

# The **Heliocentric** Model of the Solar System

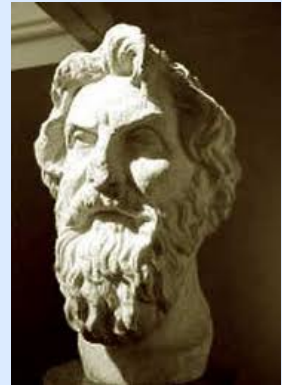


**Hypothesis:** The **Sun** is the center of the solar system.  
Only Moon orbits around Earth; Planets orbit around Sun.

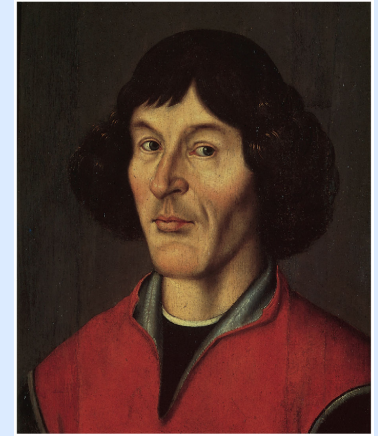
- **Aristarchus of Samos** was the first to propose it in ancient Greece (~300 BC)

-but Aristotle's model was the favorite one

- He proposed that the Sun is the 'center of life'
- Also the Earth makes **two motions**, one around itself and one around the Sun. Pretty impressive !
- Still, the Ptolemaic picture survived for almost 14 centuries



- **Nicolaus Copernicus** (~1500 AD), a Polish clerk challenged Ptolemy's model.
- Published his theory in book:
  - ' *De revolutionibus orbium coelestium* (On the Revolutions of the Celestial Spheres)'
- He introduced (again) the Heliocentric Model
- His motivation was ***simplicity***
- The critical realization that Earth is not the center of the Universe we call '***The Copernican Revolution***'
- He explained retrograde motion naturally

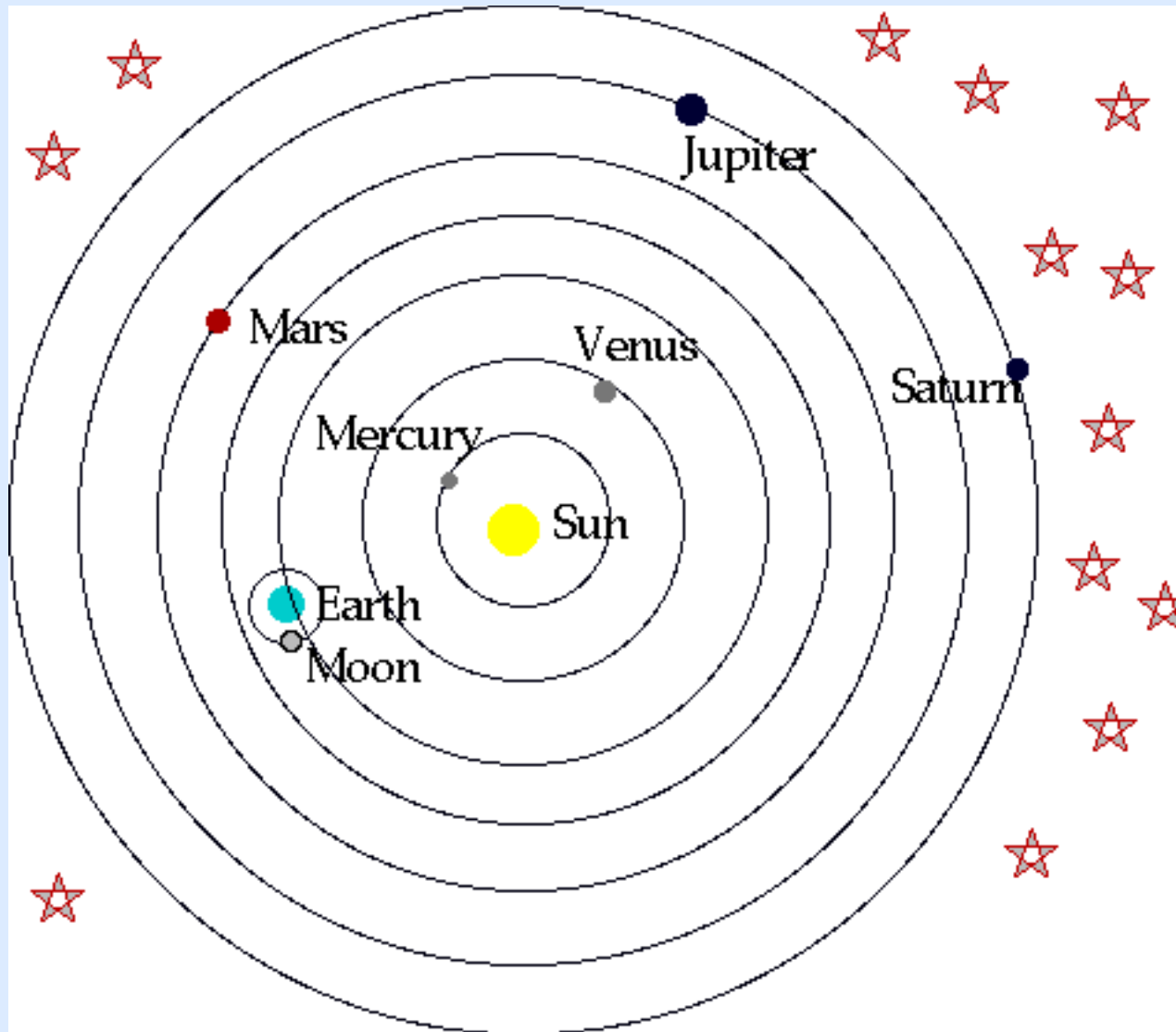


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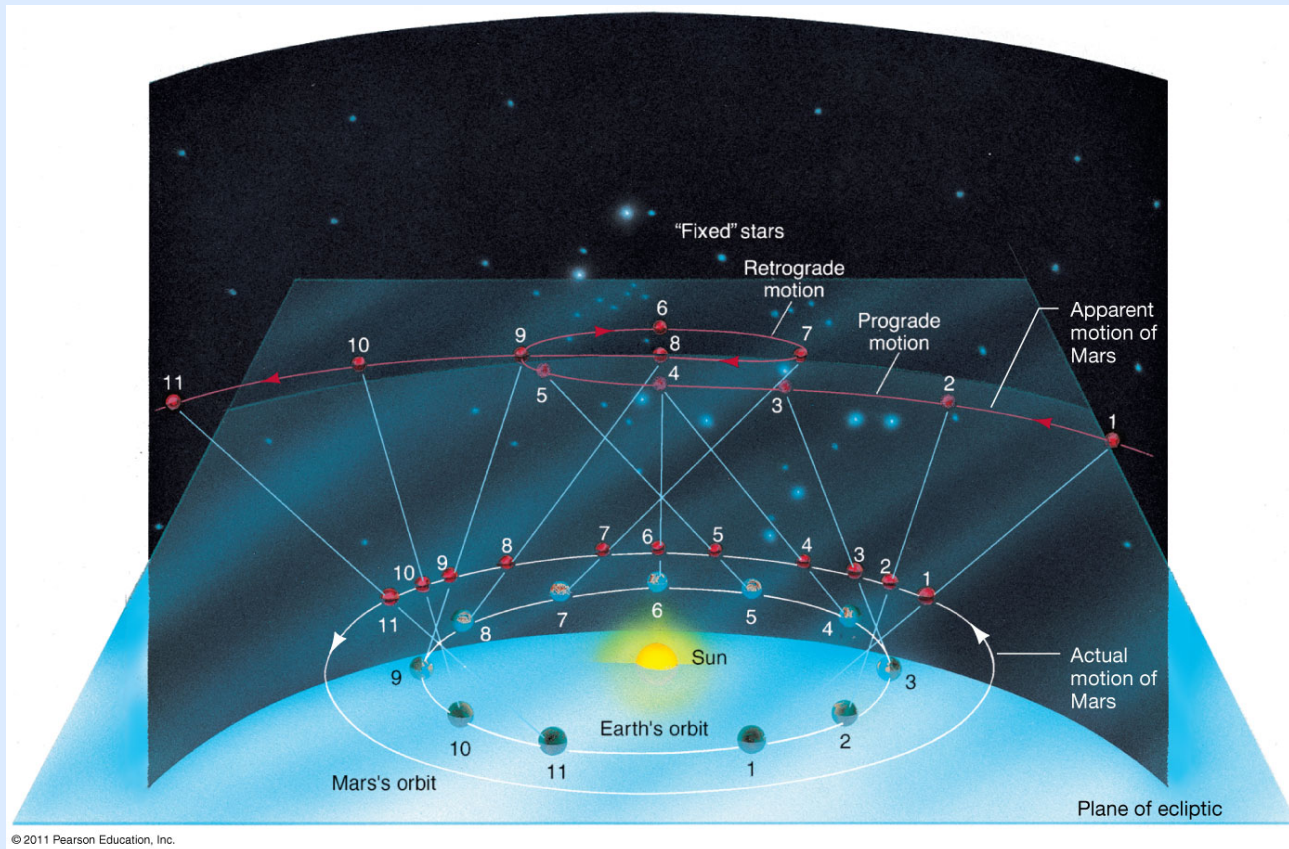
# The Foundations of the Copernican Revolution

1. Earth is not at the center of everything.
2. Center of Earth is the center of Moon's orbit.
3. All planets revolve around the Sun.
  - but still in circular orbits
4. Earth is just one of the Planets.
5. The stars are very much farther away than the Sun.
6. The apparent motion of the Sun and stars is due to Earth's rotation around itself

# The Copernican Universe



# Retrograde motion, Copernican style



Motion explained easily (Geometry and Earth moves faster)  
Watch the following video for a nice illustration of the effect

[http://www.youtube.com/watch?v=72FrZz\\_zJFU](http://www.youtube.com/watch?v=72FrZz_zJFU)

# Retrograde, Copernican style (Video)

*Retrograde Motion in the  
Copernican System*

# The Birth of Modern Astronomy



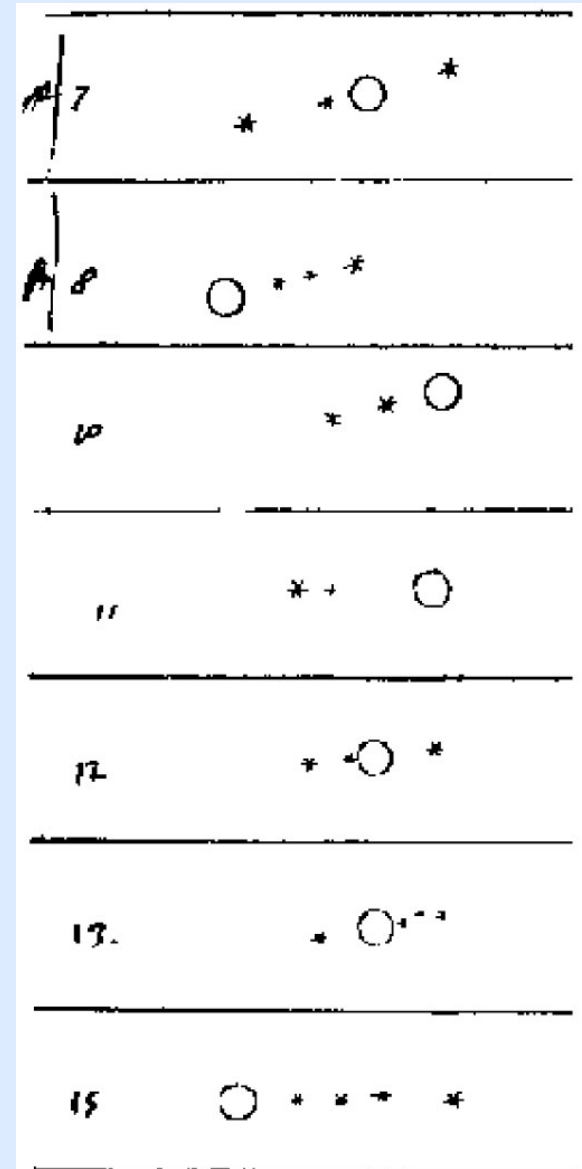
Galileo Galilei  
(1564-1642)

- Telescope was invented around 1600
- Galileo built his own, he improved (did *not* invent) telescope (from 3x to 30x)
- Was inspired by Kepler's work
- Made detailed observations
- Published *Dialogo* in 1632
- Condemned by Inquisition, sentenced to house arrest until death
- 1992: John Paul II pardons

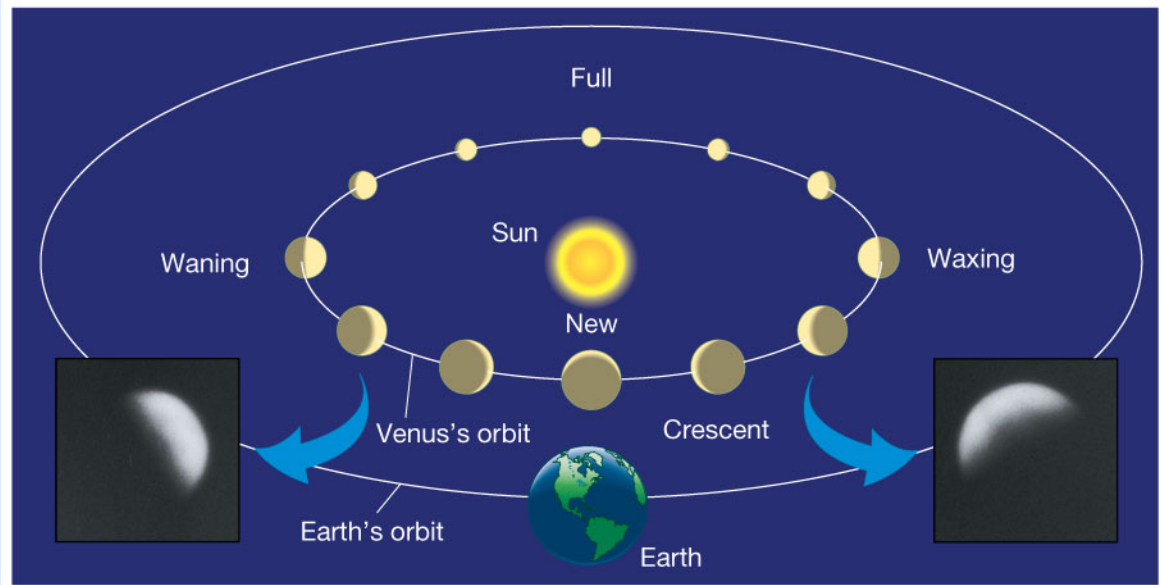
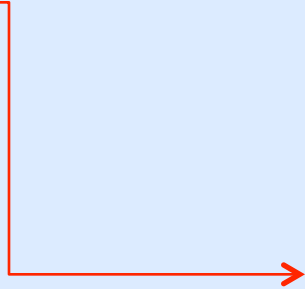


# Galileo's Observations

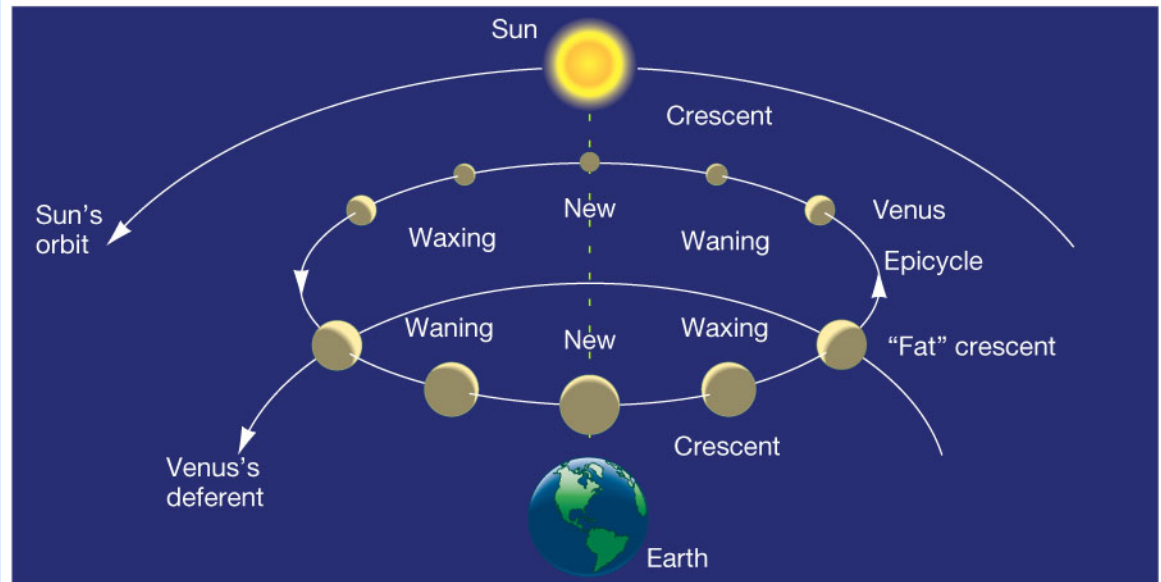
- Moon has mountains and valleys
  - terrain like that on earth
- Sun has sunspots, and rotates
- Jupiter has moons (picture)
  - smaller object rotate around larger
- Venus has phases (next slide)



The phases of Venus cannot be explained by a Geocentric model



(a) Sun-centered model



(b) Ptolemy's model

# The Laws of Planetary Motion

- Galileo demolished Ptolemy's system and established the Copernican Heliocentric system
- Copernican approach is a classic example of the Scientific method
- Still, the **LAWS** of governing the motion of celestial objects were still unknown
- Also the **Dynamics** were missing
  - *what forces* were responsible for these motions?

# Johannes Kepler (1571-1630)



- Kepler's laws were derived using observations made by Tycho Brahe
- He formulated three Laws that explain everything!
- Tycho collected the data but Kepler had the genius to see through them!

End of story? Not quite....still, the dynamics, the cause of all this motion not found

# Newton



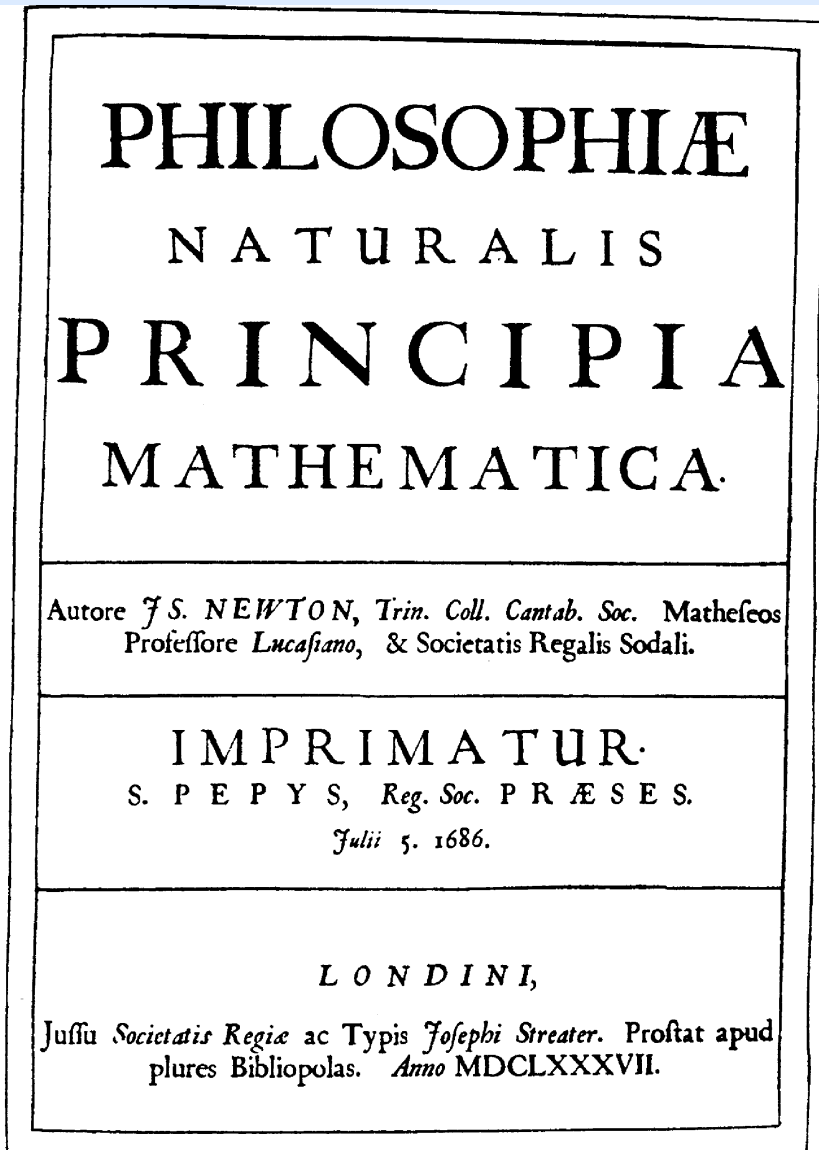
**Isaac Newton (1642-1727)**

- the Greatest ever?
- 2 year country vacation (to escape bubonic plague)
- revolutionized all of science and mathematics
- His three laws of motion and the law of gravity are the cornerstones of Classical Mechanics->sometimes called Newtonian Mechanics

# Newton's Laws

- Newton's laws of motion explain *how objects interact* with the world and with each other.
  - Kepler's laws are a simple consequence of these laws
- Newton's law of gravity identifies the responsible *force* behind celestial motion
  - plus provides the formula to estimate it

# Principia Mathematica (1686)



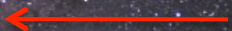
- the most important secular book in history?
- explained *all* motion
- ideas:
  - three *laws of motion*
  - plus the law of *gravity*

# A Short Tour of the Universe

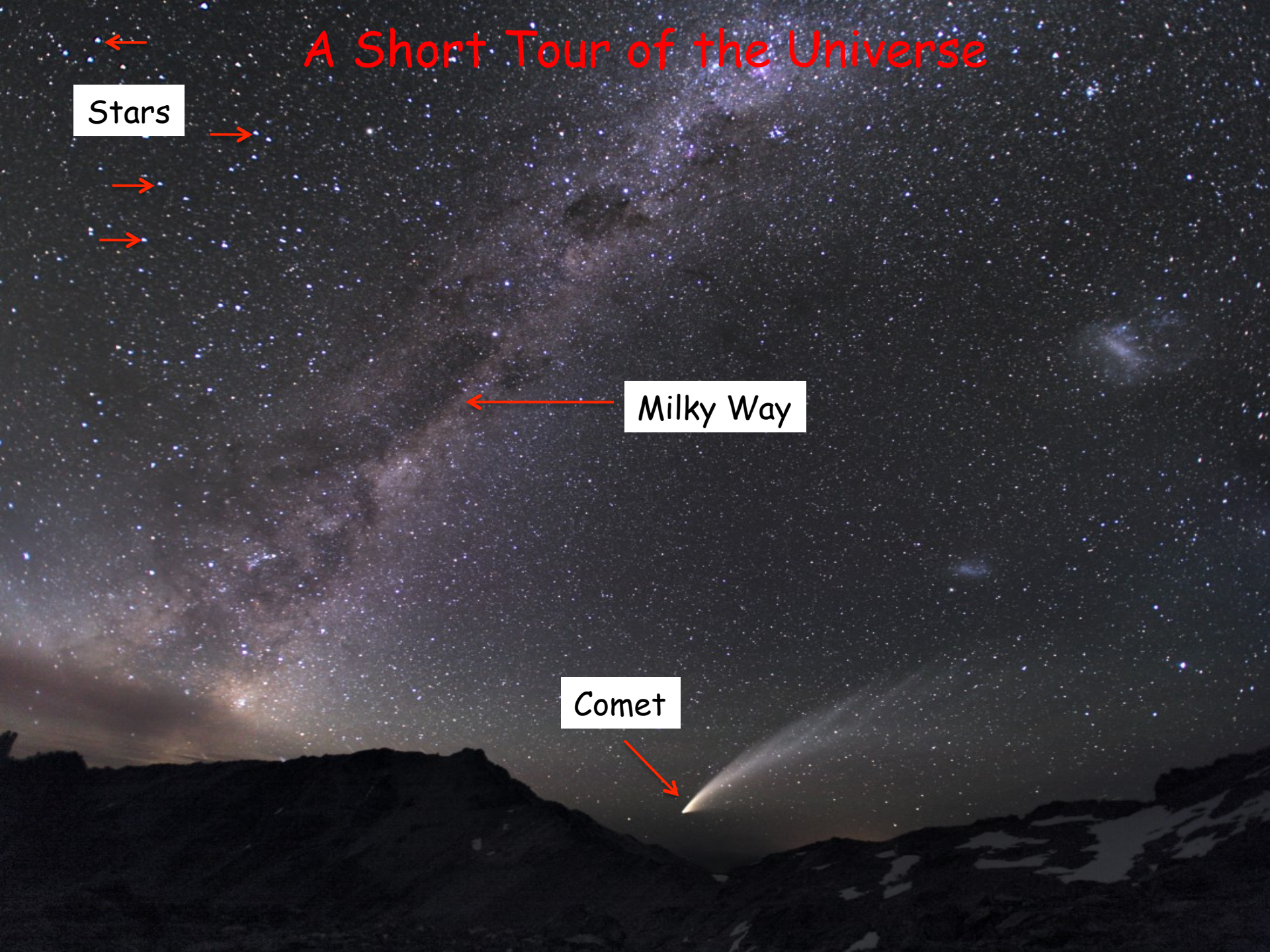
Stars



Milky Way

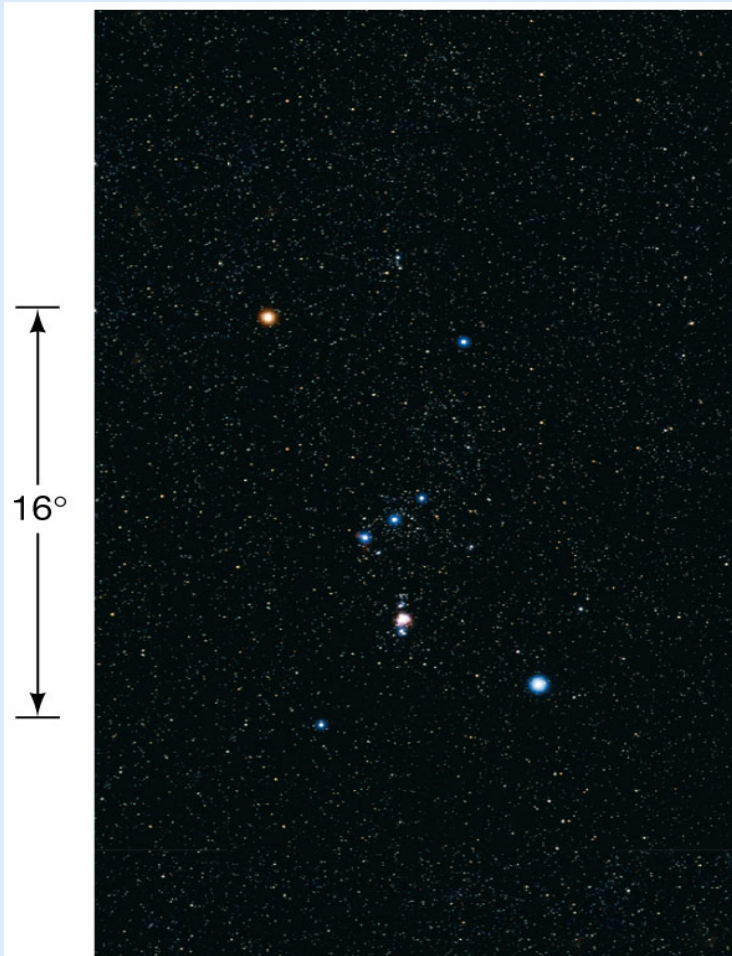


Comet





- At first sight, the night Sky appears as a sphere, a vault surrounding us with little bright ‘dots’, the stars ‘fixed’ on it. The patterns of the ‘fixed stars’ appear stable in time.
  - we call this vault *Celestial Sphere* and the stars on it *Fixed Stars*

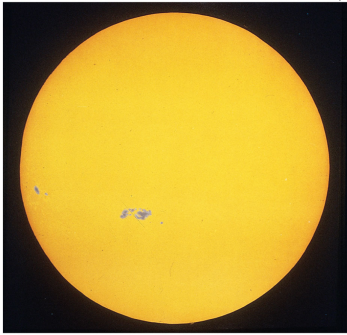


The picture on the left shows perhaps the most famous star complex on the night sky, Orion.

It is the actual sky image, more or less what the naked eye would see in a clear night far from city lights.

The relative position of the stars, for example the 3 stars on a line at the center of the picture, seems to be ‘fixed’ relative to each other, i.e. they do not change relative positions in the course of many years.

- Besides the bright **Sun** (the closest Star to us), the other big and bright object of the night (and day) sky is the **Moon**, Earth's satellite



SUN

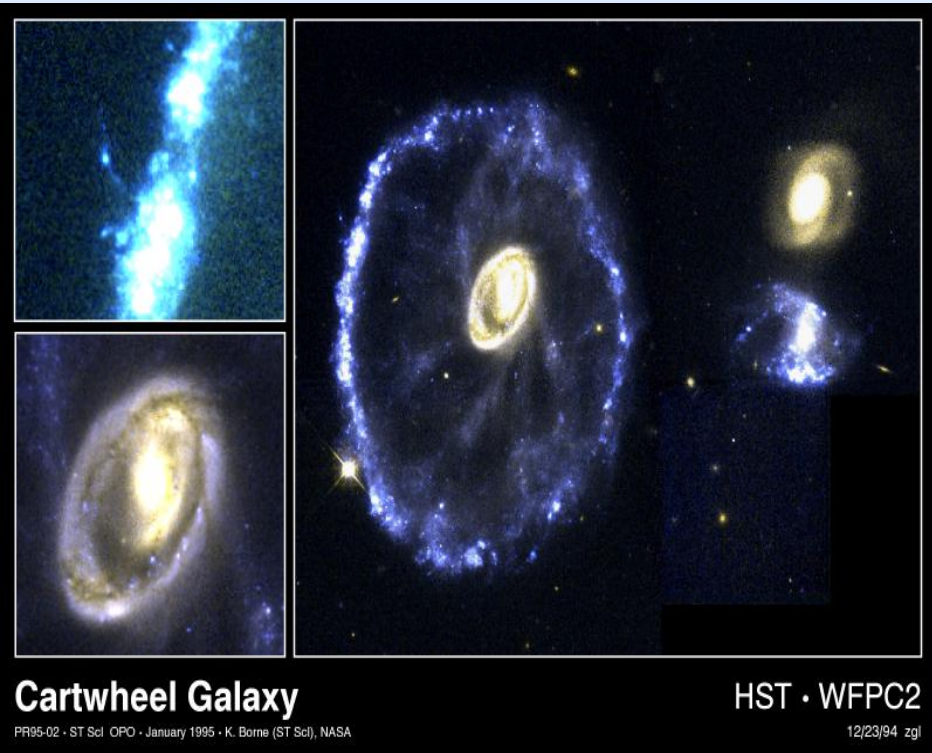


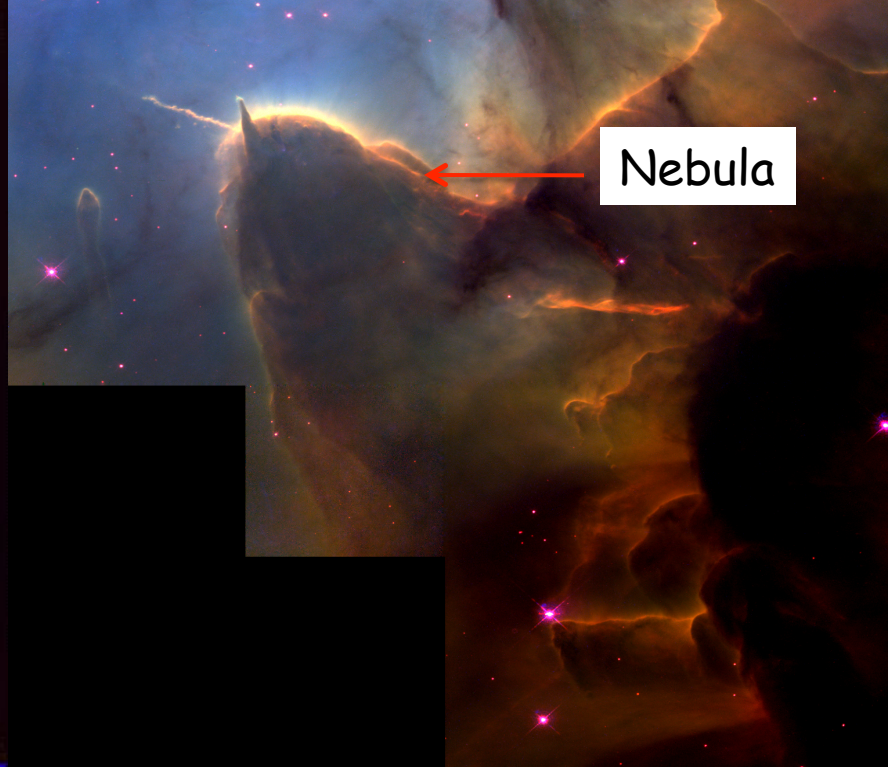
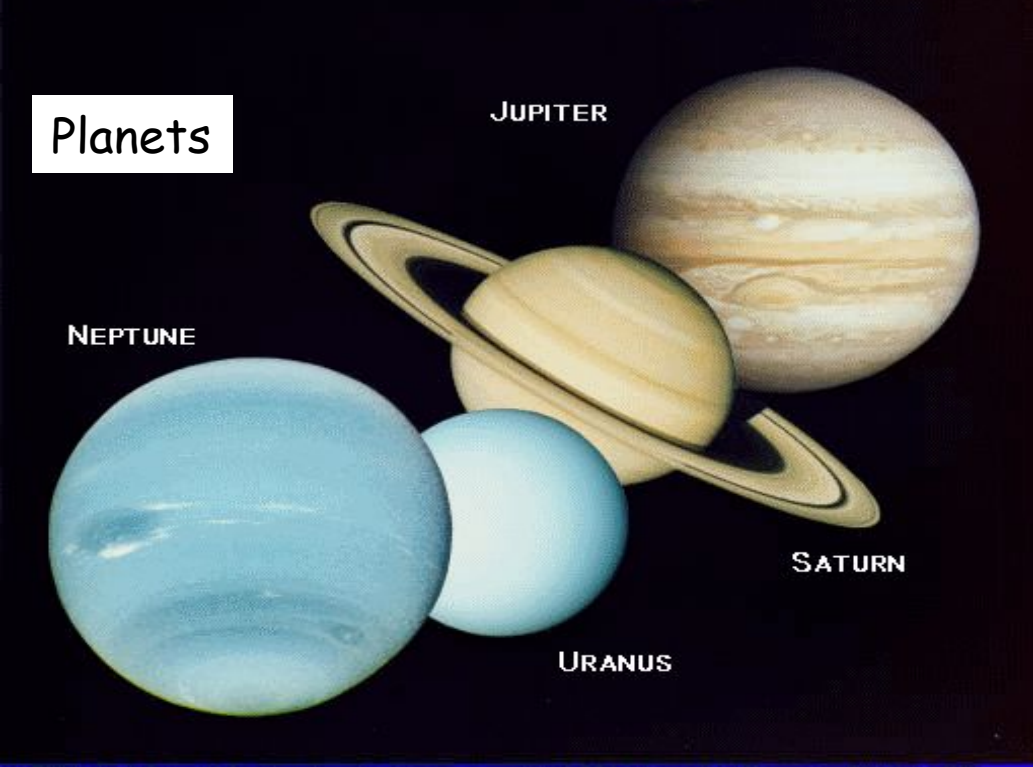
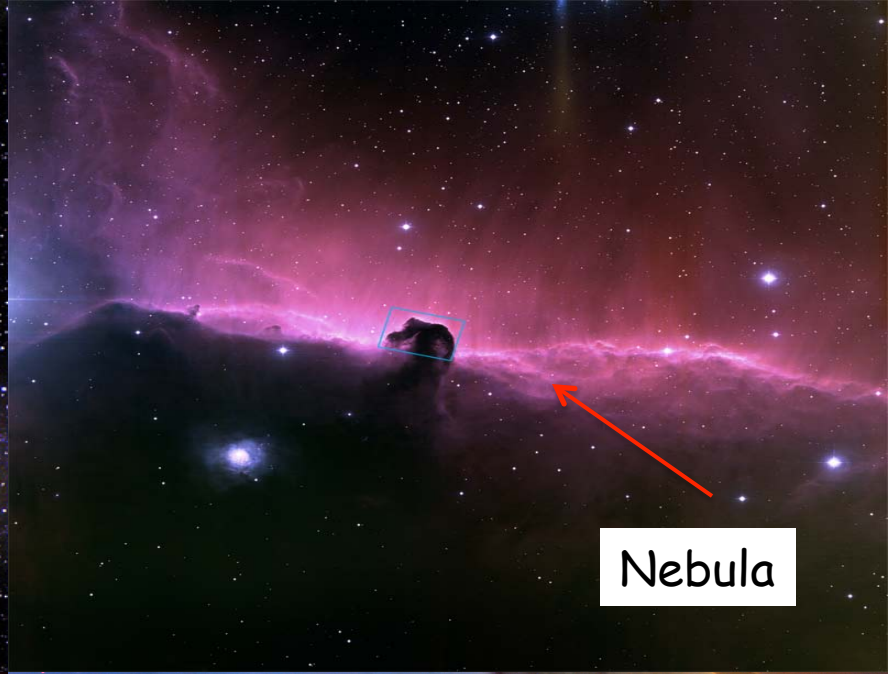
MOON

- We also see **Planets**, like Mars, Venus, Jupiter, Saturn etc that seem to move but very slowly in the sky. Our Earth is a planet too.



- The next thing in size and distance is **Stars** other than our Sun and **Galaxies** (our own galaxy, the **Milky Way** as well as others).

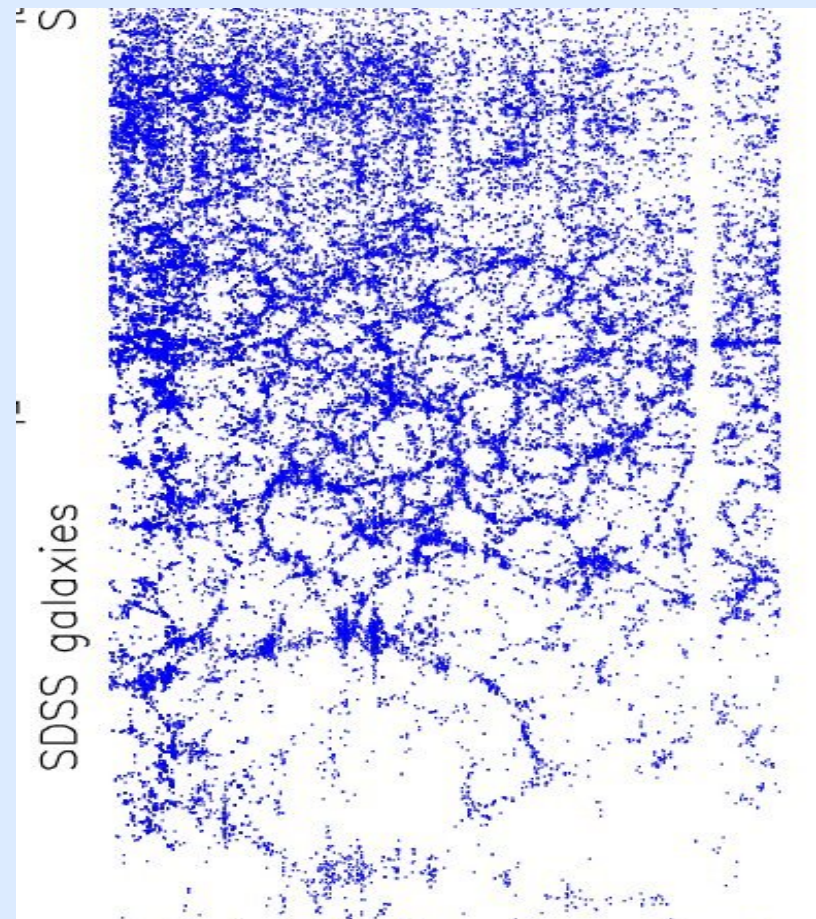




- The next thing in size and distance is **Clusters** and **Super-clusters** of Galaxies



**Each bright dot is a galaxy not just a star. This largest-known cluster contains more than 1000 galaxies. Not visible with naked eye.**



**Galaxy super-clusters. Each dot is a galaxy or a cluster of galaxies**

# Our Place in Space

## *The Scale of the Universe*

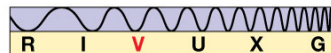
- Earth is average—we don't occupy any special place in the universe
  - Just one of eight planets circling around the Sun who, in turn, is located in one arm of our galaxy and rotates around the galactic center
- Our Sun is one (the closest to us) of about 200 Billion (200.000.000.000) Stars that make up our Galaxy, the Milky Way



- The Sun is about 100 times larger in diameter than Earth.
- In astronomy miles are too small a unit to measure distances.
- More appropriate units are the **light-year** and the **AU** (Astronomical Unit)

- A light-year is the distance a beam of light travels in a calendar year.
- The galaxy in the picture is about 100,000 light-years across, about the same as our Milky Way galaxy. For comparison the distance Earth-Moon is about 1.5 light-seconds

About 1000 quadrillion kilometers, or 100,000 light-years



- A light-year is equal to 10 Trillion kilometers or about 6 Trillion miles.
- The light travels 300,000 kilometers or 186,000 miles a second
- The distance between Earth - Sun is about 93 million miles (150 million kilometers). It is called 1 AU (astronomical unit) and serves as a big unit to measure intermediate distances.
- One AU is travelled by light in 8.3 minutes
- There are 100-500 Billion galaxies in the Universe

• Scales are very large: one can see in the picture the enormous factors involved as we move from one size to the next

