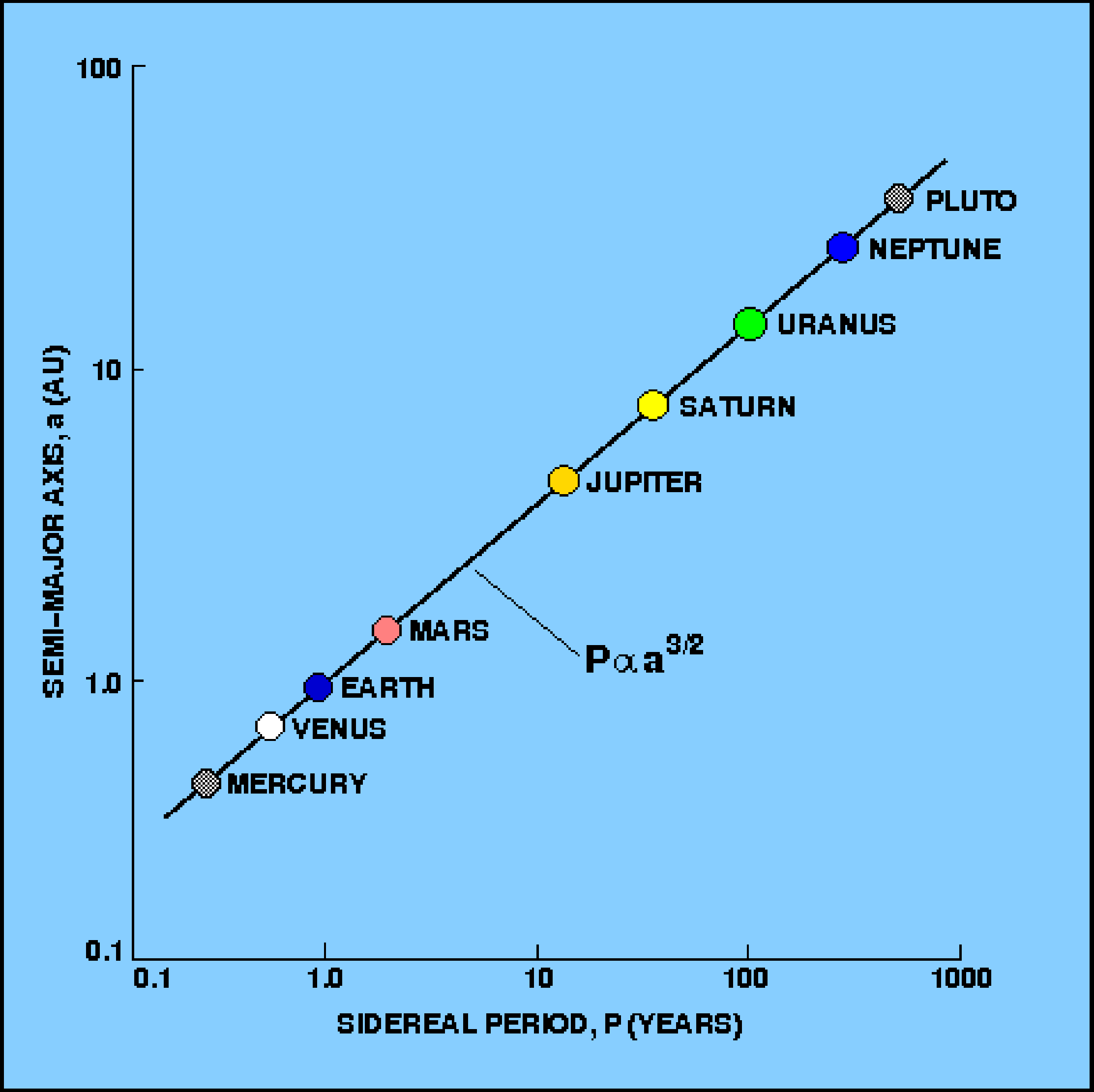
A planet's orbital period (P) squared is proportional to its average distance from the sun (A) cubed:

$$\boxed{P^2 = A^3}$$

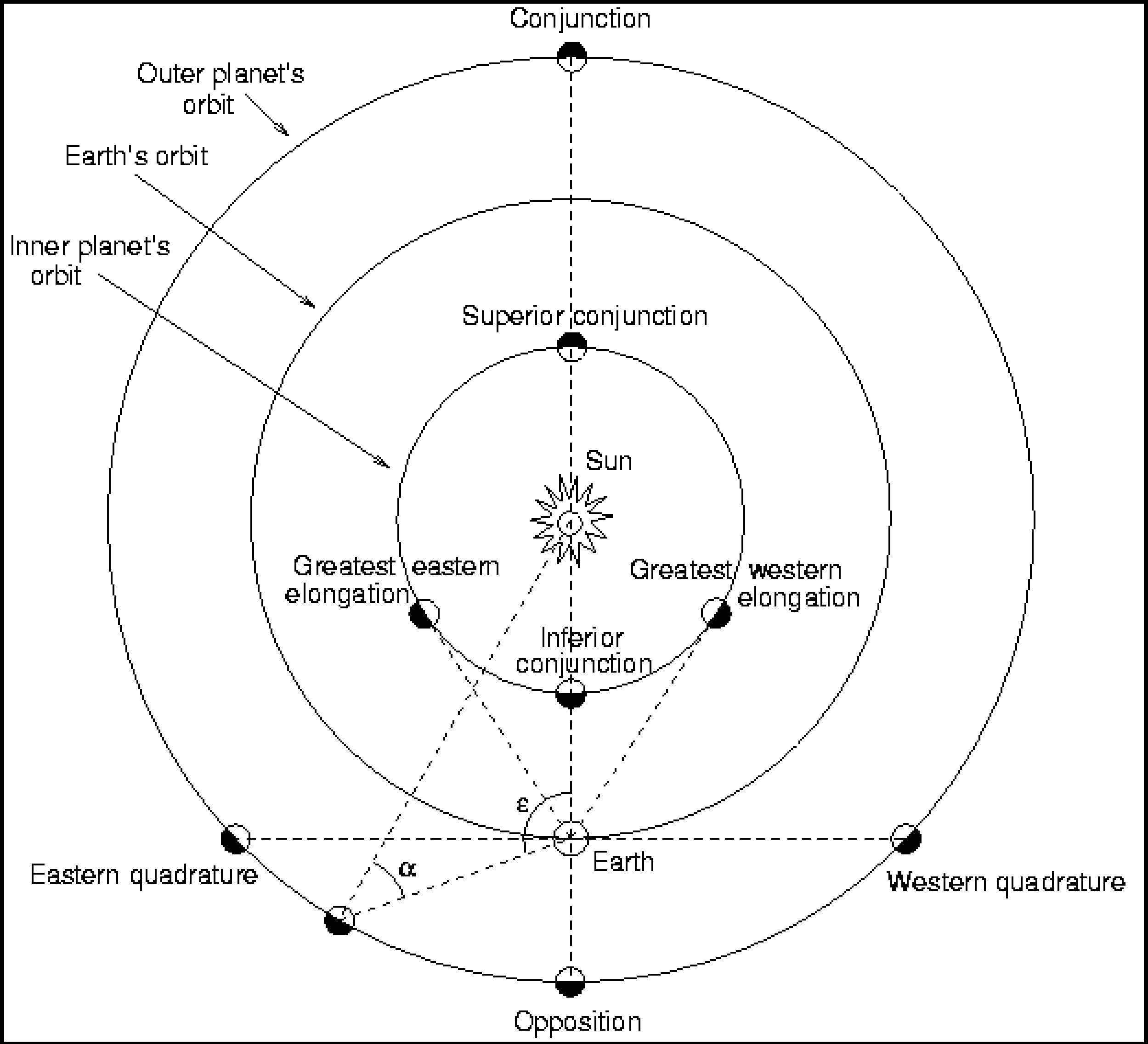
P = period in years
A = distance in AU

$\boxed{P^2 = A^3}$

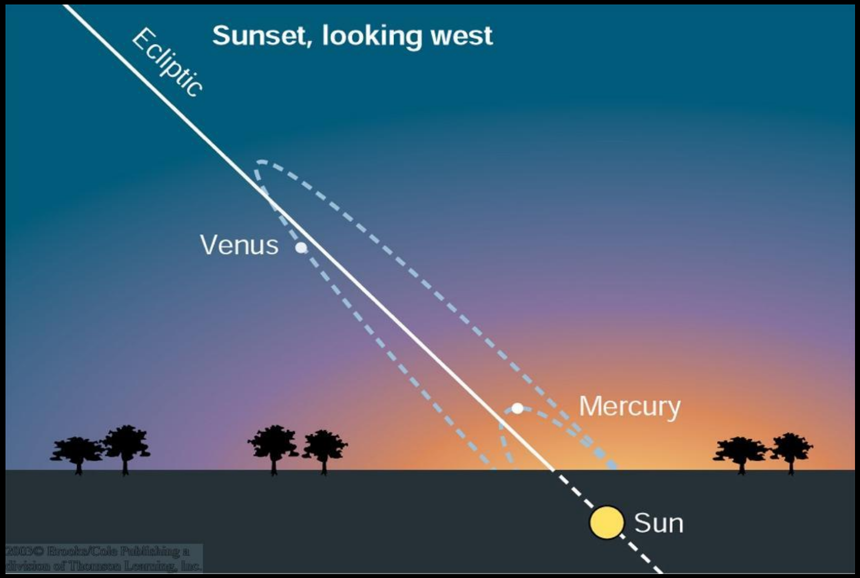
P = period in years
A = distance in AU



Planets - Inner and Outer

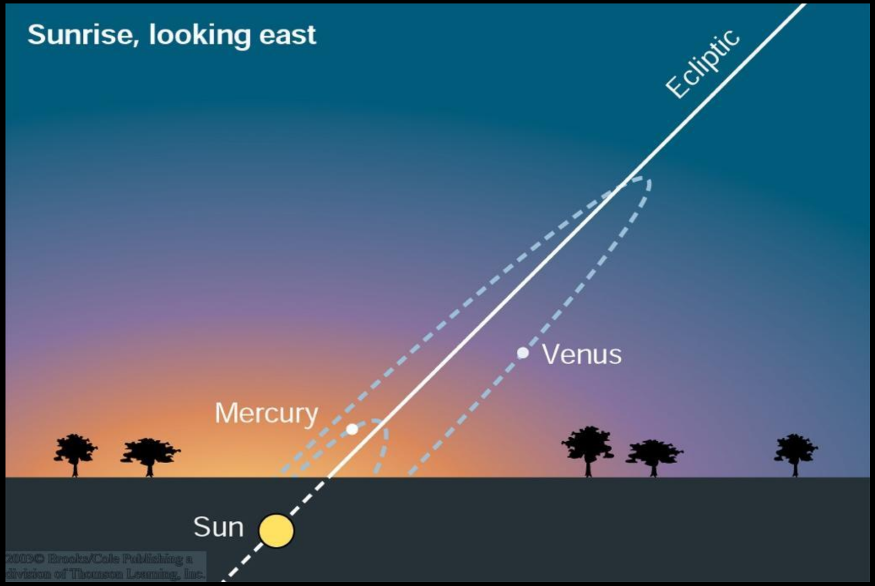


The Motion of the Inner Planets



Mercury appears at most ~28° from the sun.

It can only be seen shortly after sunset in the west or before sunrise in the east.



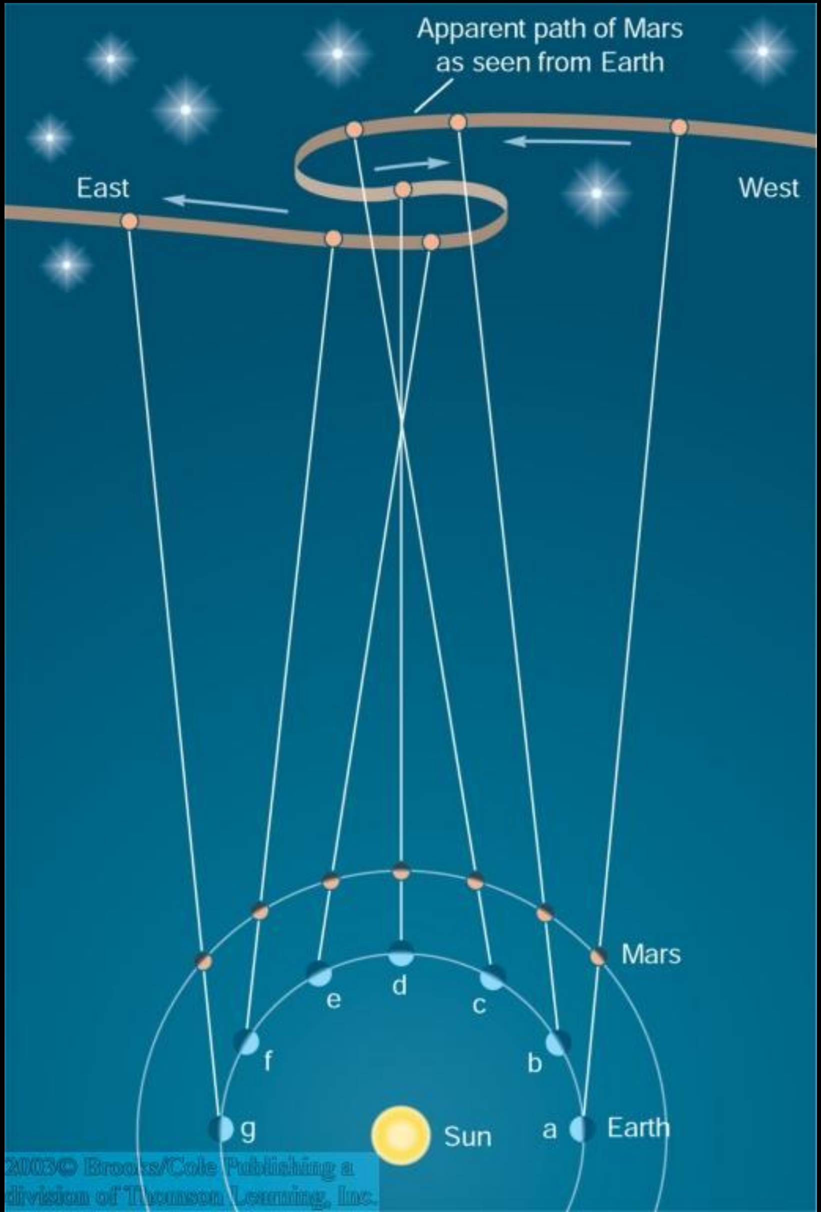
Venus appears at most ~46° from the sun.

It can only be seen for at most a few hours after sunset in the west or before sunrise in the east.

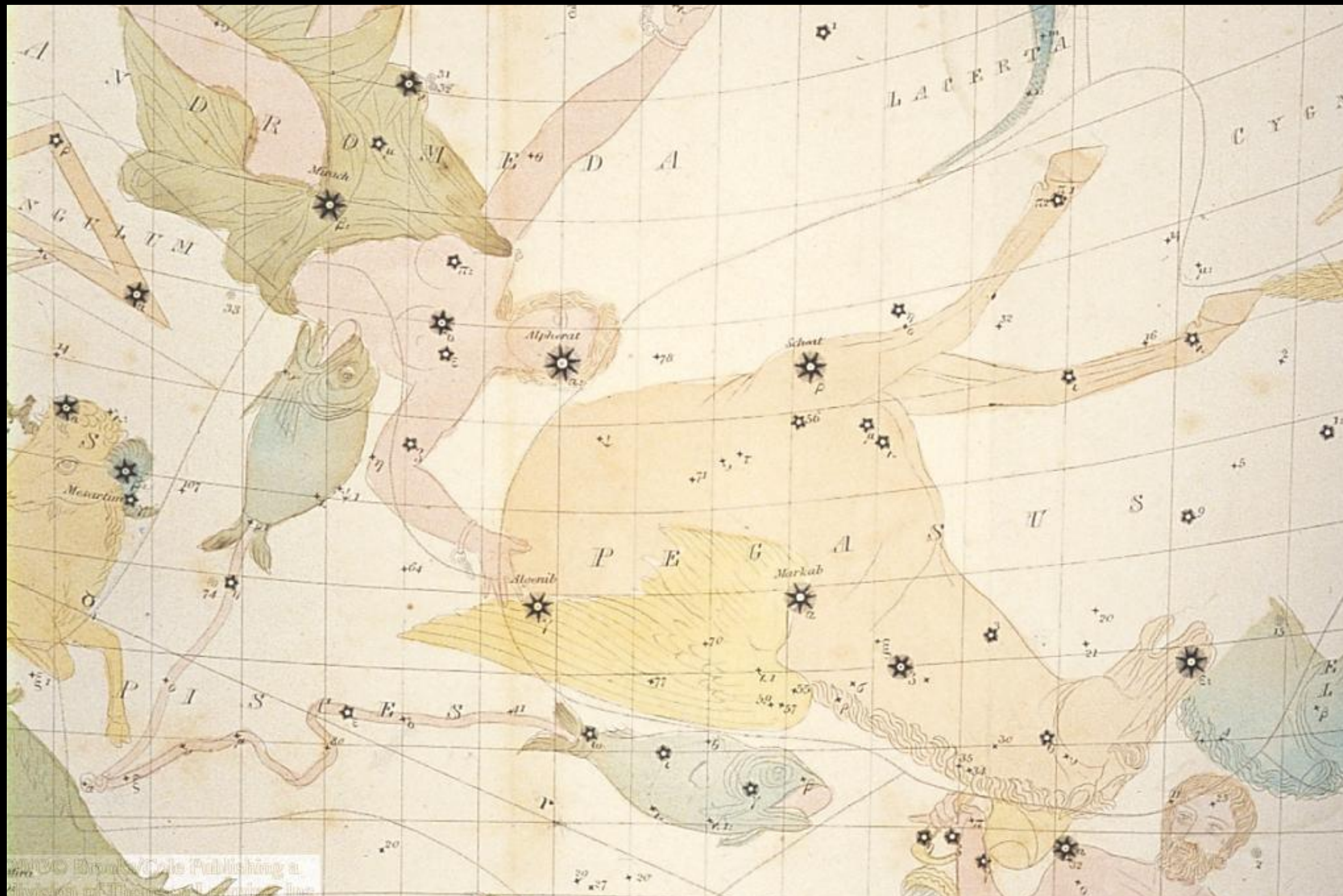
The Motion of the Outer Planets

All **outer planets** - Mars, Jupiter, Saturn, Uranus, Neptune (and Pluto) generally appear to move eastward along the Ecliptic

'Retrograde motion' occurs when the Earth 'overtakes' the planet

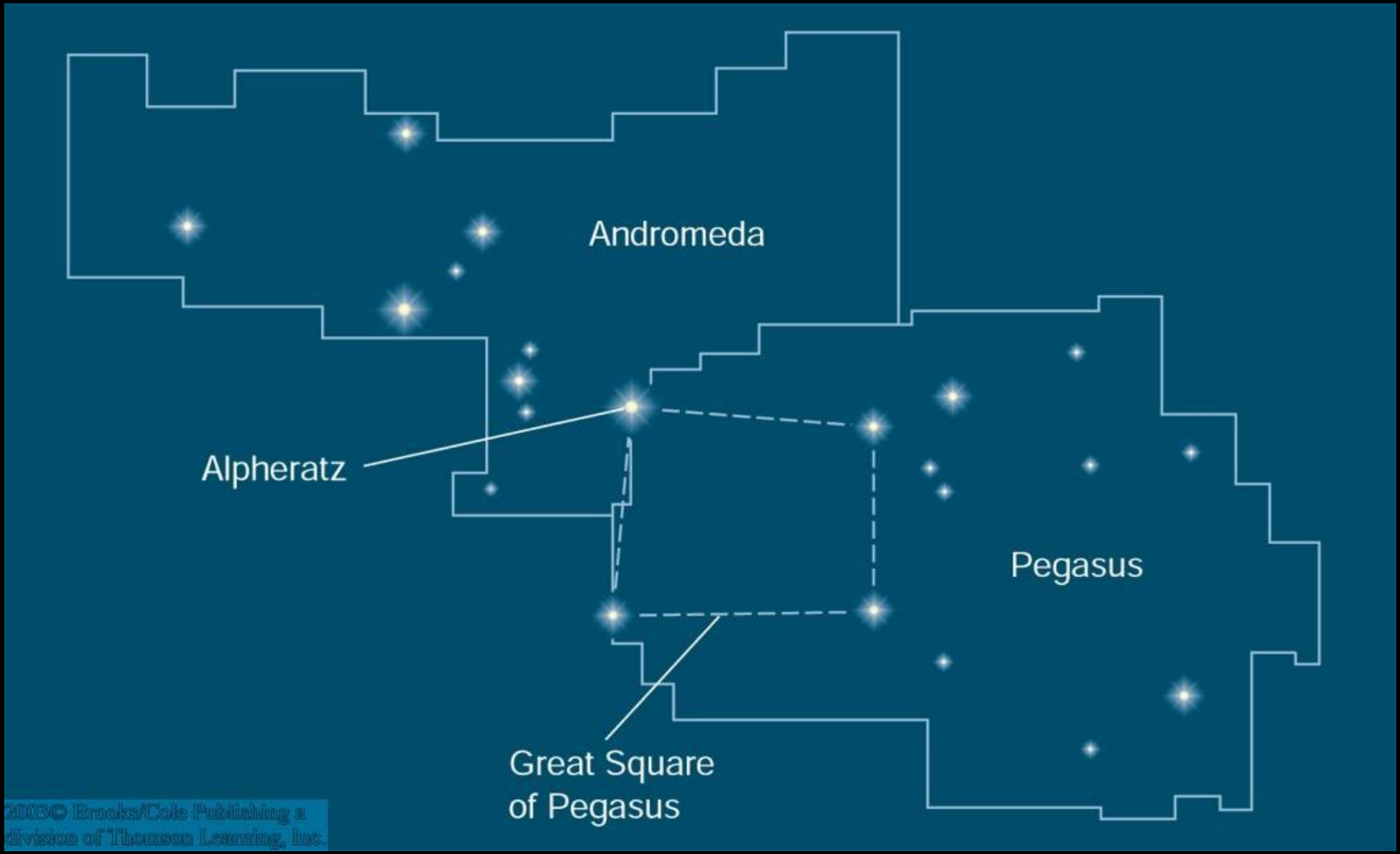


Ancient Constellations



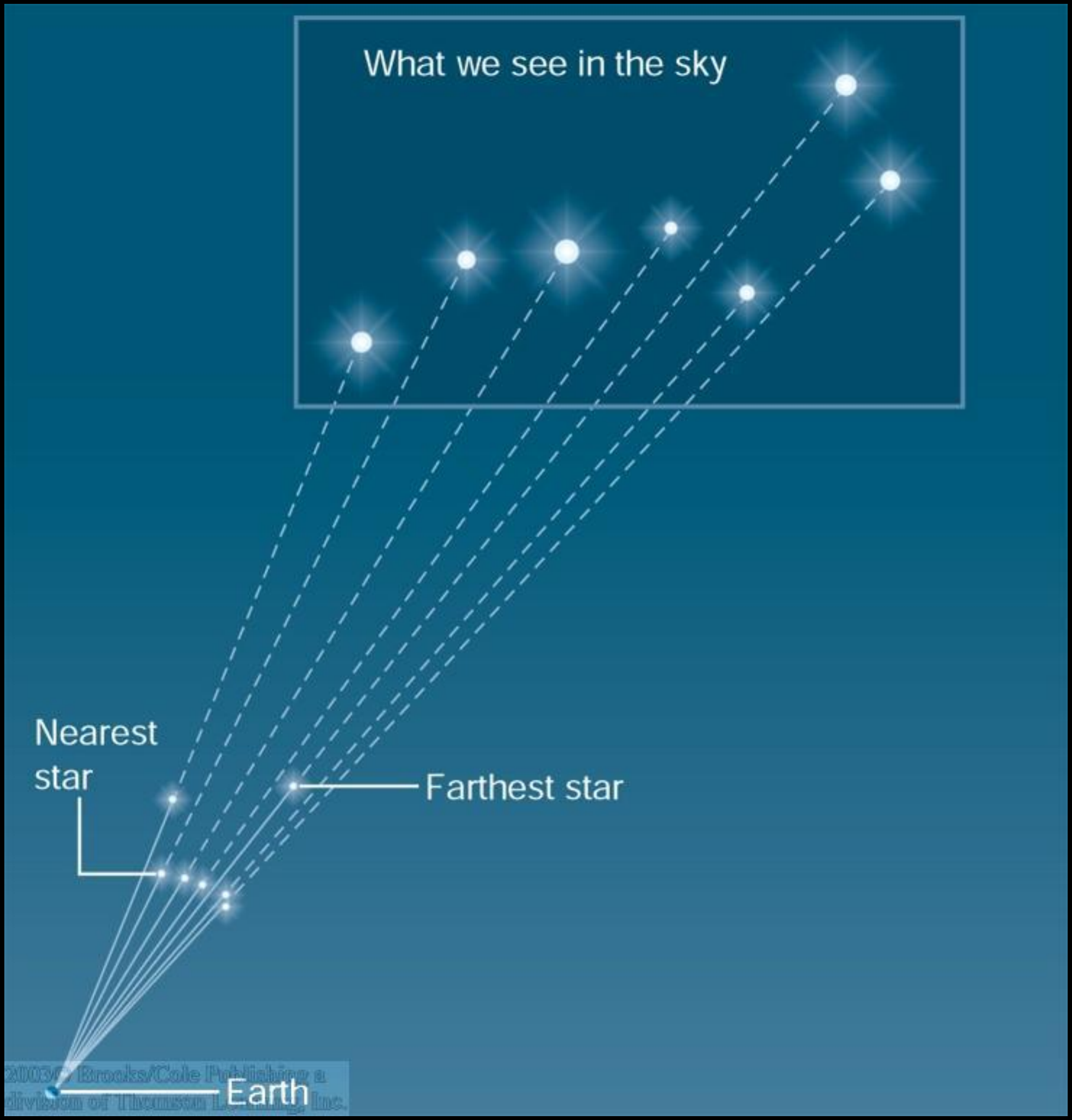
In ancient times, constellations only referred to the brightest stars that appeared to form groups, representing mythological figures.

Modern Constellations



Today, constellations are well-defined regions on the sky, irrespective of the presence or absence of bright stars in those regions.

Constellations



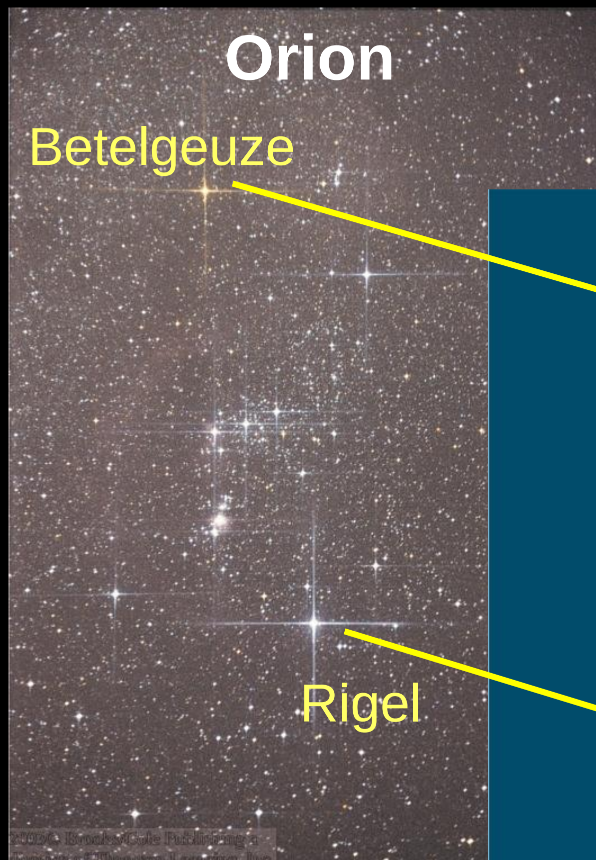
The stars of a constellation only appear to be close to one another

Often, this is only a *projection effect.*

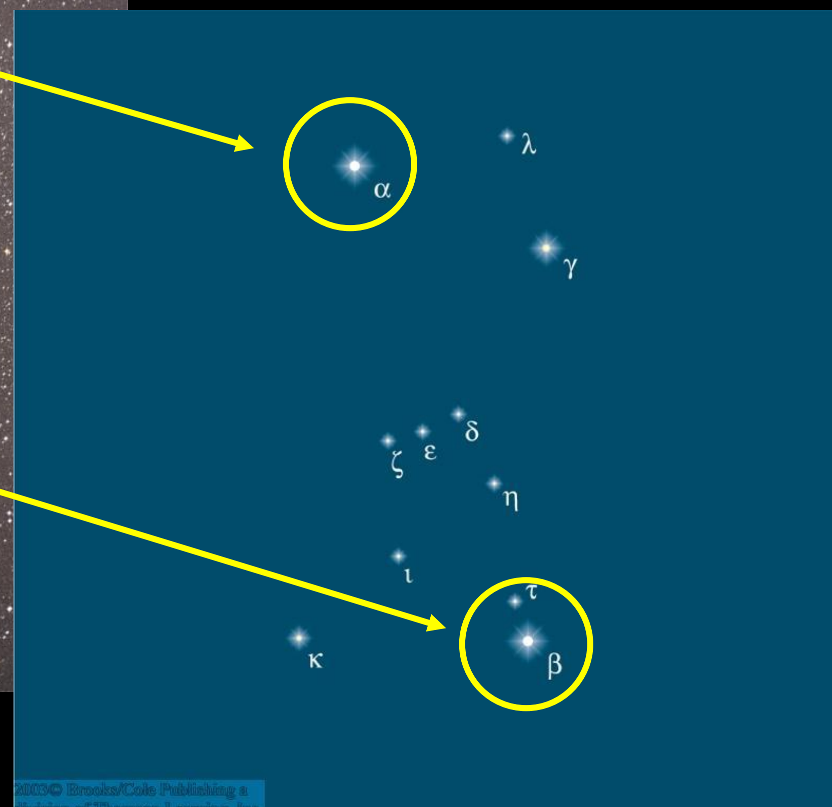
The stars of a constellation may be located at very different distances from us.

Naming of stars

Stars are named by a Greek letter (a, b, g) according to their relative brightness within a given constellation + the possessive form of the name of the constellation:



Betelgeuse = α Orionis
Rigel = β Orionis



The Apparent Brightness of Stars (Magnitude Scale)

First introduced by Hipparchus (160 - 127 B.C.):

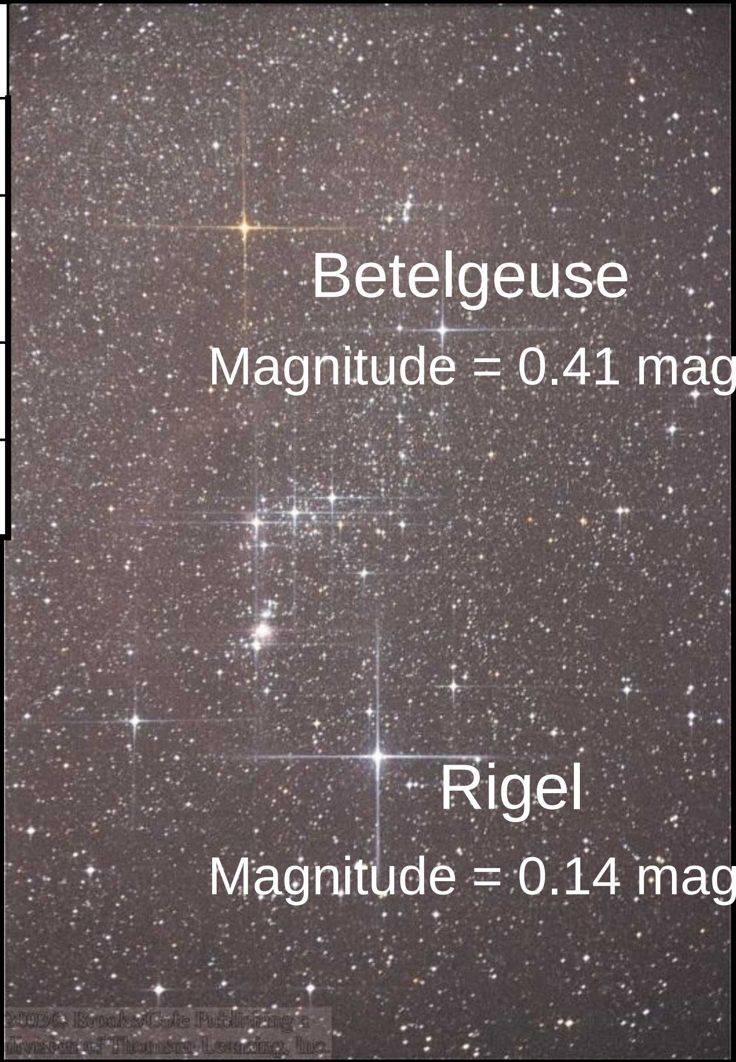
- Brightest stars: ~1st magnitude
- Faintest stars (unaided eye): 6th magnitude

More quantitative:

- 1st mag. stars appear 100 times brighter than 6th mag. stars
- 1 mag. difference gives a factor of 2.512 in apparent brightness (larger magnitude => fainter object!)

The Magnitude Scale (Example)

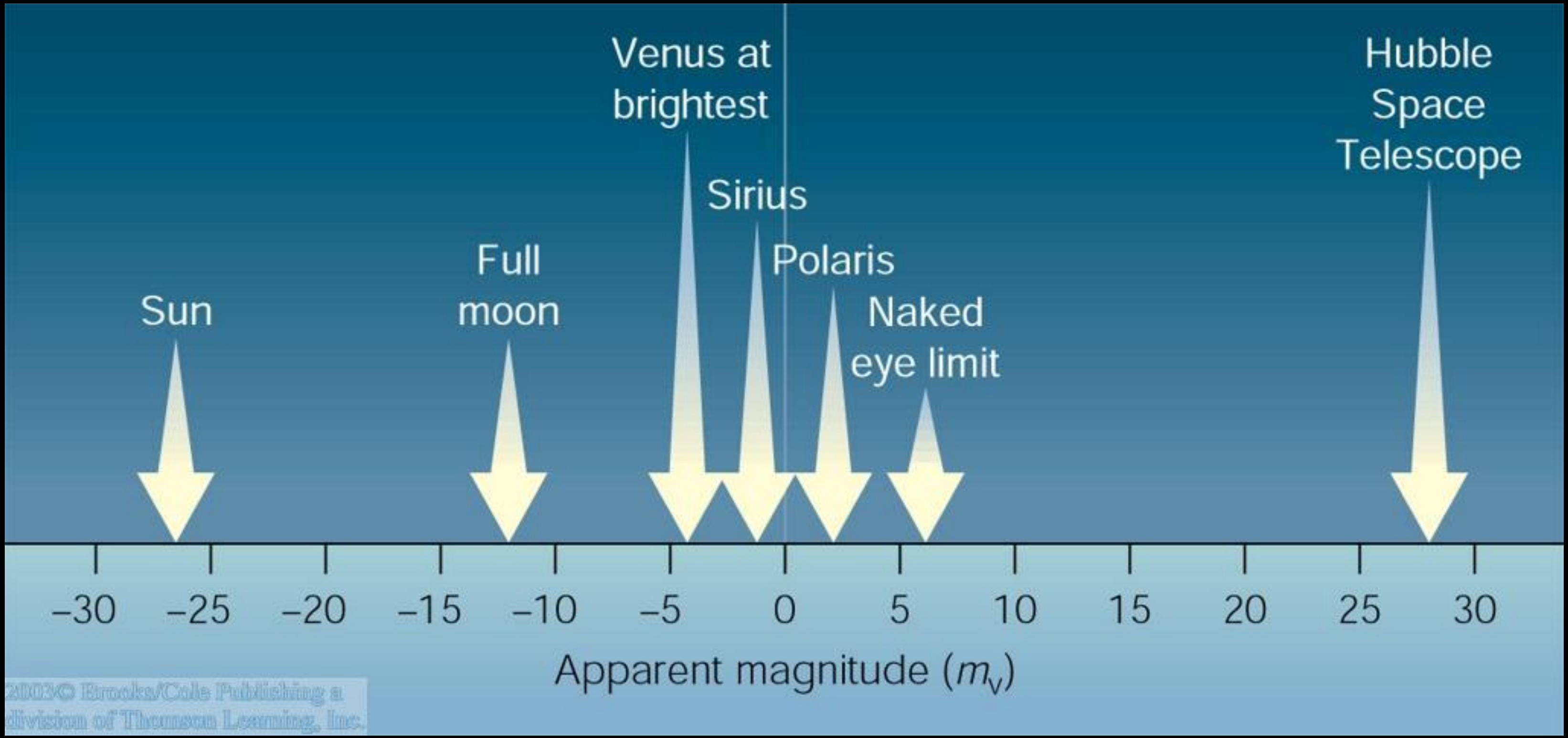
Magn. Diff.	Intensity Ratio
1	2.512
2	$2.512*2.512 = (2.512)^2 = 6.31$
…	…
5	$(2.512)^5 = 100$



For a magnitude difference of 0.41 – 0.14 = 0.27, we find an intensity ratio of $(2.512)^{0.27} = 1.28$.

The Magnitude Scale

The magnitude scale system can be extended towards negative numbers (very bright) and numbers > 6 (faint objects):

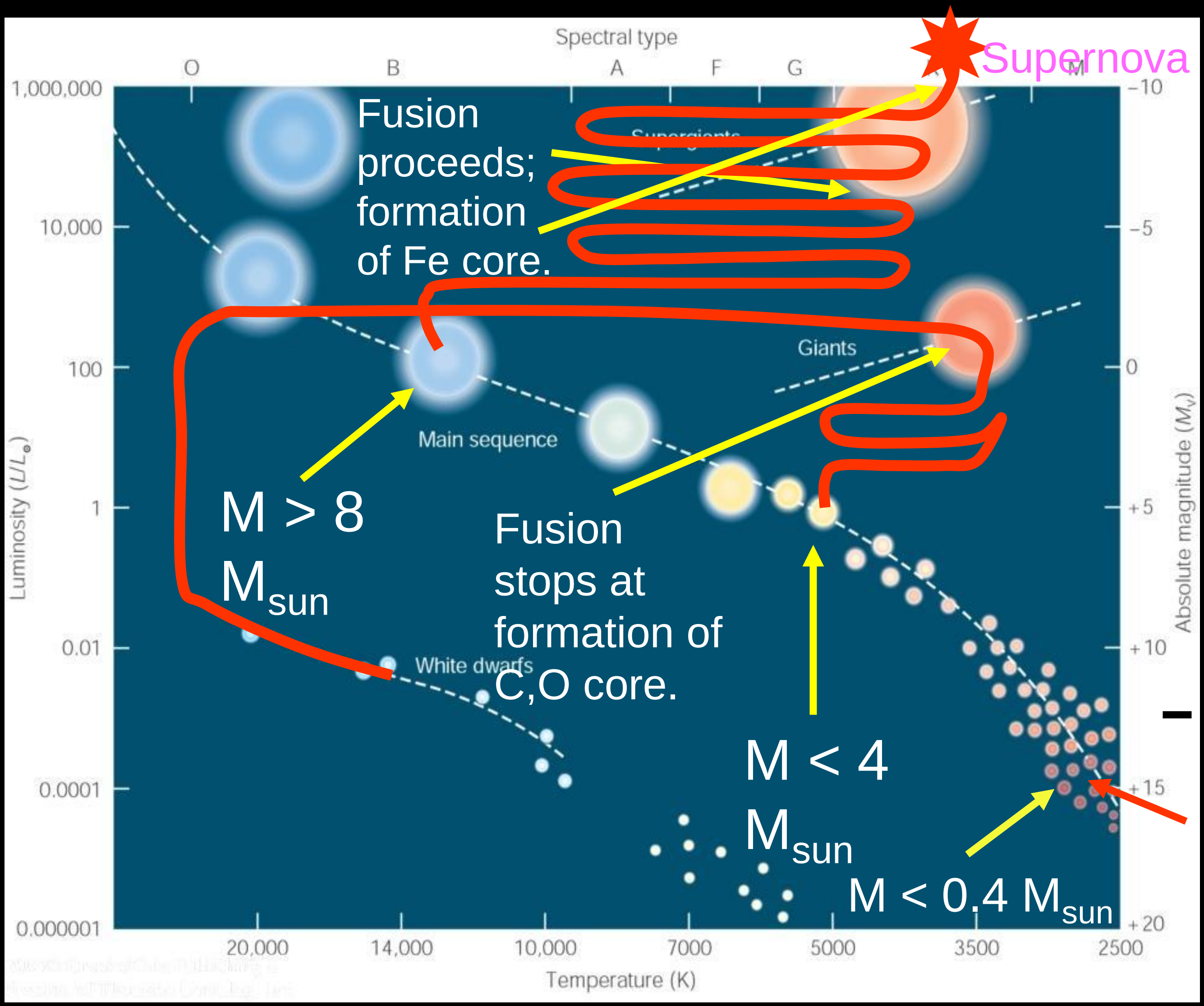


Sirius (brightest star in the sky): m_v = -1.42

Full moon: m_v = -12.5

Sun: m_v = -26.5

Evolution of Stars: Hertsprung-Russell Diagram

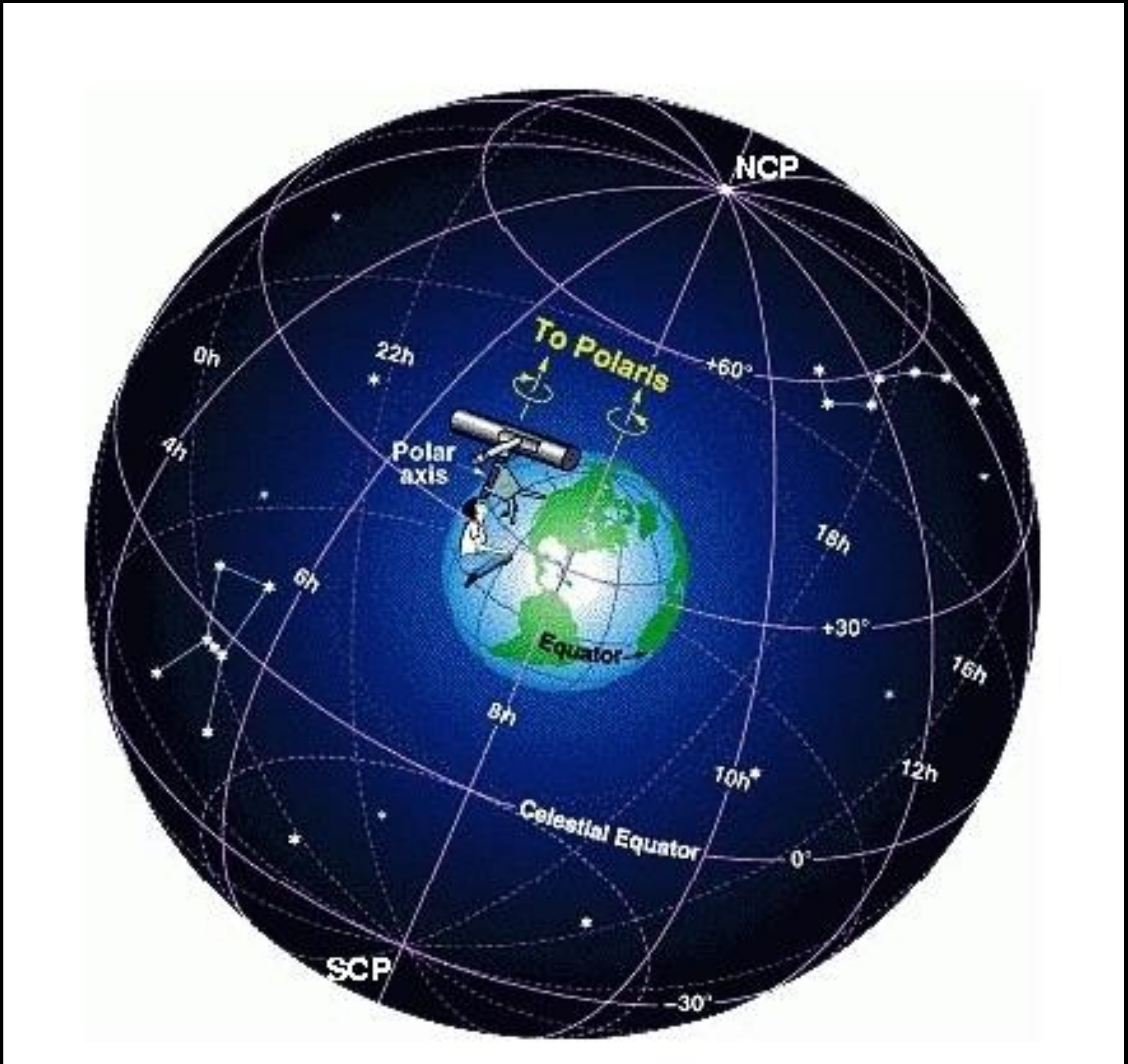


Evolution of 4 - 8 M_{sun} stars is still uncertain.

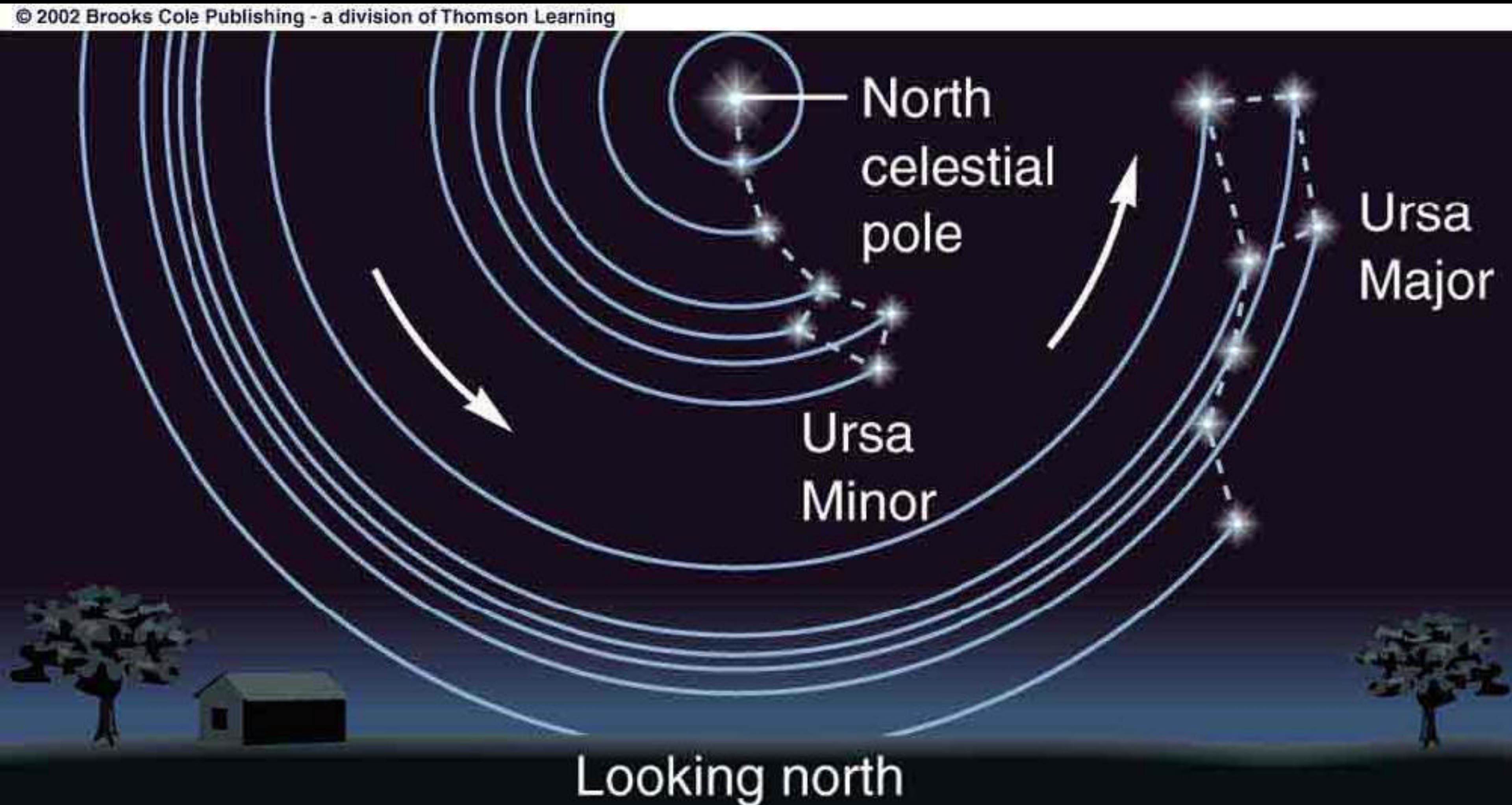
Mass loss in stellar winds may reduce them all to < 4 M_{sun} stars.

Red dwarfs: He burning never ignites

The Celestial Sphere

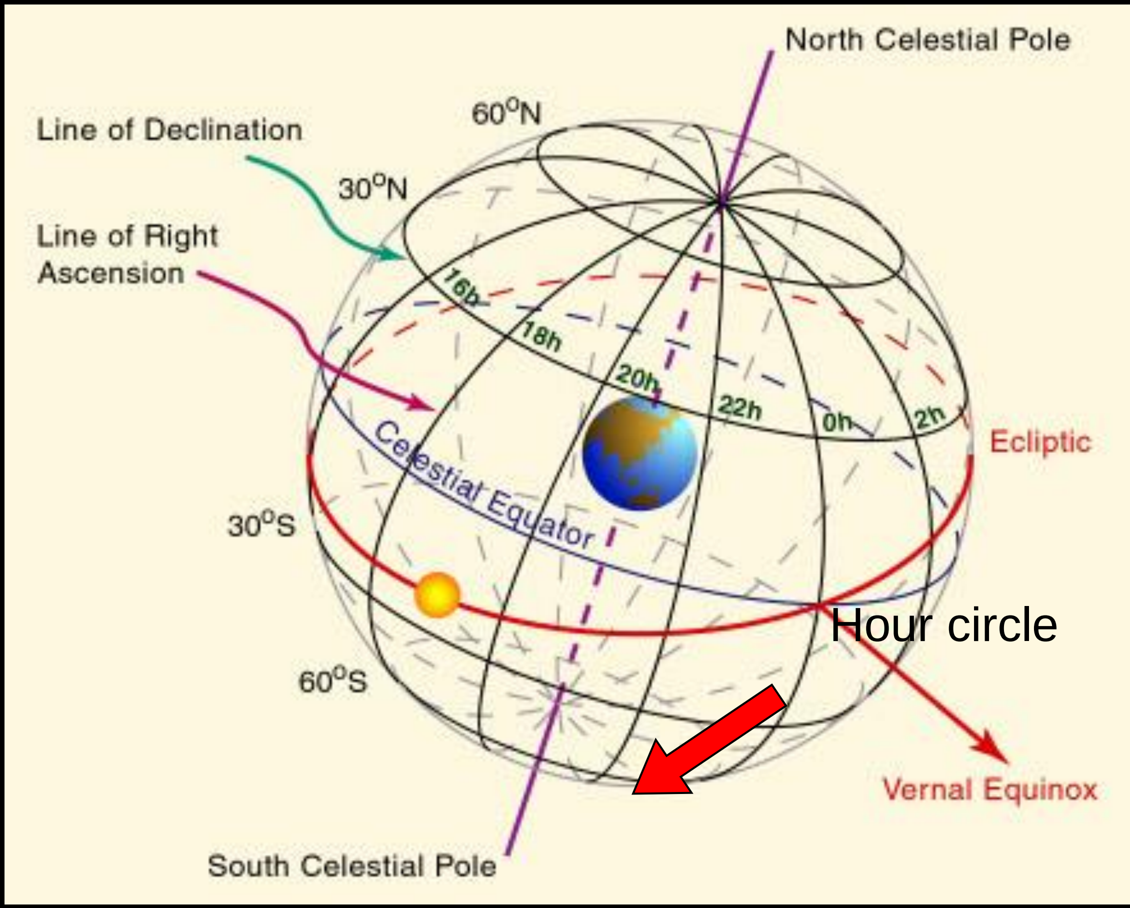


Apparent Motion of The Celestial Sphere



Equatorial Coordinate System

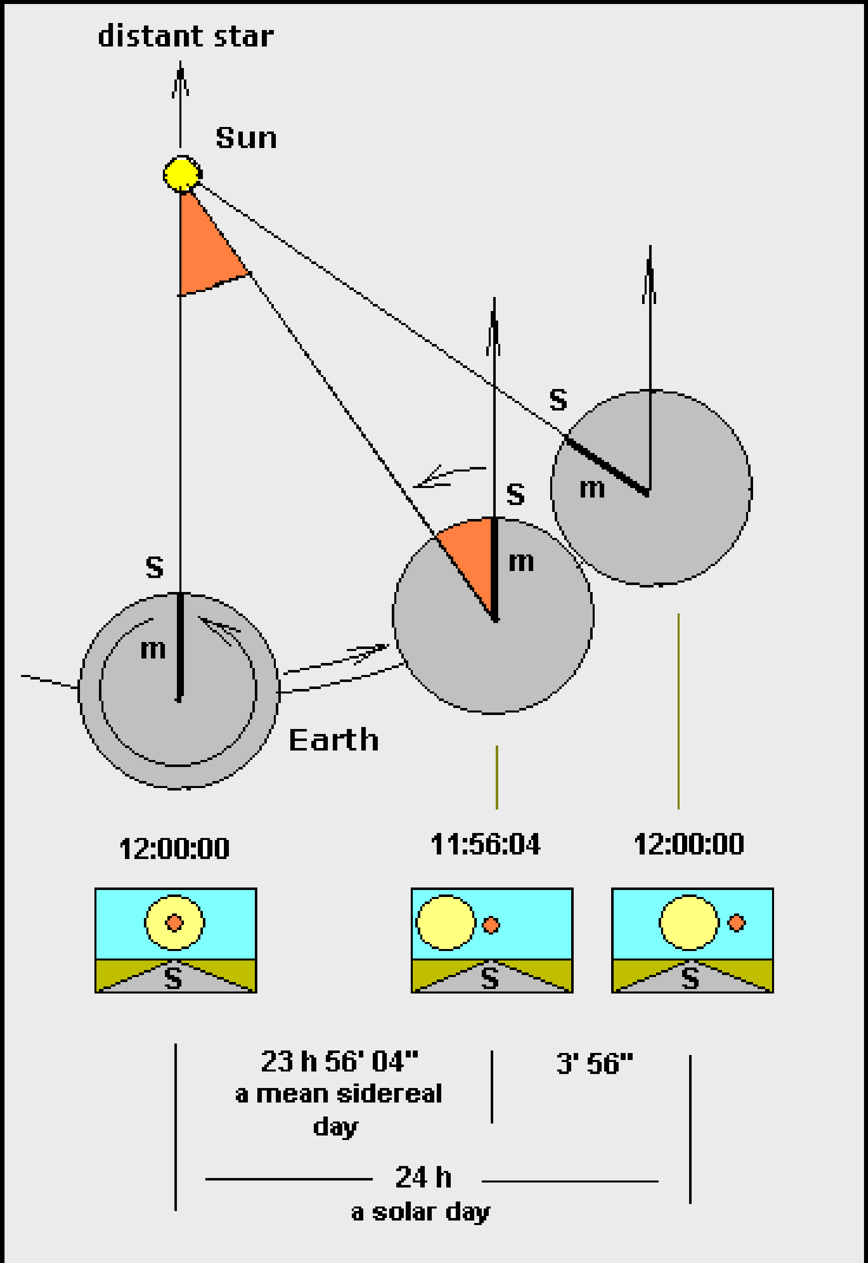
- Results in nearly constant values for the positions of distant celestial objects.
- Based on latitude-longitude coordinate system for the Earth.
- **Declination** - coordinate on celestial sphere analogous to latitude and is measured in degrees north or south of the celestial equator
- **Right Ascension** - coordinate on celestial sphere analogous to longitude and is measured eastward along the celestial equator from the vernal equinox γ to its intersection with the objects hour circle



What is a day?

- Solar day
  - Is defined as an **average** interval of 24 hours between meridian crossings of the Sun.
  - The earth actually rotates about its axis by nearly 361° in one solar day.

- Sidereal day
  - Time between consecutive meridian crossings of a given star. The earth rotates exactly 360° w.r.t the background stars in one sidereal day
    = 23h 56m 4s

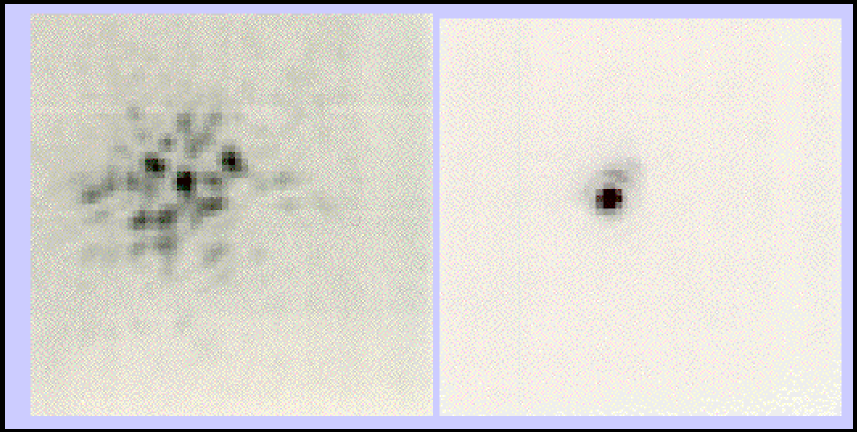


Observing guides

- Philips' Planisphere
- Norton's Star Atlas and Reference Handbook
- Turn left at Orion

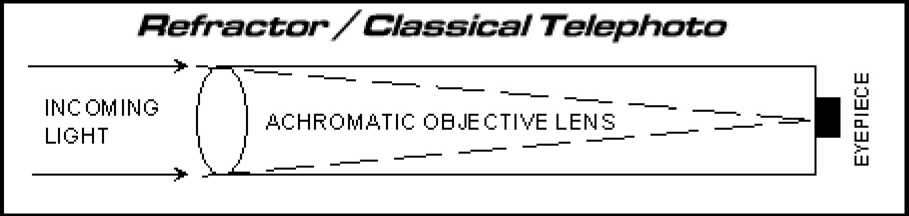
Astronomical "seeing"

- Blurring effect of looking through air
- Causes stars to twinkle and planetary detail to blur
- Not to be confused with good transparency

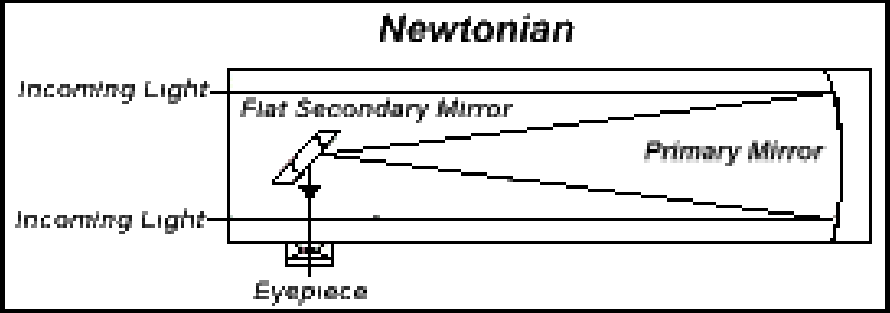


Types of Telescope

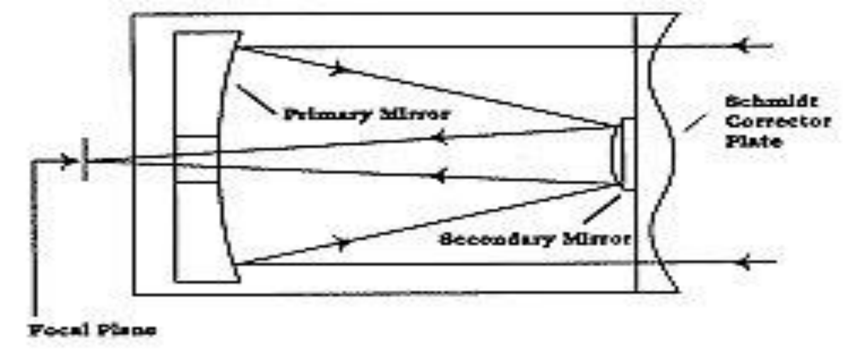
Refractor



Reflector



Catadioptric



Acknowledgements

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- 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