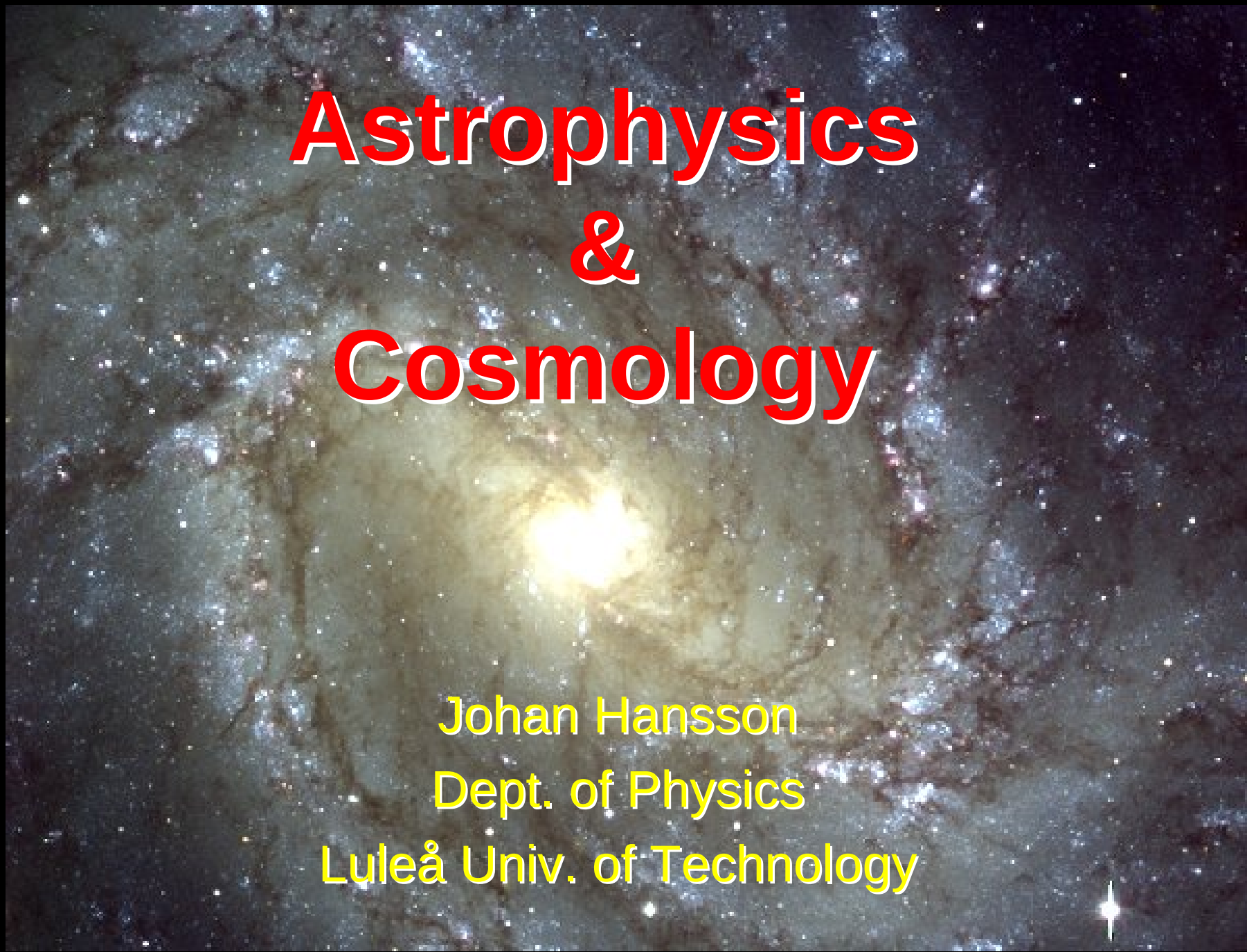


Astrophysics & Cosmology

Johan Hansson
Dept. of Physics
Luleå Univ. of Technology

ME = Johan Hansson, Ph.D.

- **Associate Professor** (“Docent”) in Physics
- **Teacher + Researcher** (Part.+Astrophys.)
- ***Undergraduate*** (1993): **Uppsala U.** (Helsinki U., Sussex U.)
- ***Ph.D.*** (1998): **Luleå U.** (Torino, Paris, Thessaloniki, Clermont-Ferrand)
- ***Research*** Berkeley, Torino, etc.

Lecture 1

Overview

To understand the universe, astrophysicists use the laws of physics to construct testable theories and models.

Scientific method

- *Based on observation, logic, and skepticism.*

Hypothesis

- *A collection of well thought-out ideas to explain a phenomenon*

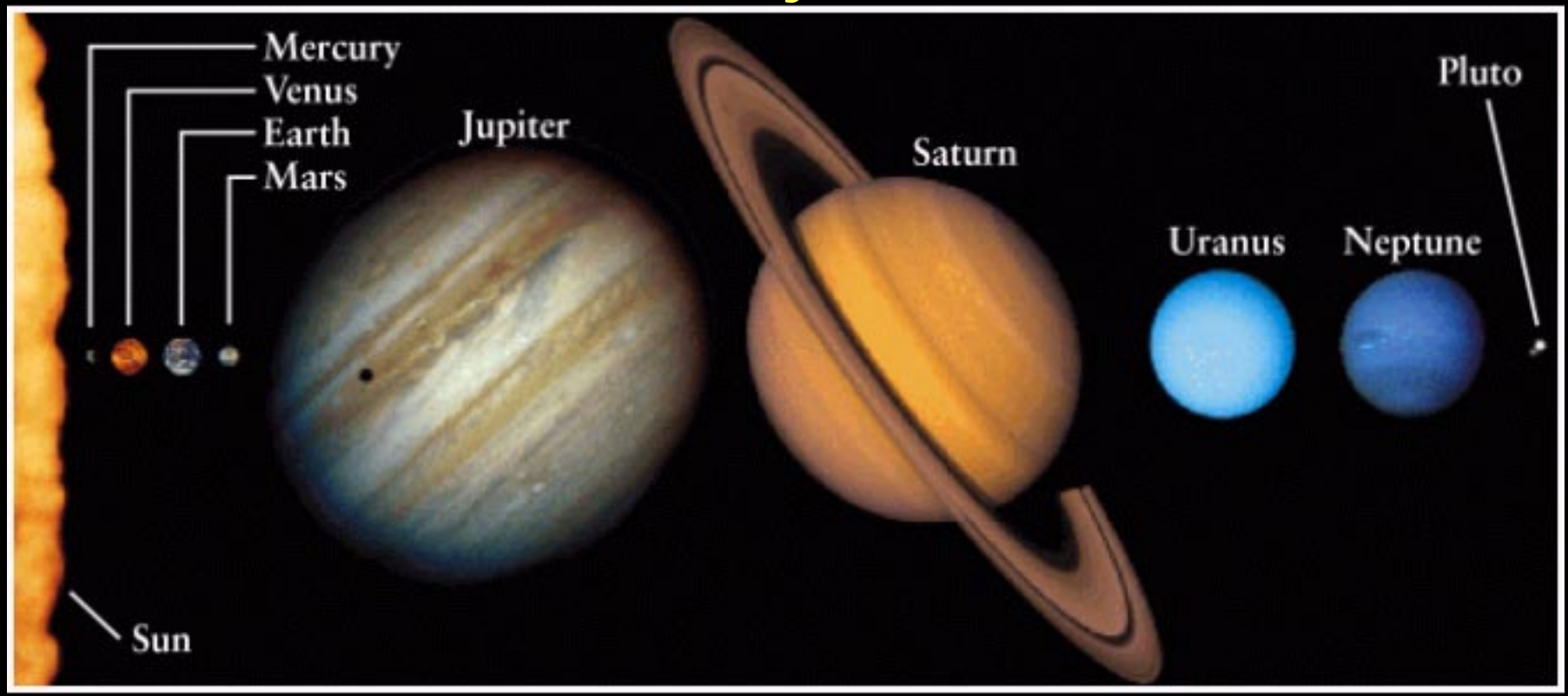
Model.

- *Hypotheses that have withstood observational and experimental tests.*

Theory

- *A well-founded body of related hypotheses and models that form a self-consistent description of nature.*

By exploring the planets, astronomers uncover clues about the formation of the solar system.

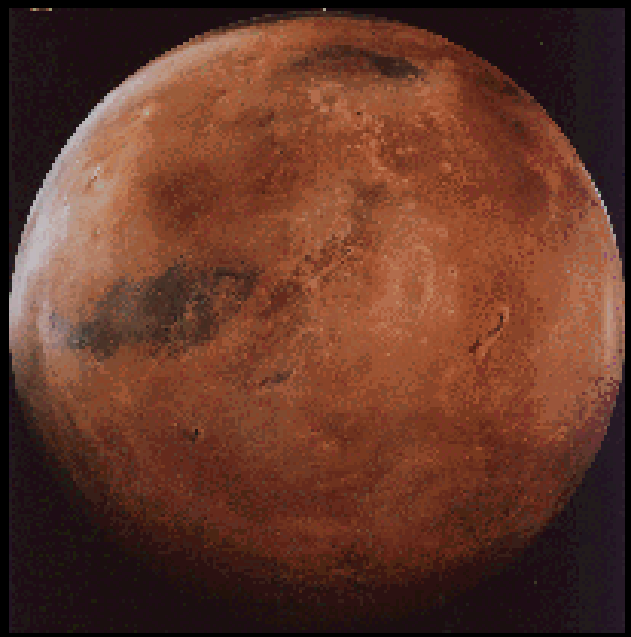


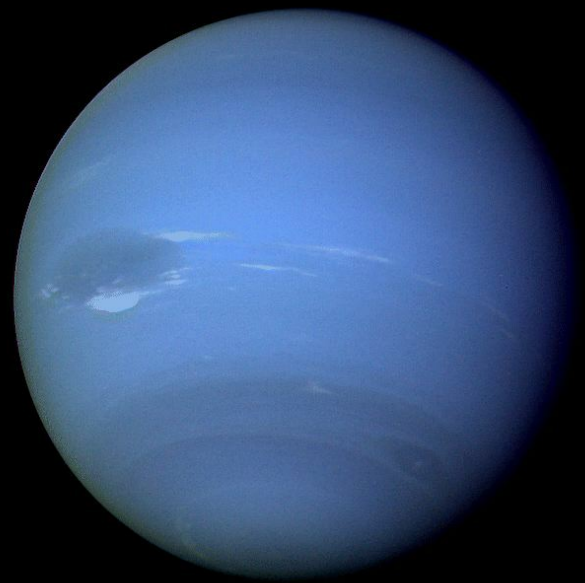
Solar system: *one star (the Sun), at least eight planets, nearly 100 moons, countless asteroids and comets.*

Star

A large, glowing ball of gas that generates heat and light through nuclear fusion

Planet





A moderately large object which orbits a star; it shines by reflected light. Planets may be rocky, icy, or gaseous in composition.

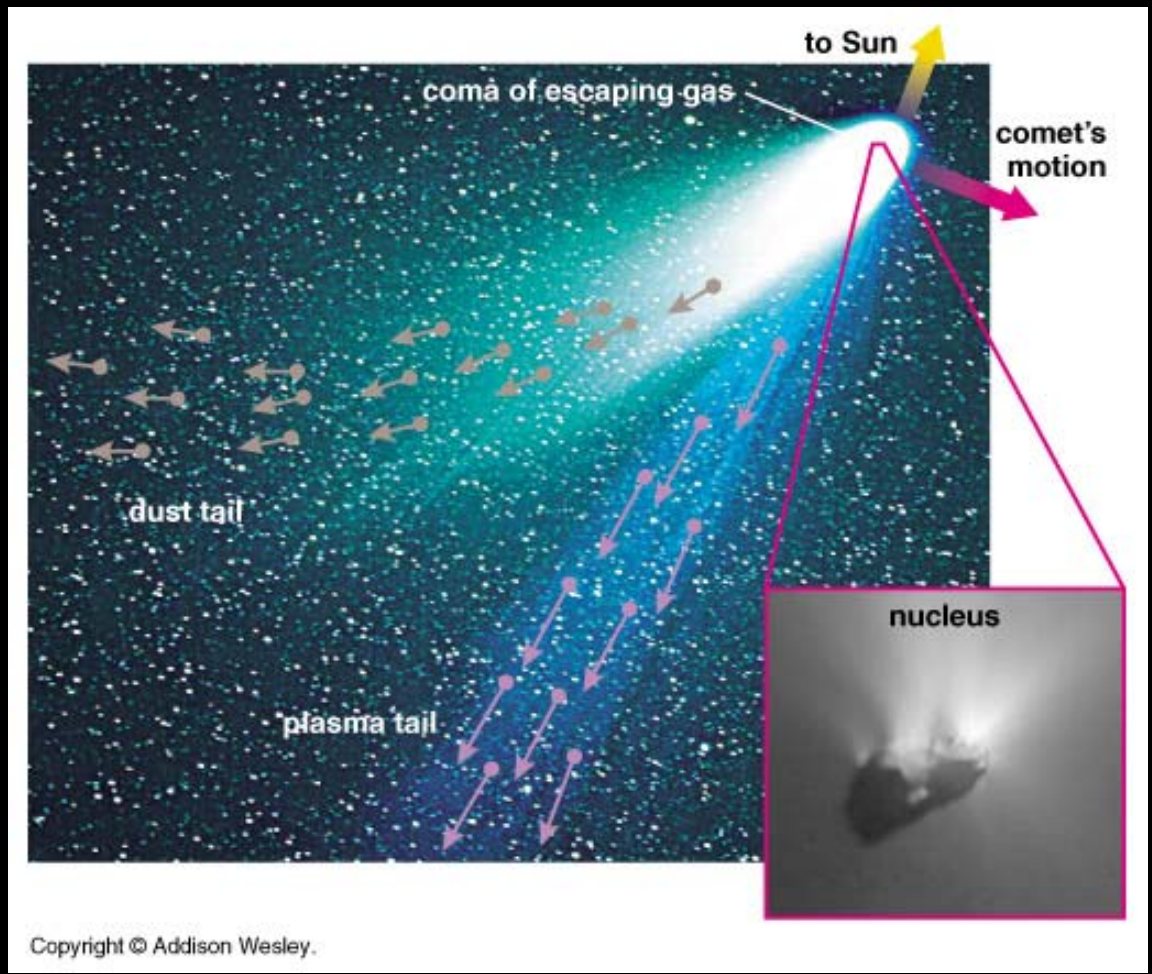
Moon

An object which orbits a planet.

Asteroid

A relatively small and rocky object which orbits a star.

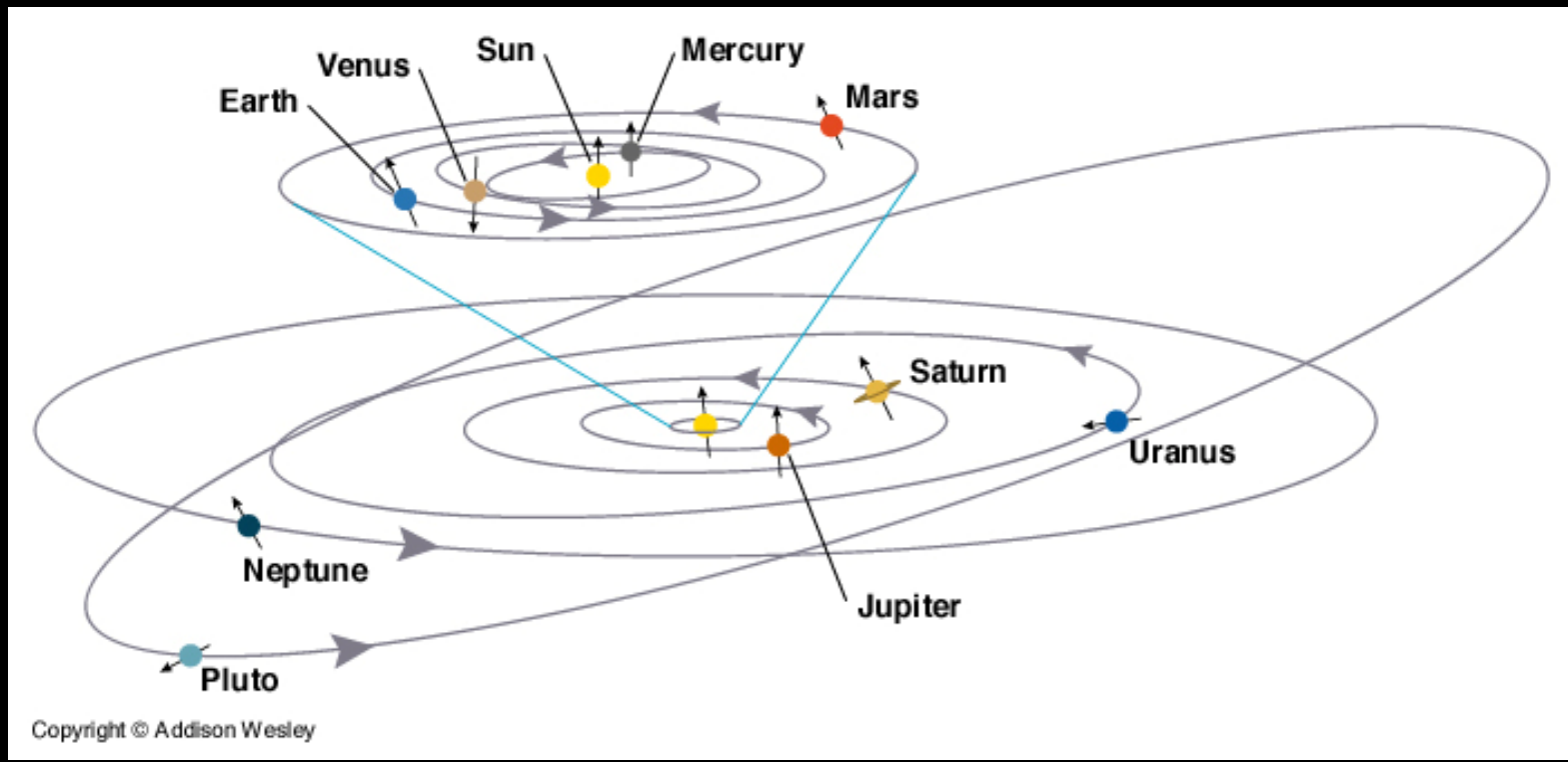
Comet



A relatively small and icy object which orbits a star.

Solar (Star) System

A star and all the material which orbits it, including its planets and moons



Nebula

An interstellar cloud of gas and/or dust

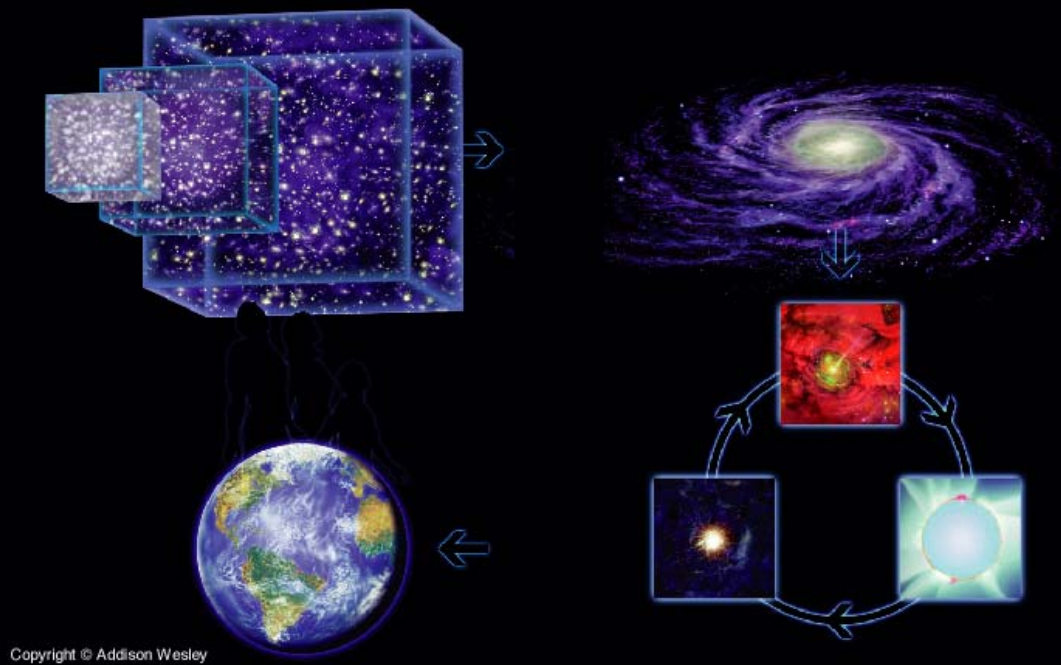
Galaxy

A great island of stars in space, all held together by gravity and orbiting a common center

Where do we come from?

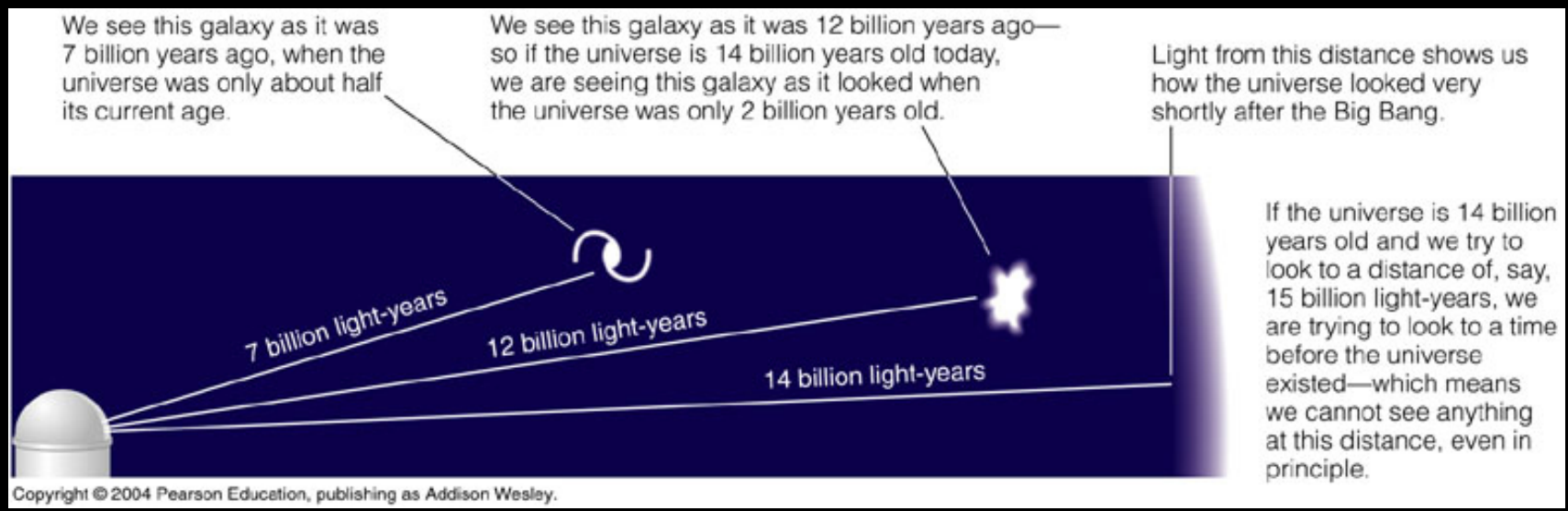
- The first (and simplest) atoms were created during the **Big Bang**.
- More complex atoms were created in stars.
- When the star dies, they are expelled into space…. to form new stars and planets!

Most of the atoms in our bodies were created in the core of a star!



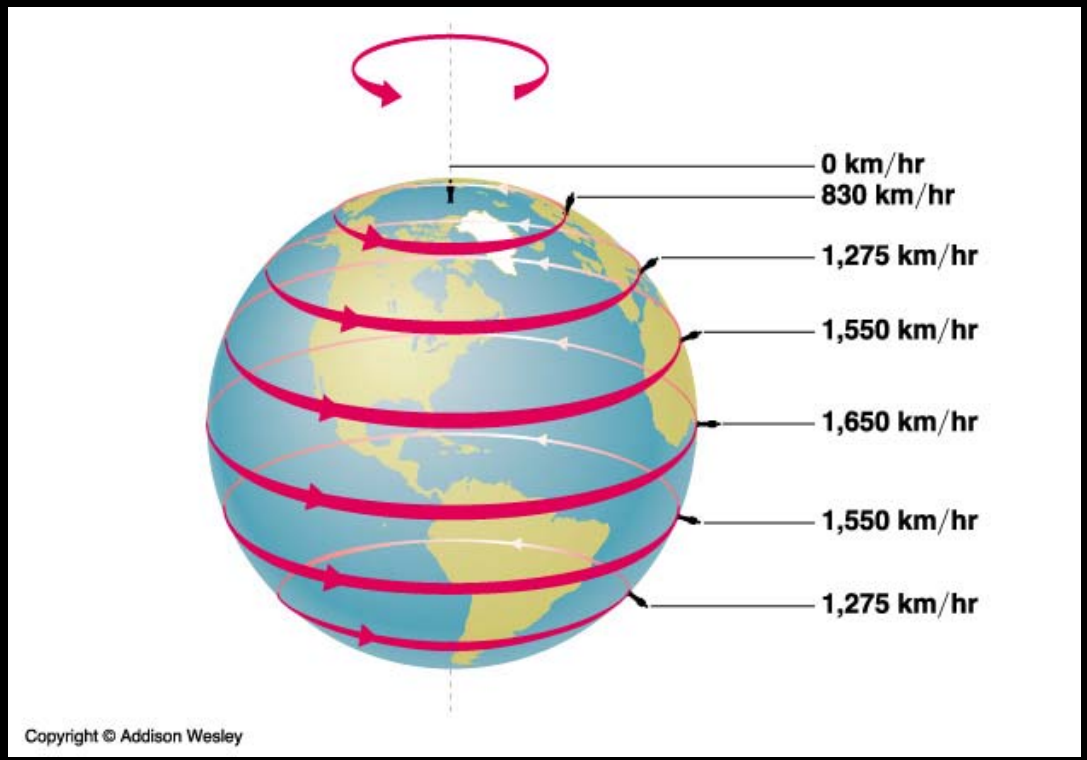
Looking back in time

- Light, although fast, travels at a finite speed.
- It takes:
  - 8 minutes to reach us from the Sun
  - 8 years to reach us from Sirius (8 light-years away)
  - 1,500 years to reach us from the Orion Nebula
- The farther out we look into the Universe, the farther back in time we see!



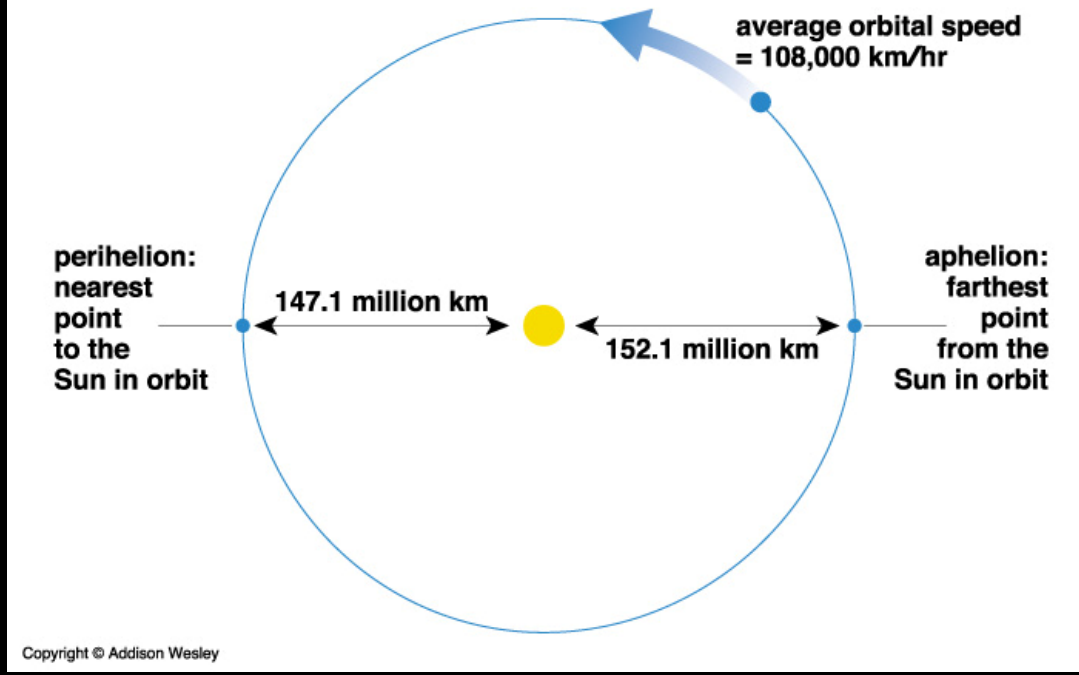
A Universe in motion

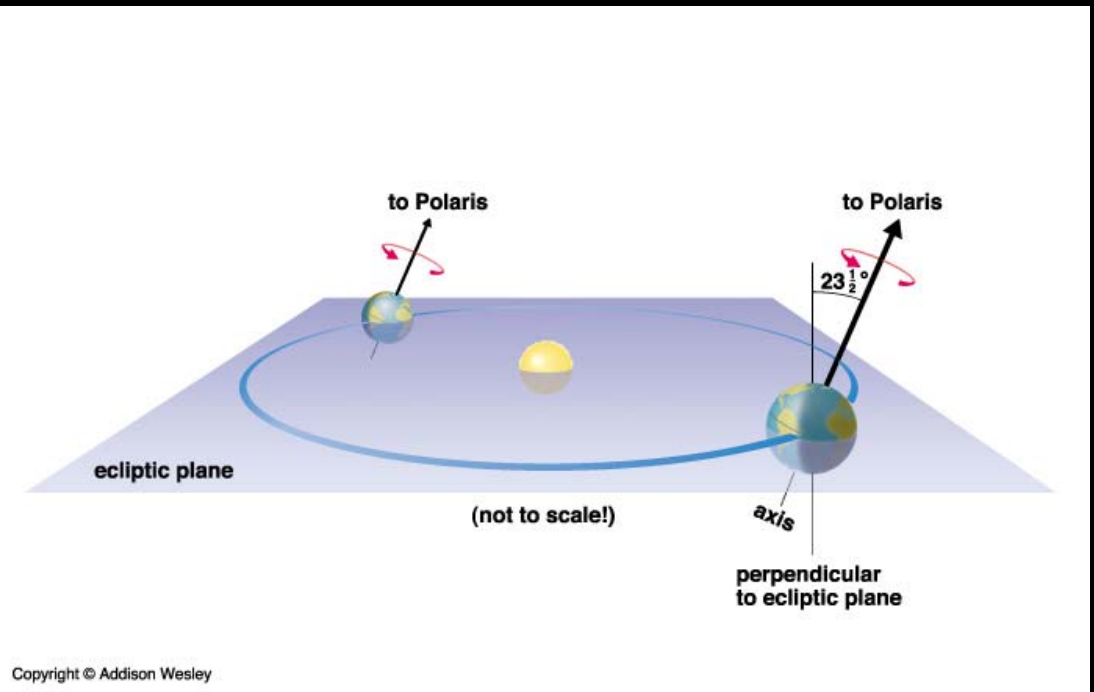
- Contrary to our perception, we are not “sitting still.”
- We are moving with the Earth.
  - and not just in one direction



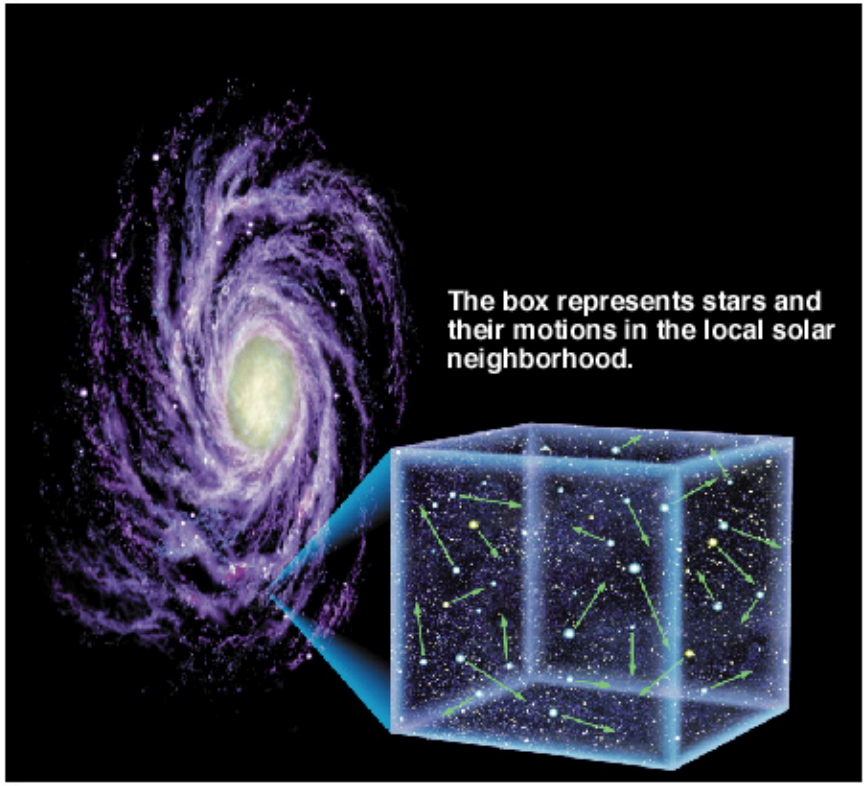
The Earth rotates around it’s axis once every day!

The Earth orbits around the Sun once every year!





The Earth's axis is tilted by 23.5°!



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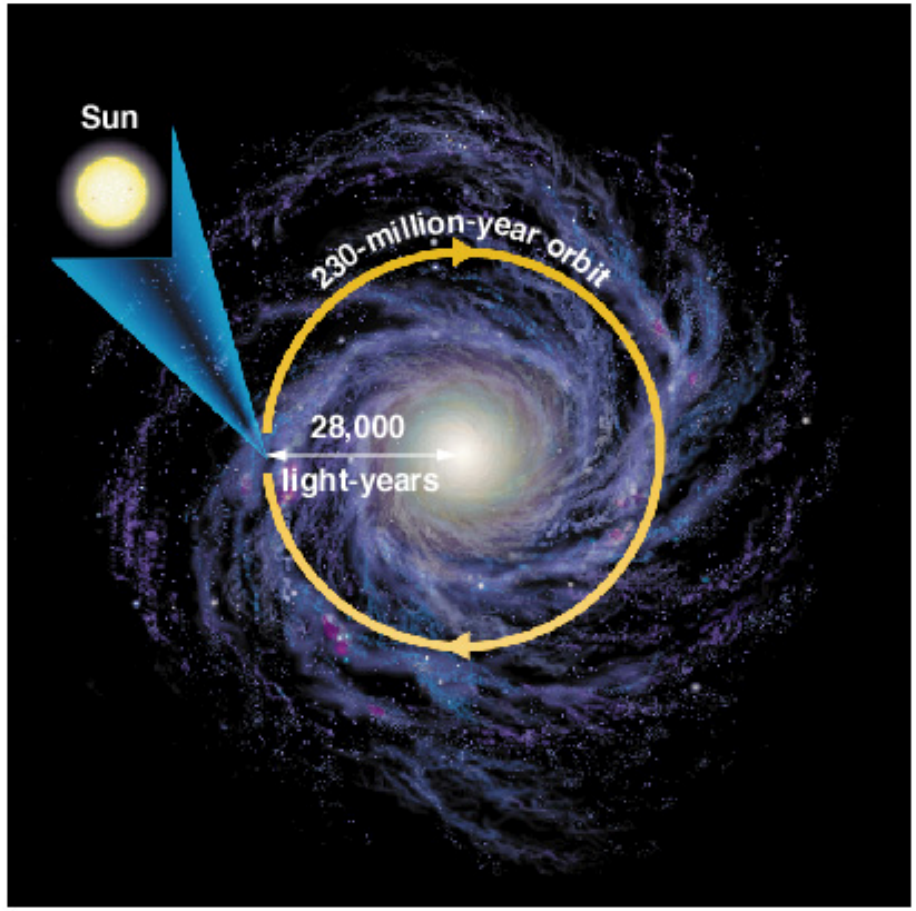
Our Sun moves relative to the other stars in the local Solar neighborhood!

Our Sun and the stars of the local Solar neighborhood orbit around the center of the Milky Way Galaxy every 230 million years!



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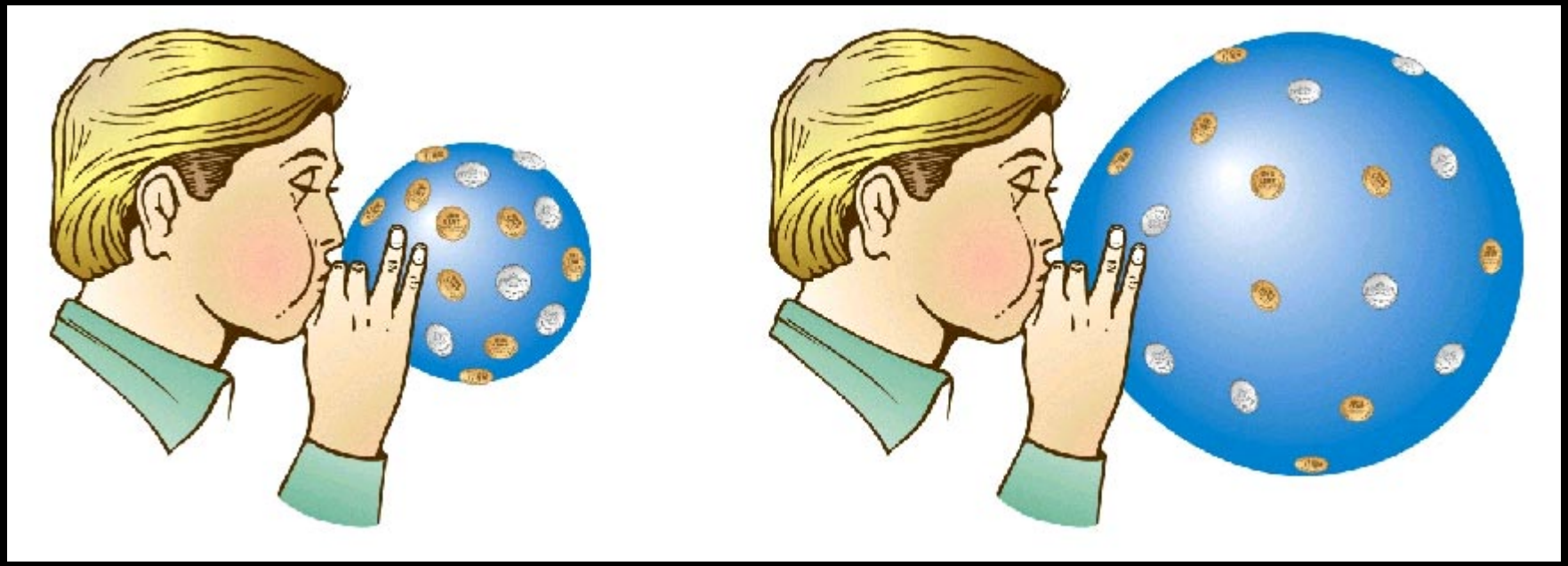
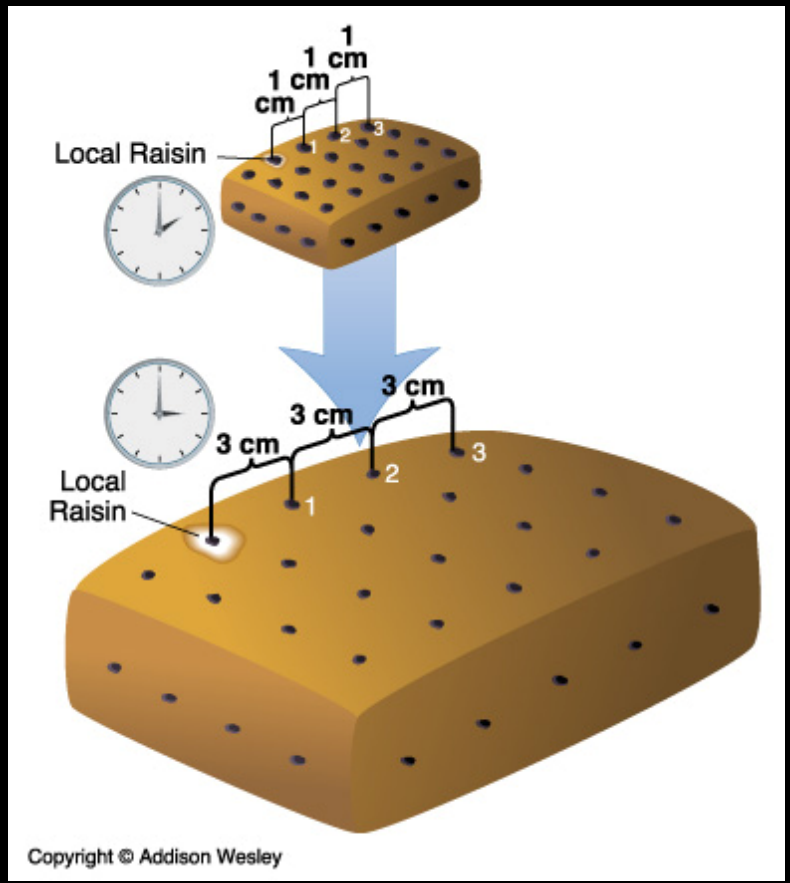
The universe is expanding

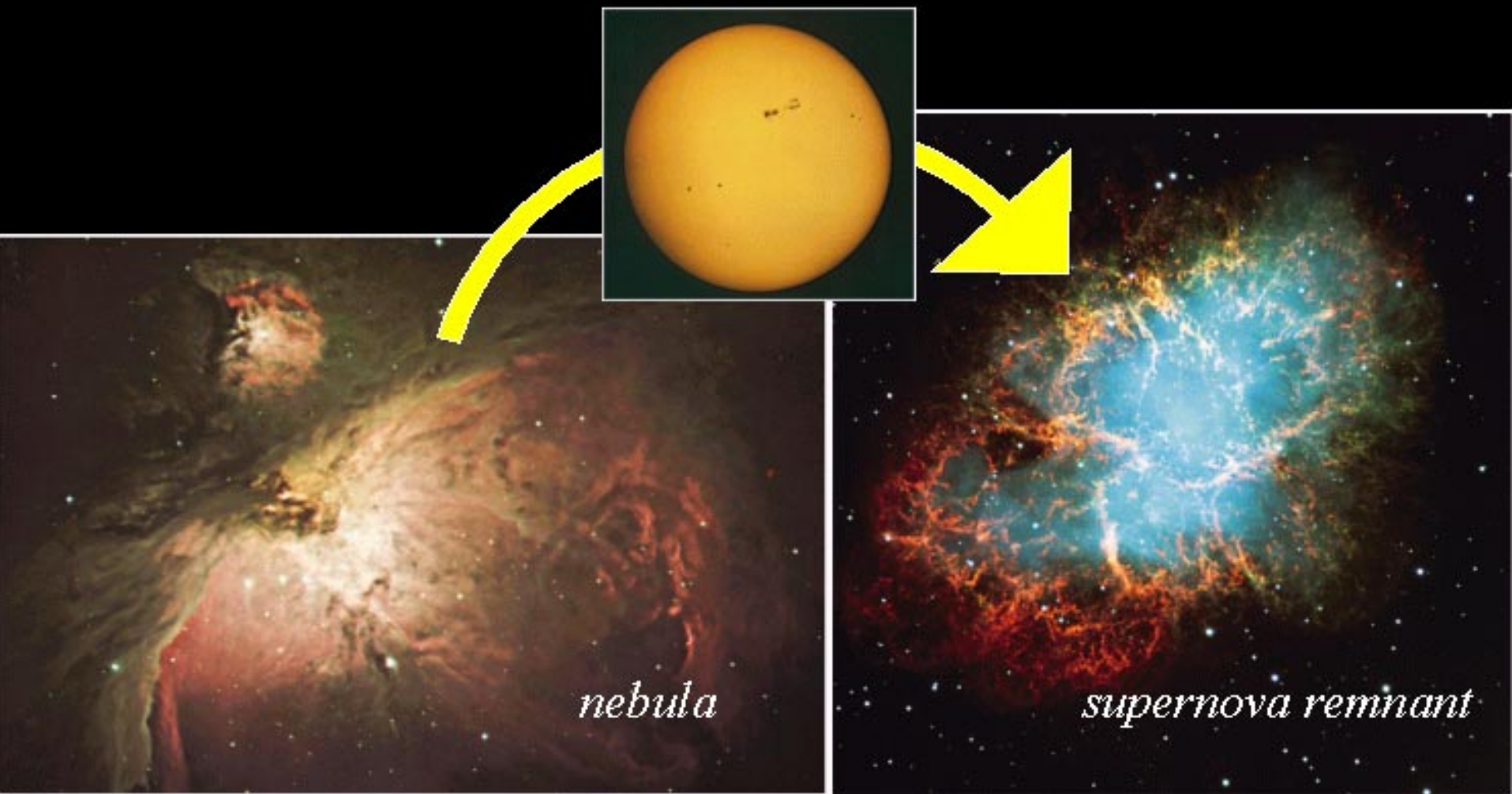


The Milky Way moves with the expansion of the Universe!



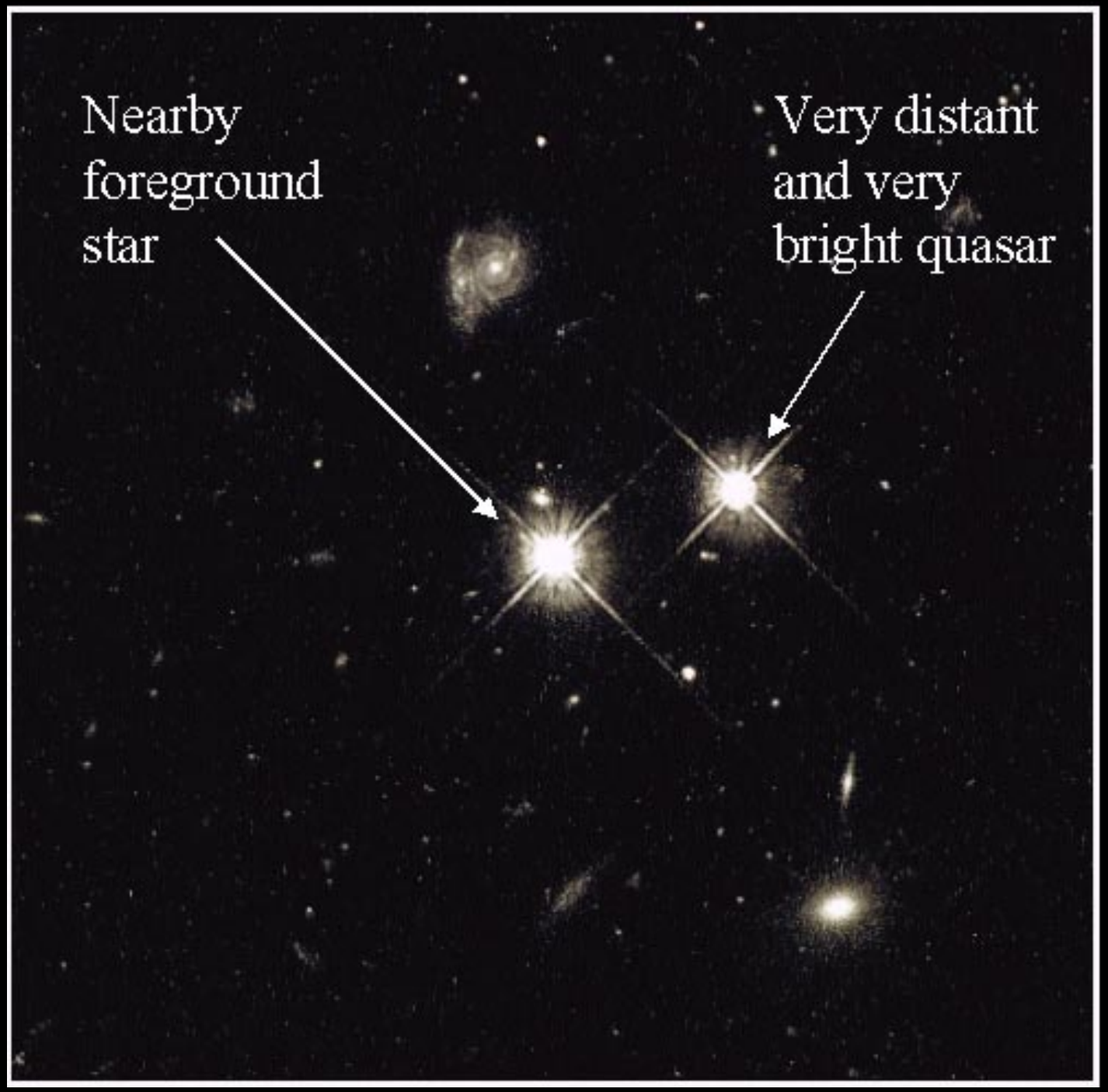
- Mostly all galaxies appear to be moving away from us.
- The farther away they are, the faster they are moving.
  - Just like raisins in a raisin cake; they all move apart from each other as the dough (space itself) expands.

By studying stars and nebulae, astronomers discover how stars are born, grow old, and die.

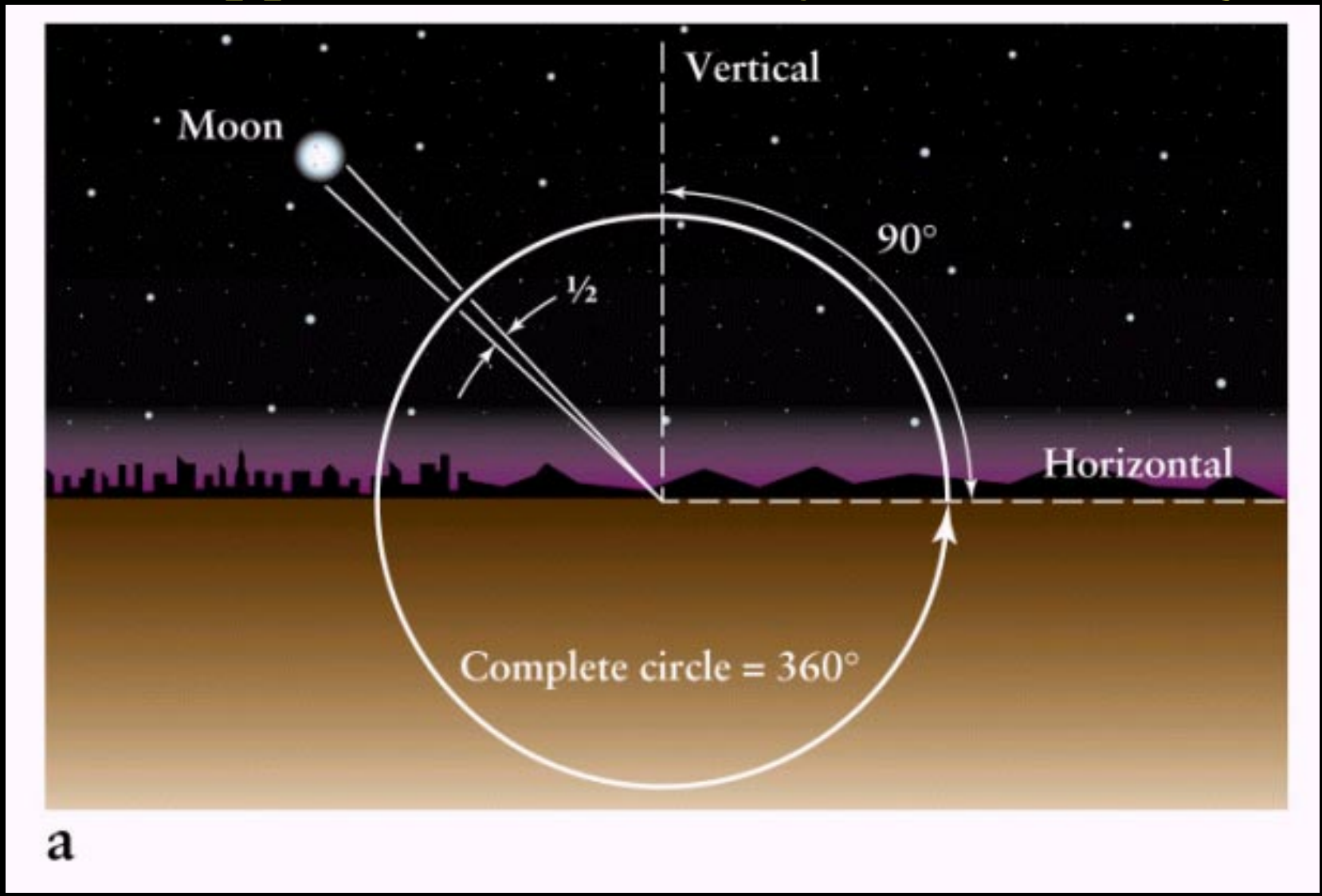


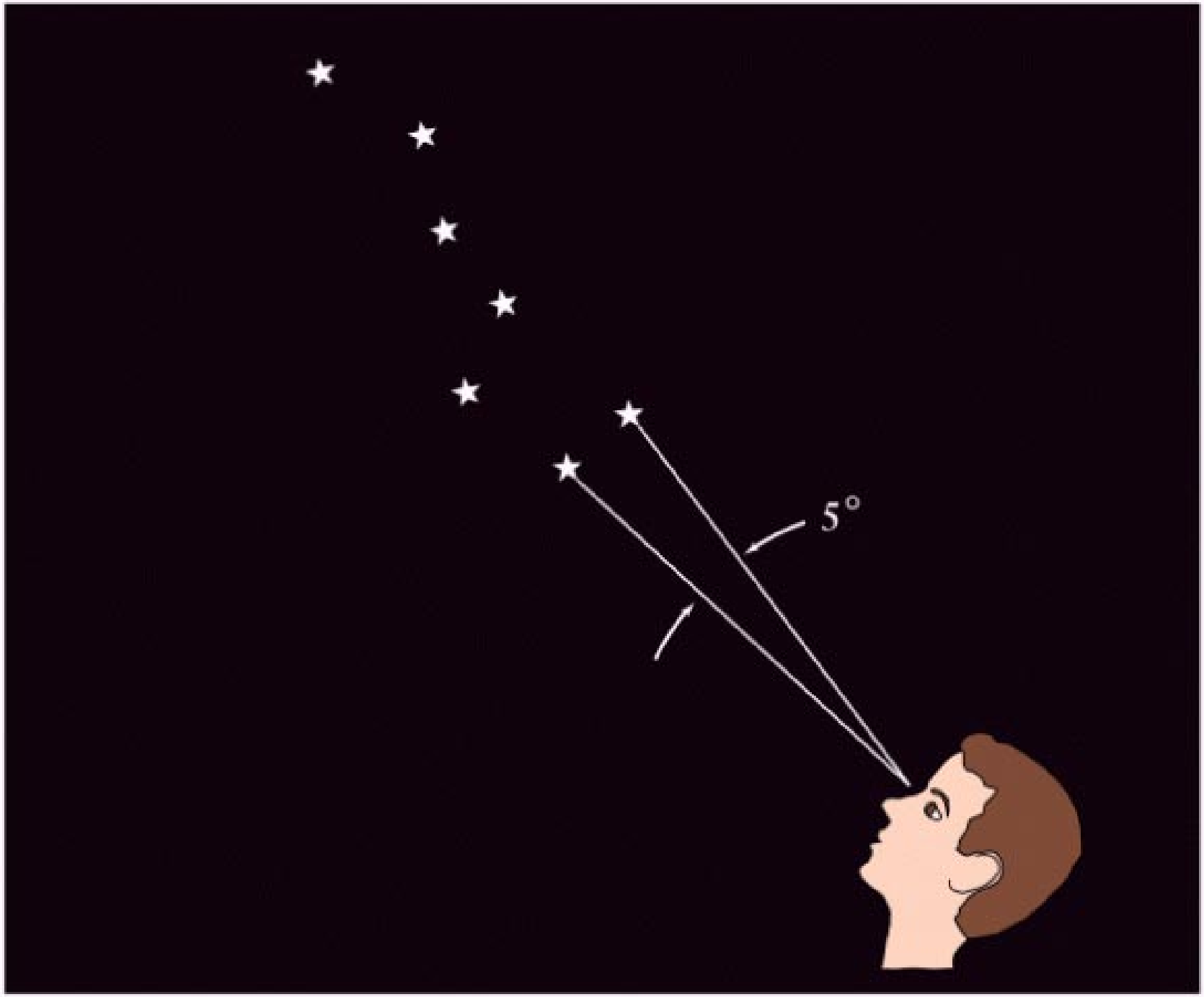
By observing galaxies, astronomers learn about the origin and fate of the universe.

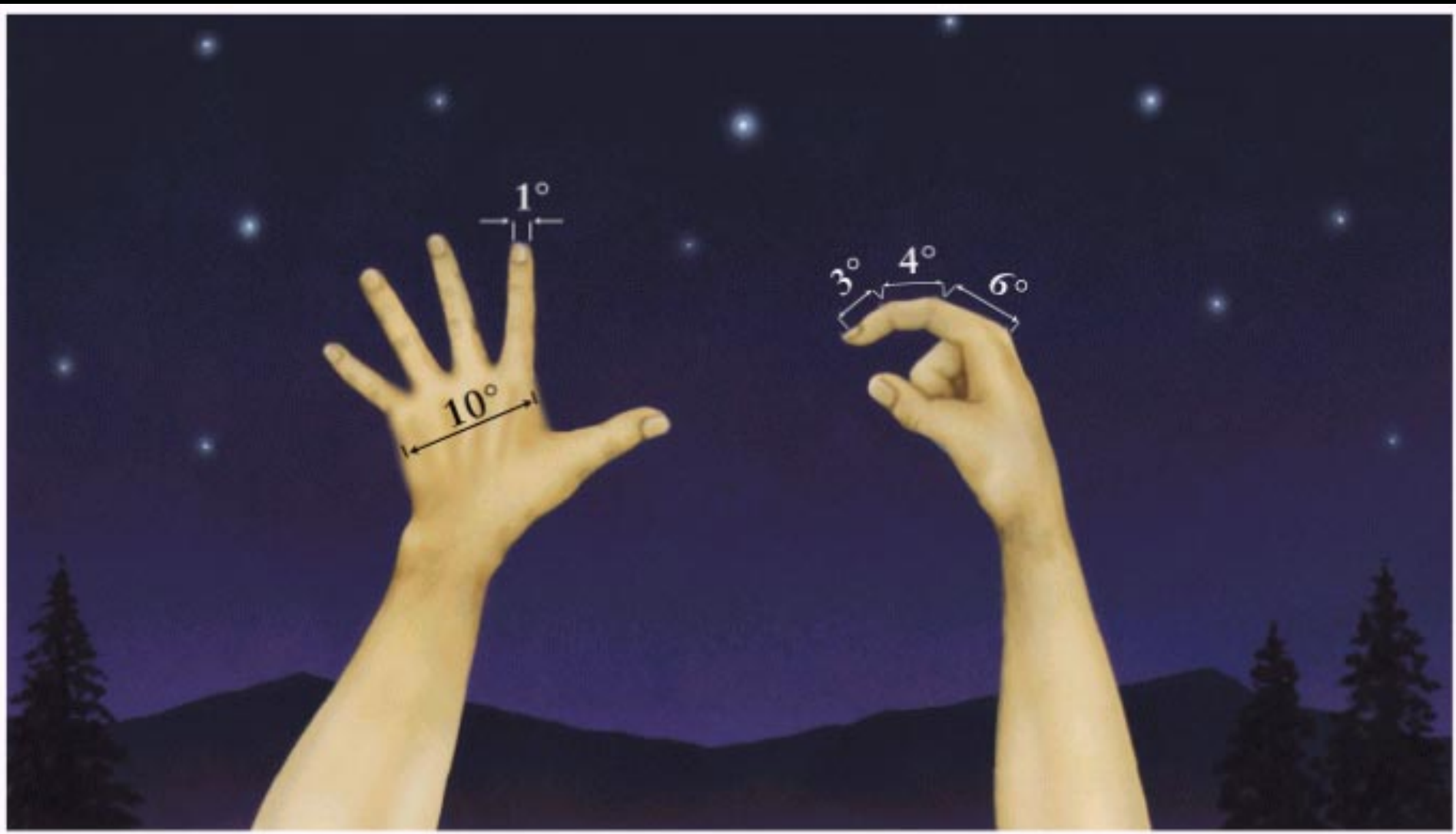
Galaxy: *an isolated collection of stars numbering in the hundreds of thousands up to hundreds of billions of stars.*


Nearby
foreground
star
Very distant
and very
bright quasar

Astronomers use angles to denote the positions and apparent sizes of objects in the sky.




5°


1°
10°
3°
4°
6°

Angular Measure for Small Angles

$1^{o} = 60$ arcminutes $= 60'$

$1' = 60$ arcseconds $= 60''$

e.g., On January 1, 2001, the planet Saturn had an angular diameter of 19.7” as viewed from Earth.

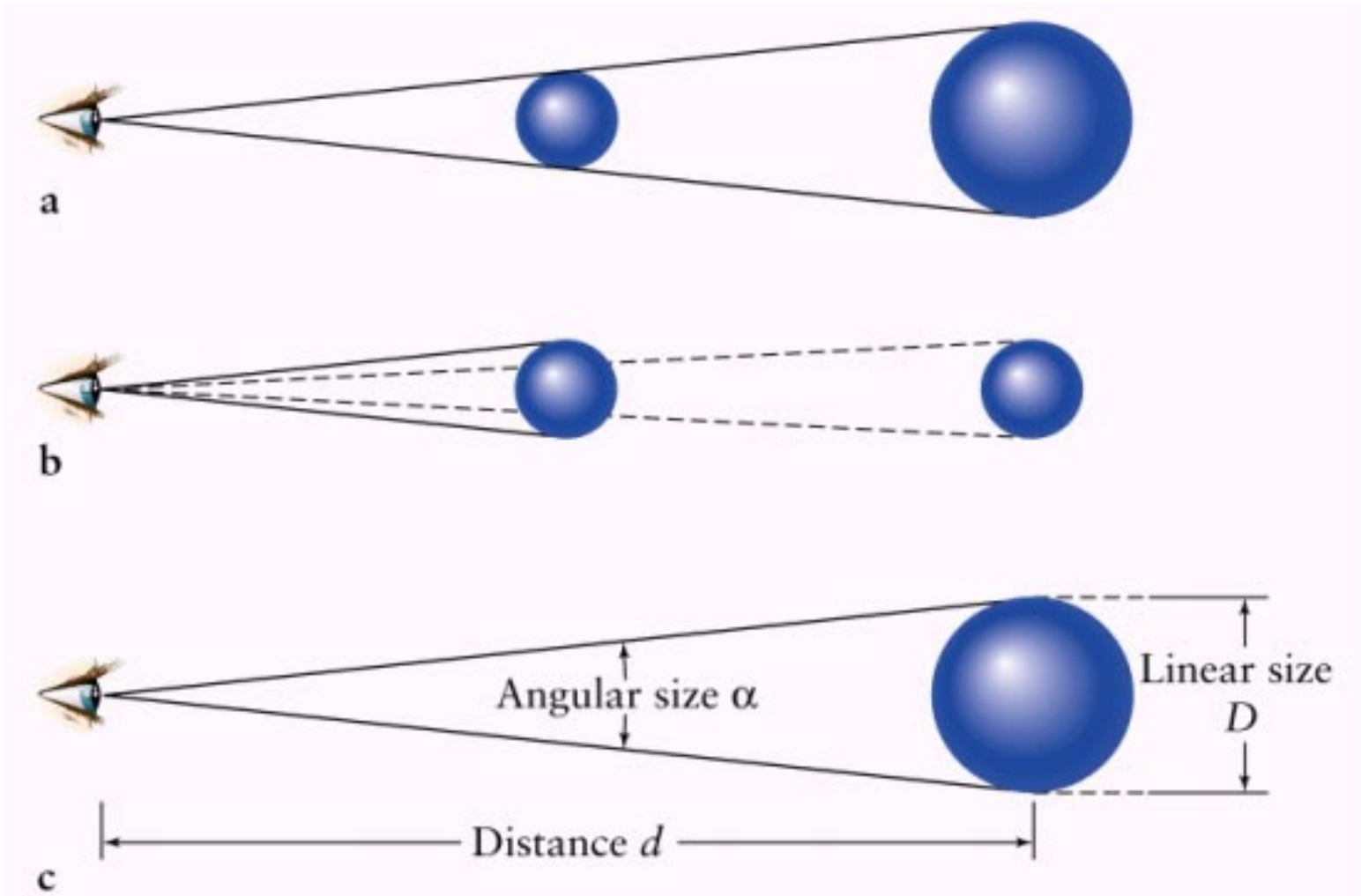
The Small-Angle Formula

$$D = \alpha \times d \div 206{,}265$$

D = linear size of object

α = angular size of object (in arcsec)

d = distance to the object



Example: On November 28, 2000, the planet Jupiter was 609 million kilometers from Earth and had an angular diameter of 48.6”. Using the small-angle formula, determine Jupiter’s actual diameter.

D = 48.6” x 609,000,000 km ÷ 206206 = 143,000 km

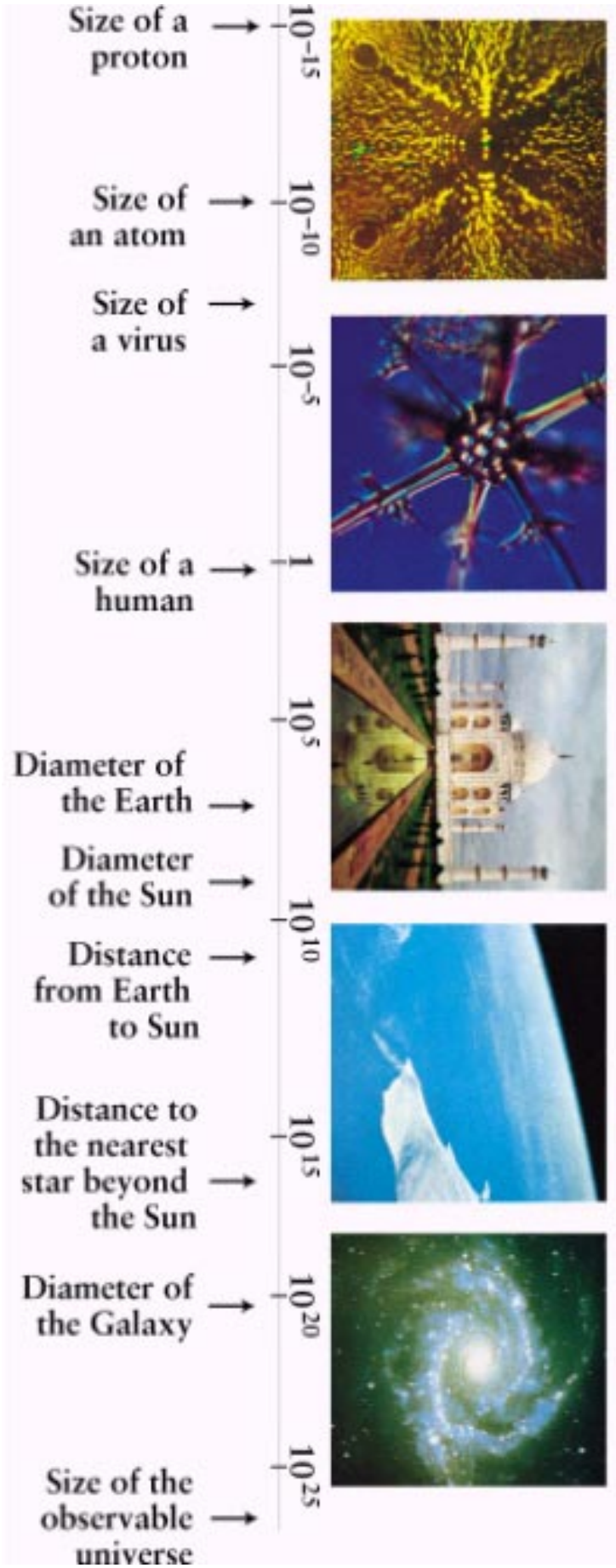
The Small-Angle Formula

D = α x *d* ÷ 206,265

D = linear size of object

α = angular size of object (in arcsec)

d = distance to the object

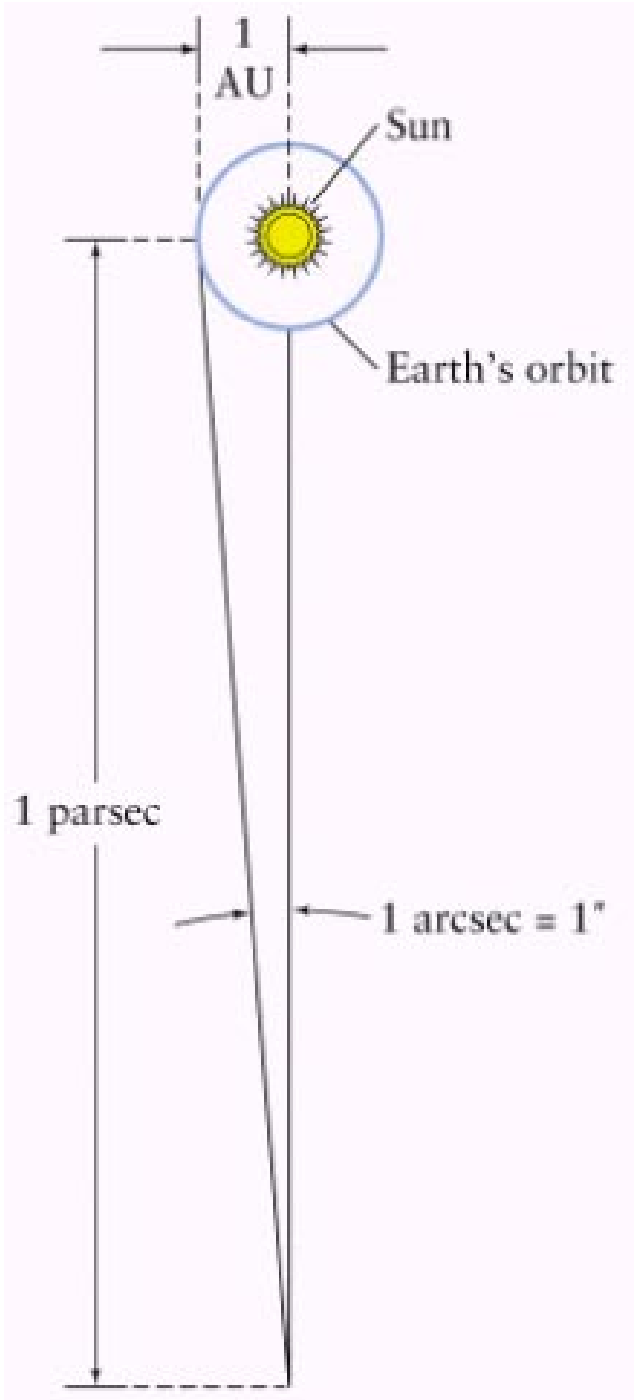

Size of a proton
10^{-15}
Size of an atom
10^{-10}
Size of a virus
10^{-5}
Size of a human
1
10^{5}
Diameter of the Earth
Diameter of the Sun
10^{10}
Distance from Earth to Sun
Distance to the nearest star beyond the Sun
10^{15}
Diameter of the Galaxy
10^{20}
Size of the observable universe
10^{25}

Astronomical distances are often measured in astronomical units, parsecs, or light years.

Astronomical Unit (AU): *One AU is the average distance between Earth and the Sun (1.496 X 10^8 km or 92.96 million miles).*

Light Year (ly): *One ly is the distance light can travel in one year at a speed of about 3 x 10^5 km/s or 186,000 miles/s (9.46 X 10^{12} km or 63,240 AU).*

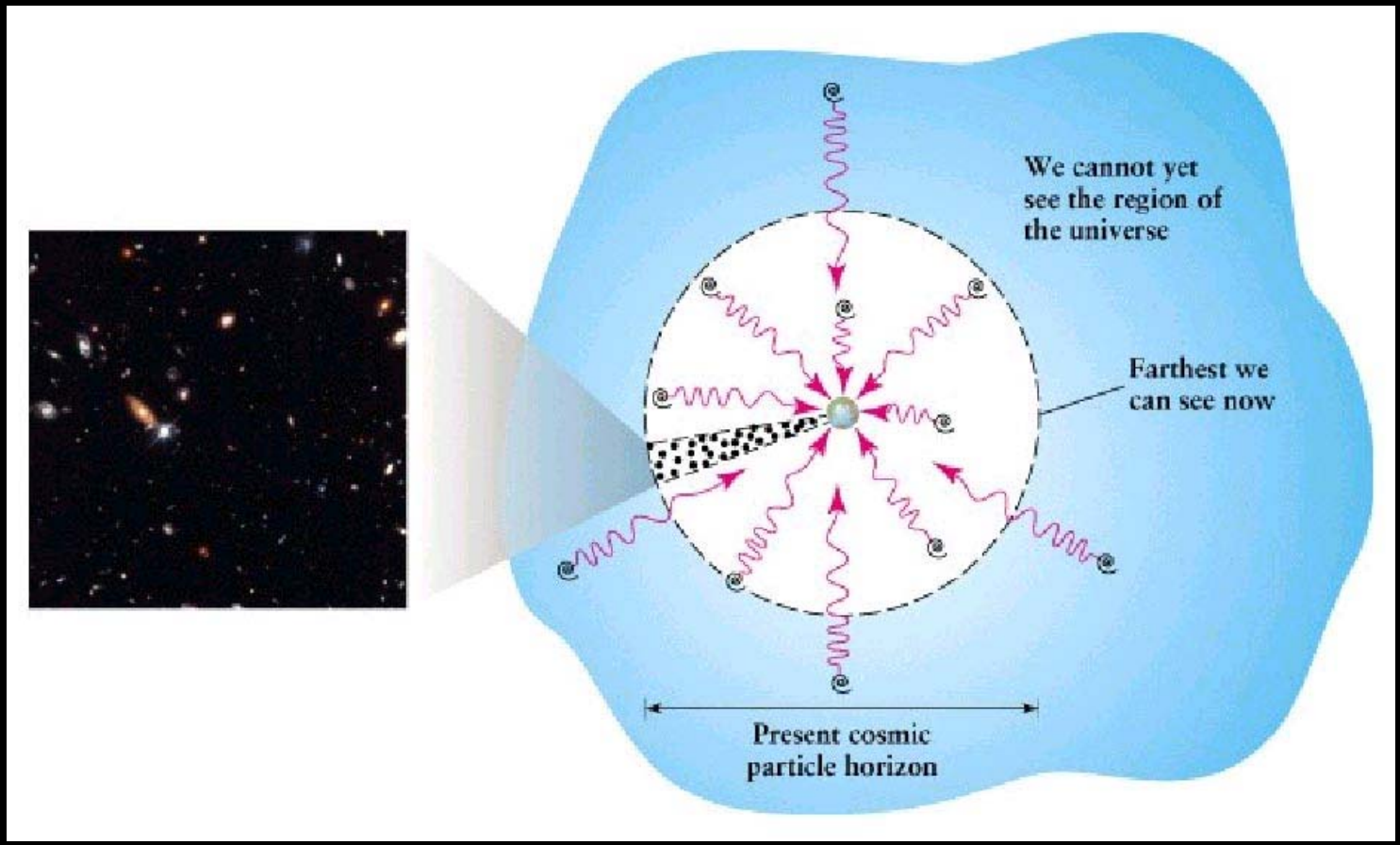
One Parsec (pc): *One pc is the distance from which Earth would appear to be one arcsecond from the Sun.*



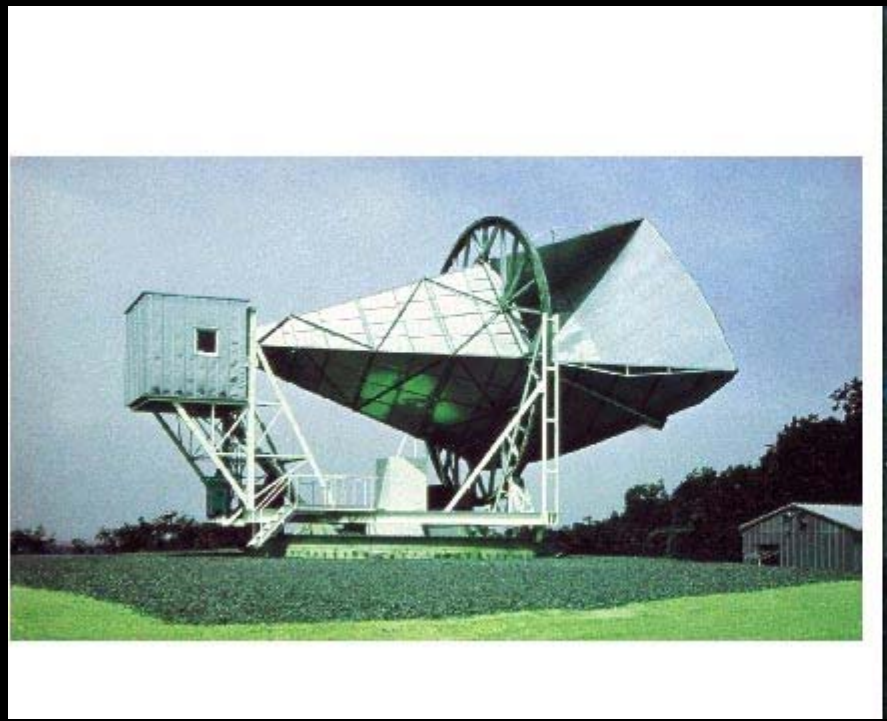
One Parsec (pc)

One pc is the distance from which Earth would appear to be one arcsecond from the Sun.

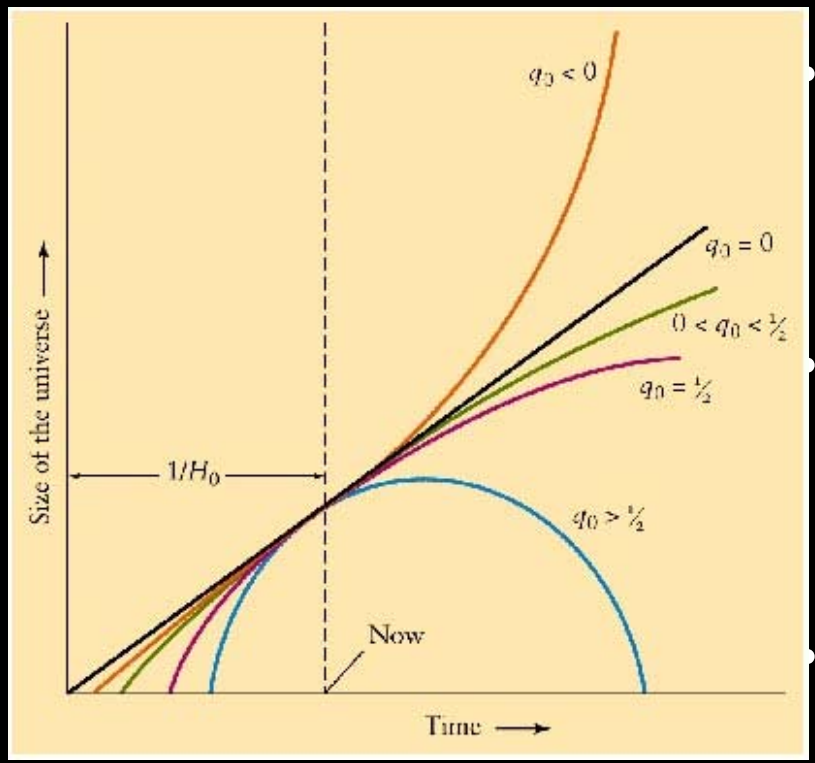
The farther we look into space, the farther back in time we are seeing.



The microwave radiation that fills all space is one evidence of a hot Big Bang.



The matter and dark energy in the universe determine its future evolution.



Deceleration parameter (q_0)

- If $q_0 = 0$, then the universe expands forever at a constant rate.
- If $q_0 = ½$, then the universe is marginally bounded and just barely is able to continue expanding.
- If $q_0 < ½$, then the universe is unbounded when the universe expands at a decreasing rate, but never stops.
- If $q_0 > ½$, then the universe is bounded and will eventually collapse in on itself ending in a *big crunch*.