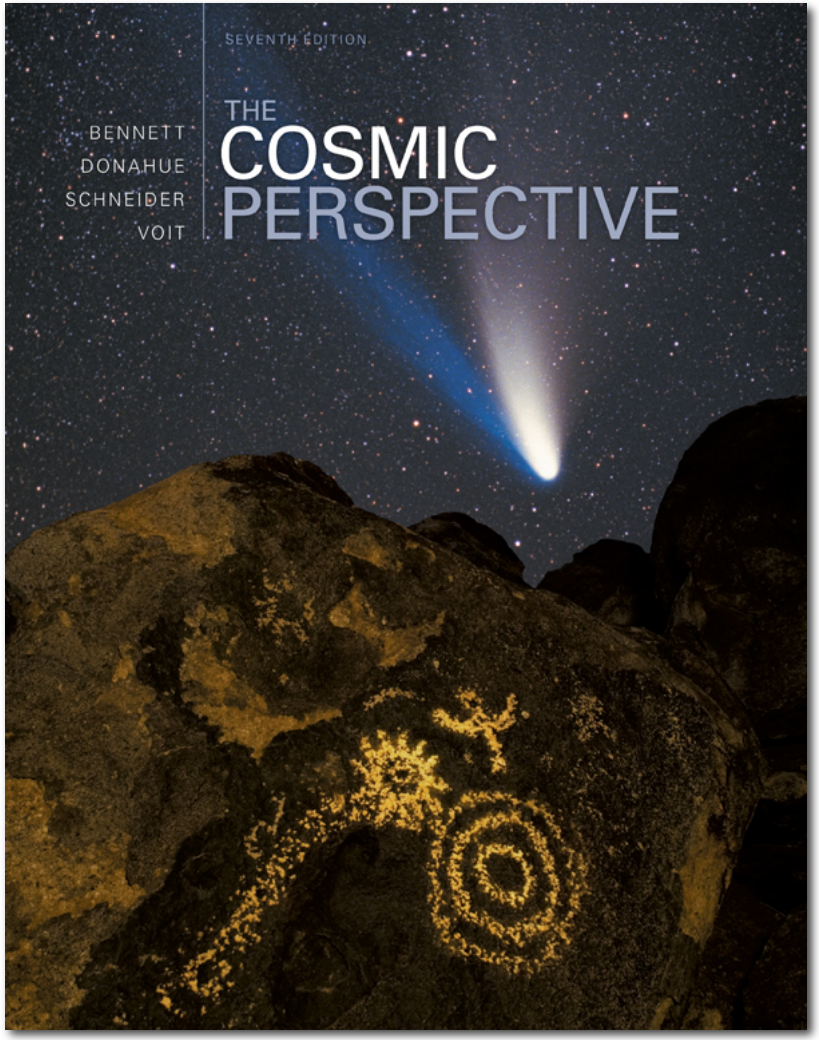
Chapter 1 Lecture

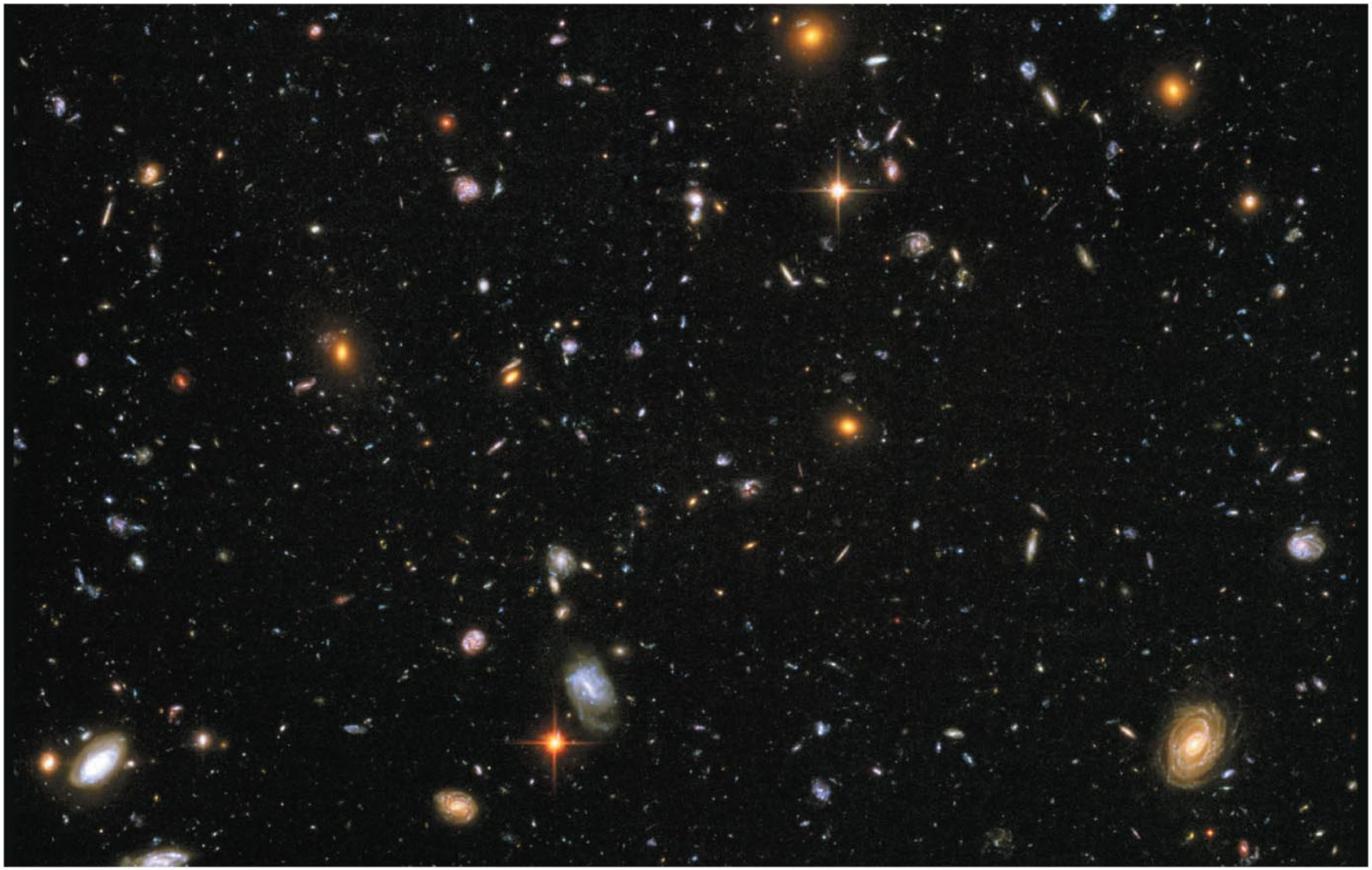
The Cosmic Perspective

Seventh Edition



A Modern View of the Universe

The Distant Universe



Course Introduction

Professor: George Chartas
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Office Hours: TR 3:00-5:30 pm

Texbook:Bennett, The Cosmic Perspective 7th Edition
Lecture website: http://chartasg.people.cofc.edu/chartas/Teaching.html

Lectures: Tuesday and Thursday
Time: 12:45-1:55pm

Lecture Hall: Harbor Walk West, room 112

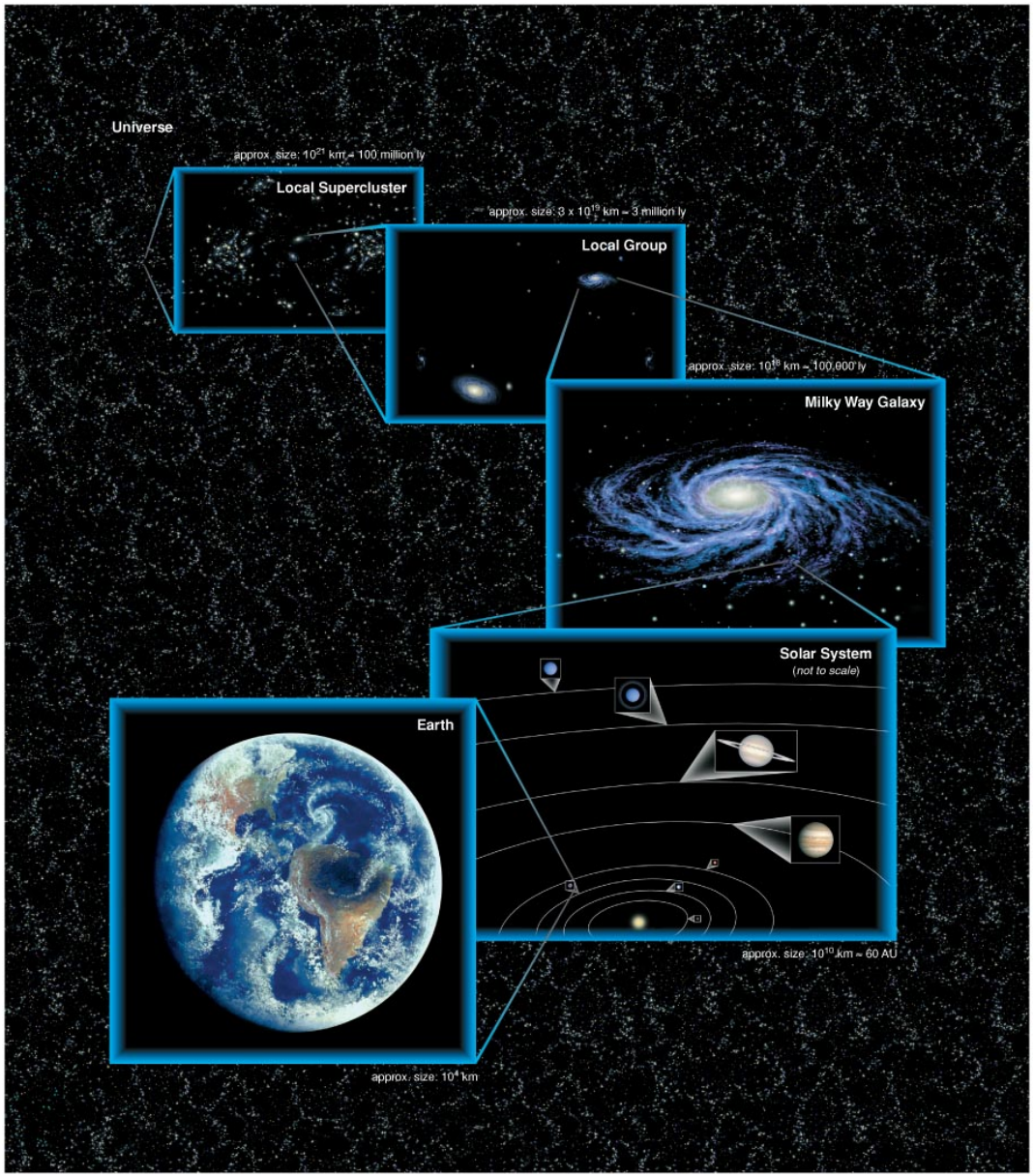
Course Requirements

- Read text before course
- Attend lectures
- Participate in discussions during lecture, ask questions
- Homework (5% of your grade)
- Quizzes in class (15% of your grade)
- THREE MIDTERM EXAMS (45% of your grade)
- FINAL EXAM (35% of grade)

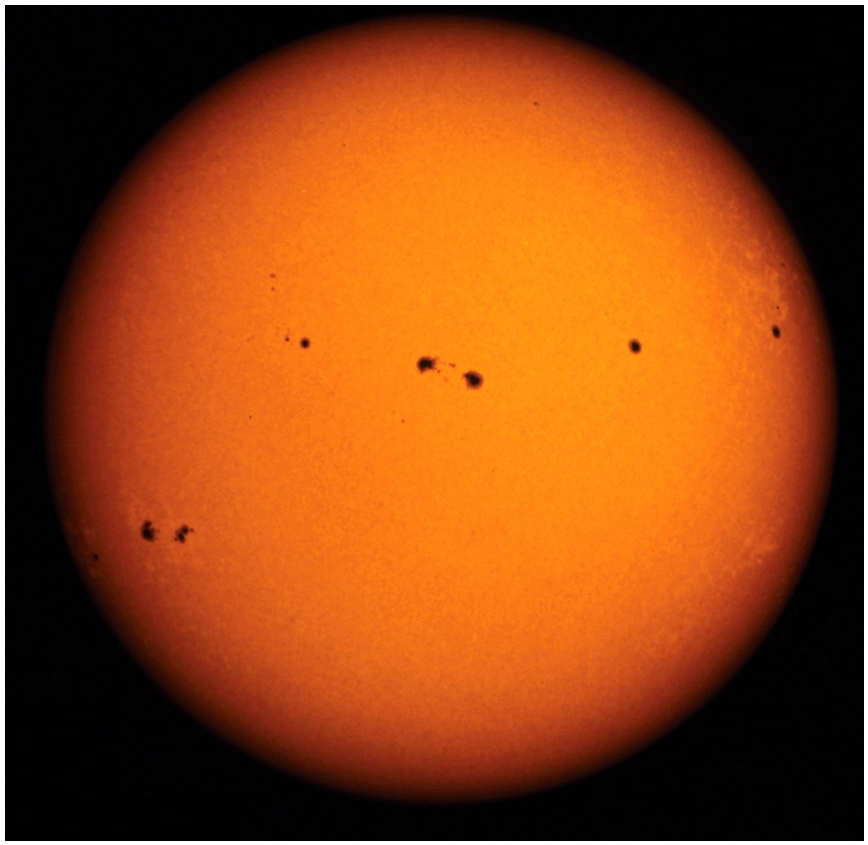
1.1 The Scale of the Universe

- Our goals for learning:
  - **What is our place in the universe?**
  - **How big is the universe?**

What is our place in the universe?



The Nearest Star to Earth



- A large ball of gas that generates heat, light and energetic particles through nuclear fusion.

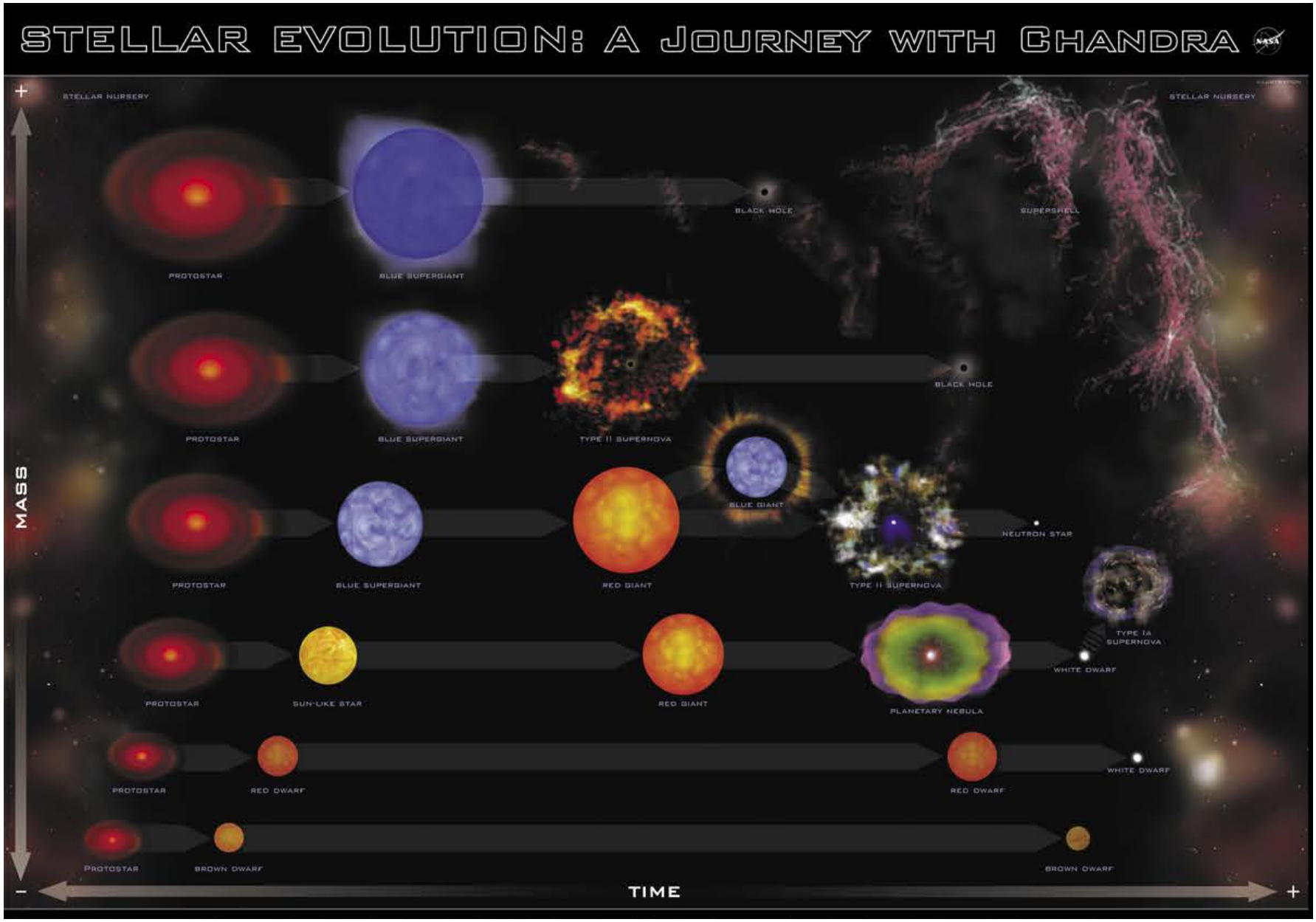
- The Sun is the nearest star to Earth at an average distance of

1 AU ~ 150,000,000,000 m
(= 1.5×10^{11} m)

AU = Astronomical Unit

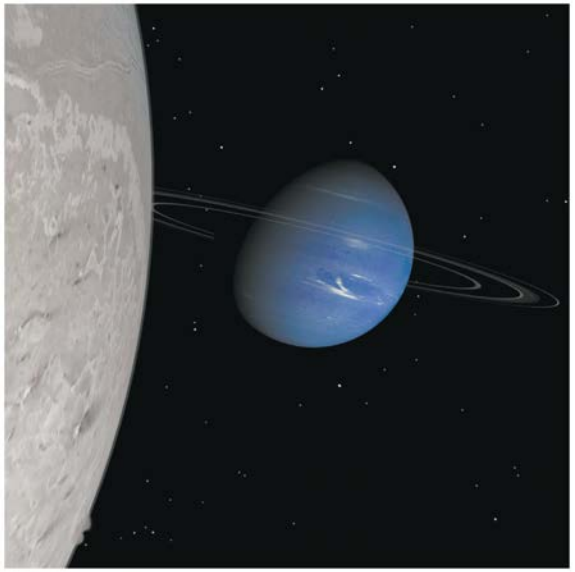
The next nearest star is about 100,000 (= 1×10^{5}) times further away.

Why Study Stars?



Planet

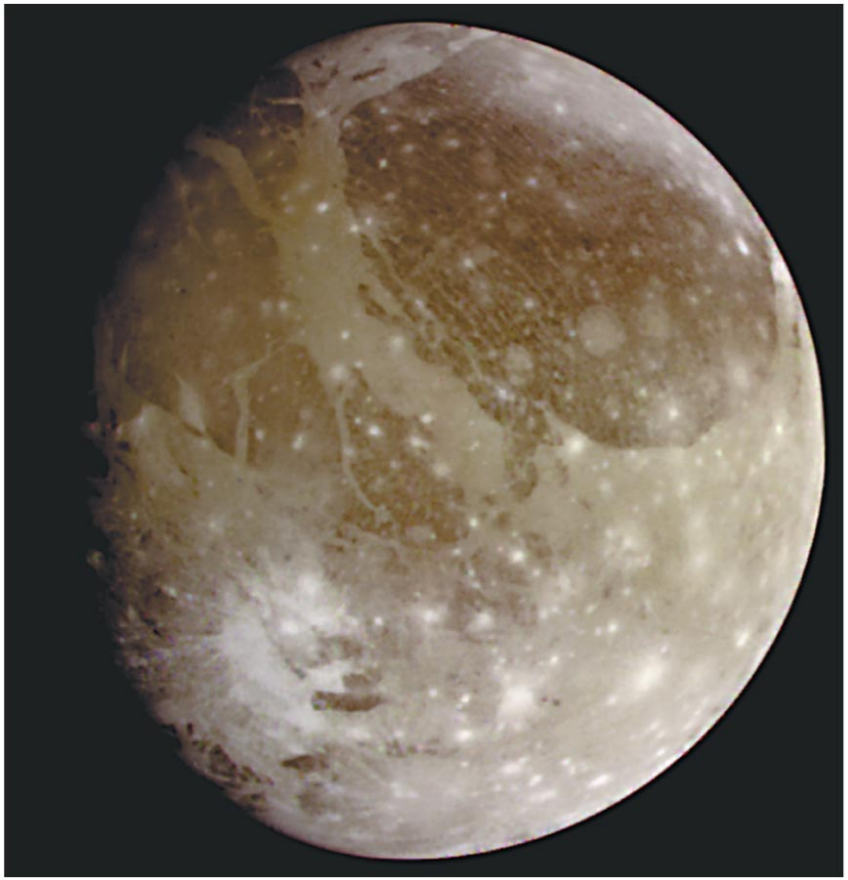
Mars



Neptune

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

Moon (or Satellite)

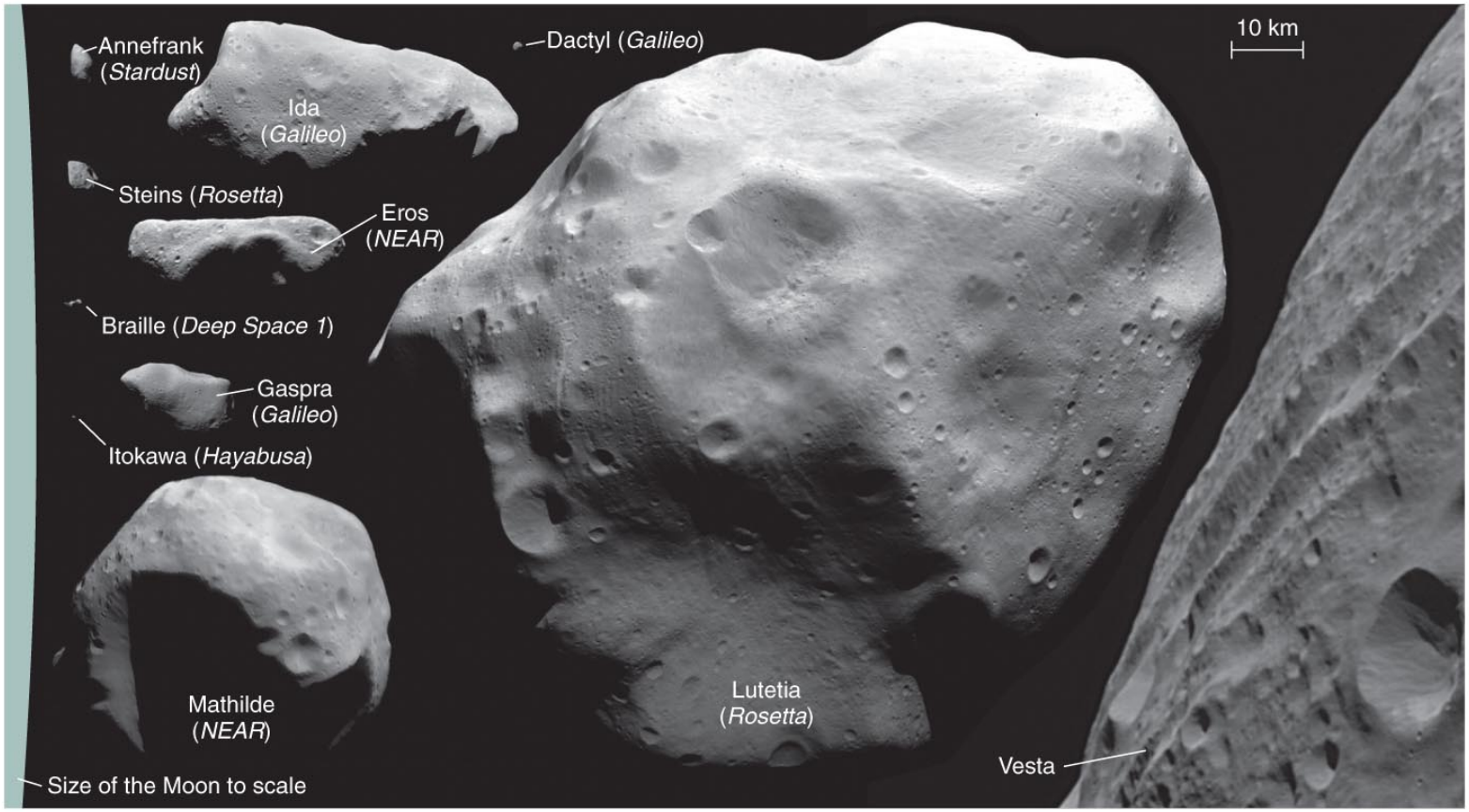


Ganymede (orbits Jupiter)

- An object that orbits a planet

Asteroid

- A relatively small and rocky object that orbits a star

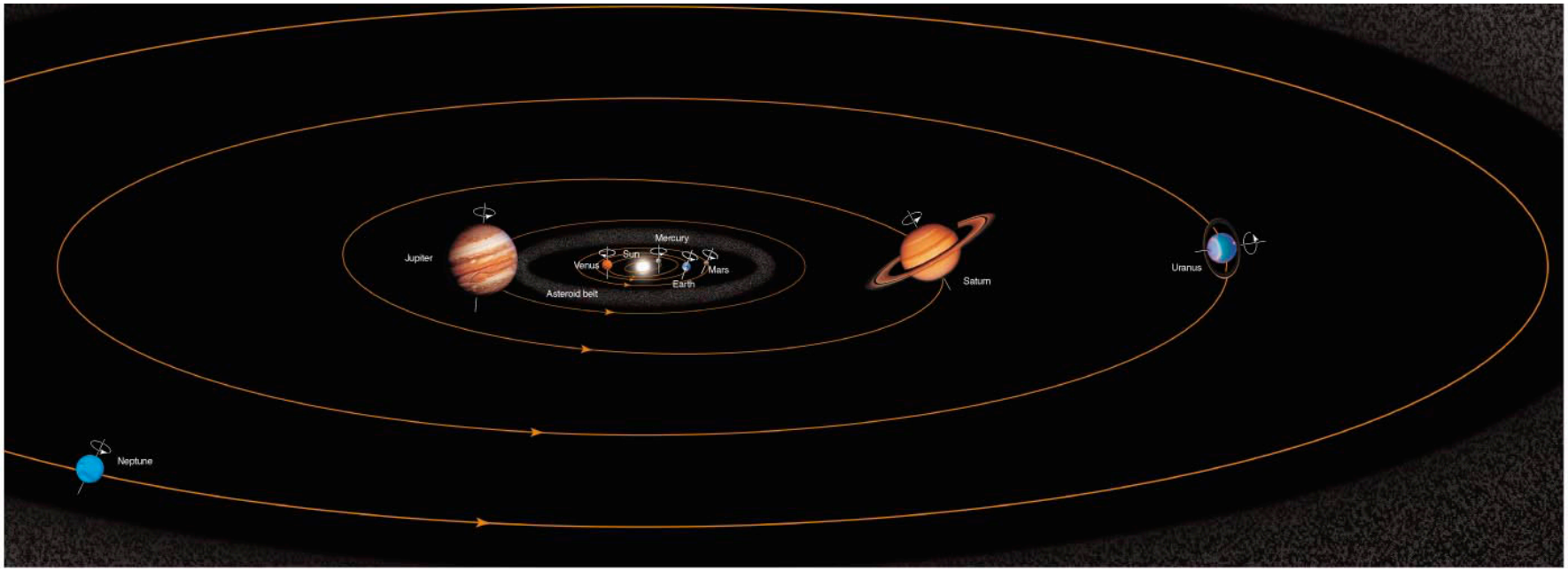


Comet

- A relatively small and icy object that orbits a star

Solar (Star) System

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



Nebula

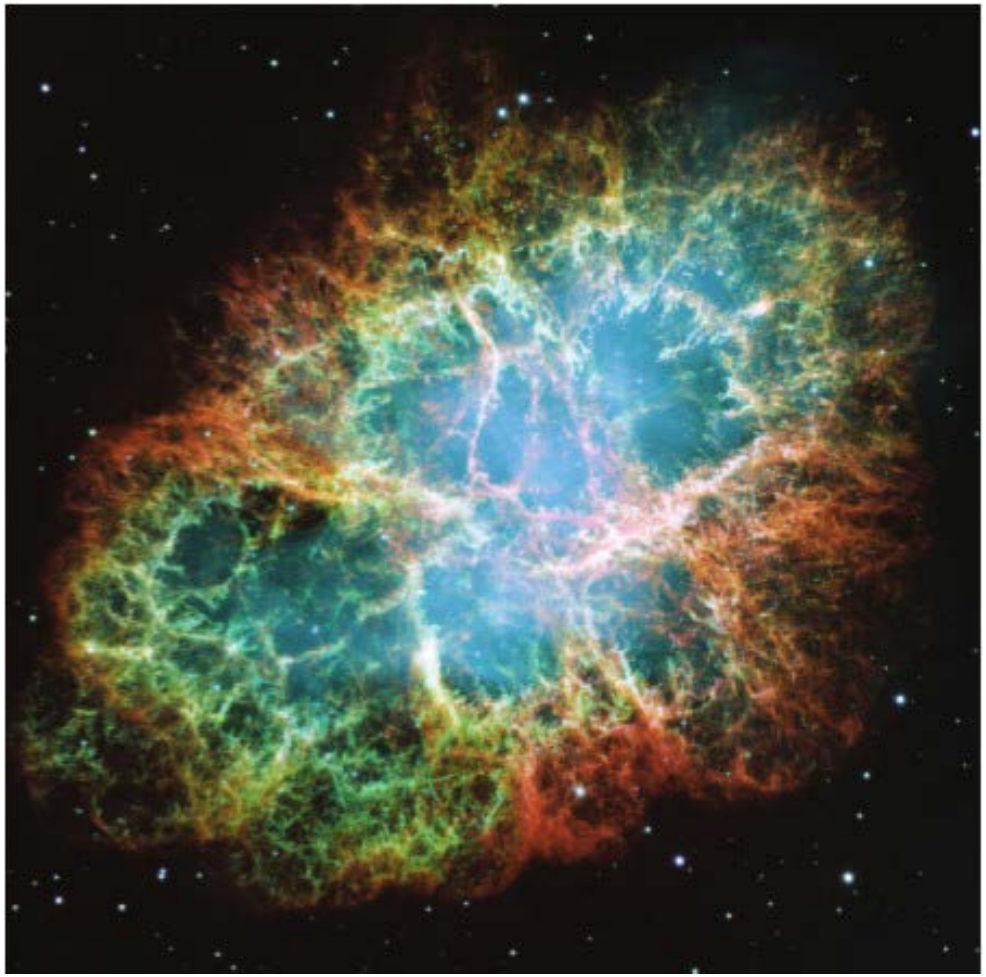
The Orion Nebular, Birthplace of Stars

- Nebulae are huge clouds of interstellar gas and are the birth places of stars.

- By studying many stars in nebulae we can learn about the life-cycles of stars.

- Intense ultraviolet light from newborn stars excites the surrounding gas and causes it to glow.

Exploding Stars

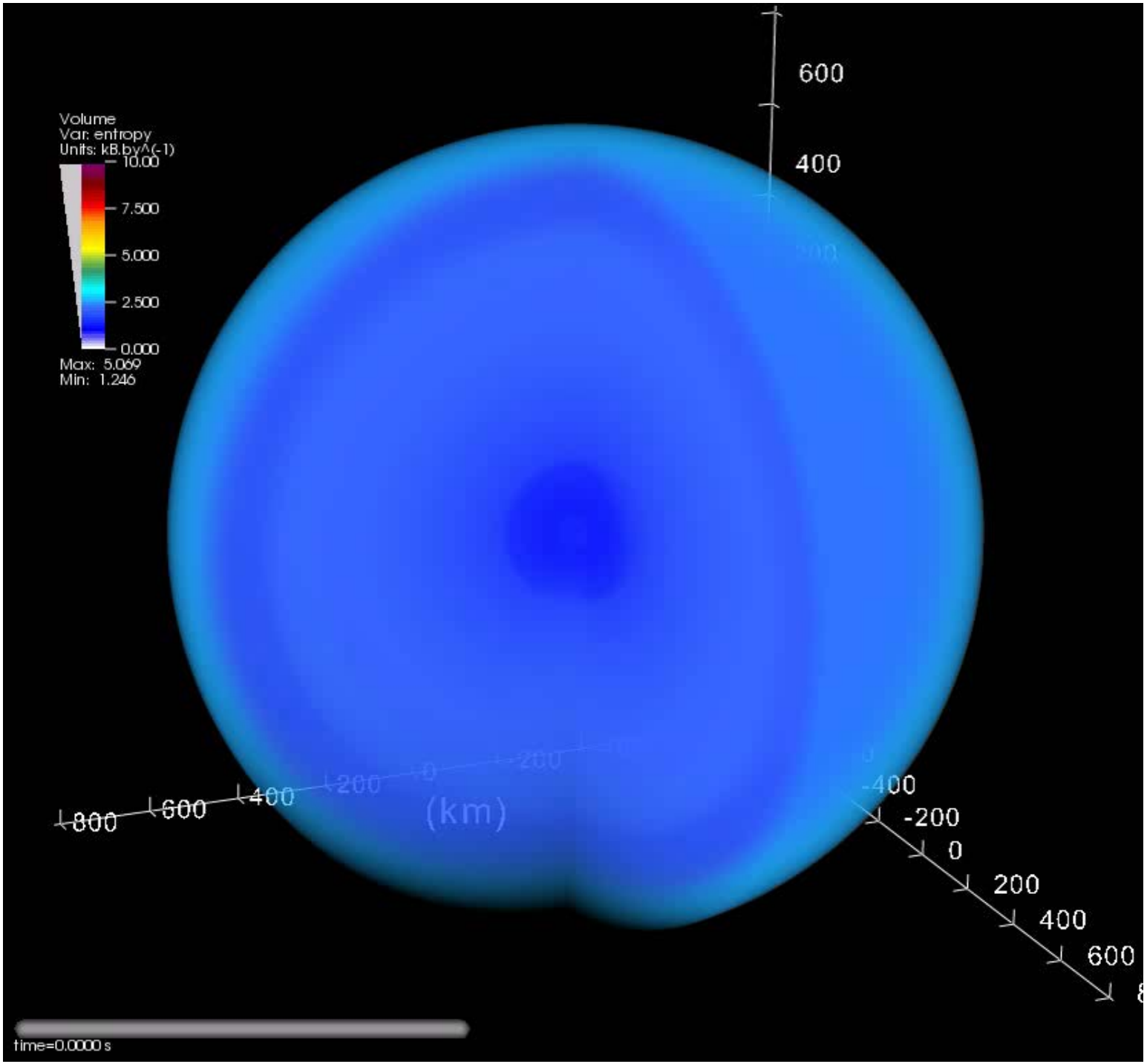


- Exploding stars enrich their interstellar neighborhood with heavy elements

- The Sun and the planets were created from material ejected from a supernova.

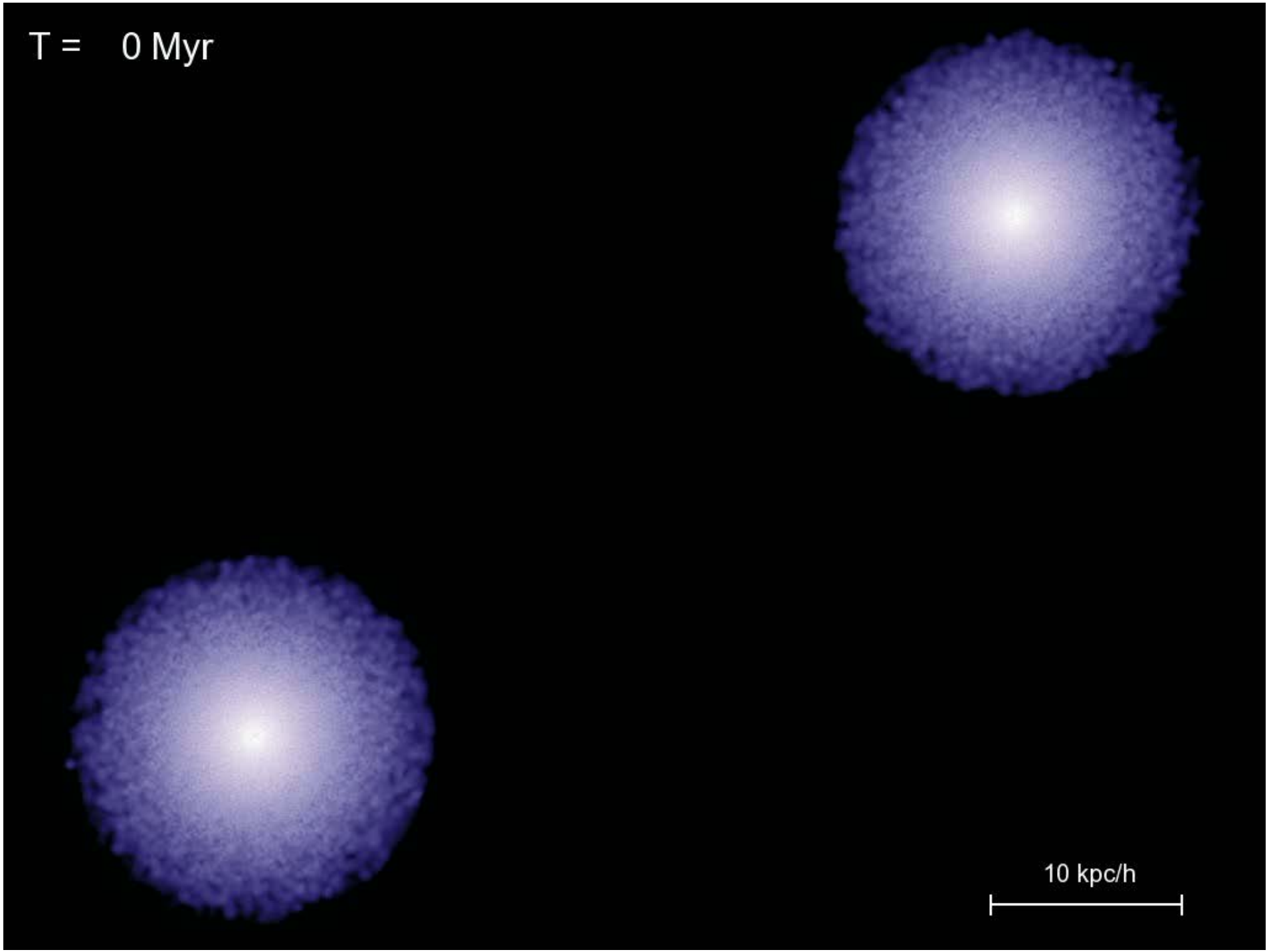
- The carbon in our bodies was manufactured deep inside stars that exploded many many years ago.

The Crab Nebular, Core collapse supernova
Distance to Earth ~ 6,500 ly


Volume
Var: entropy
Units: kB.by^(-1)
10.00
7.500
5.000
2.500
0.000
Max: 5.069
Min: 1.246
600
400
800
600
400
200
0
200
(km)
-400
-200
0
200
400
600
time=0.0000 s

Galaxy

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


T = 0 Myr
10 kpc/h

Universe

- The sum total of all matter and energy; that is, everything within and between all galaxies

Far away means back in time?

- Light travels at a finite speed (300,000 km/s).

Destination	Light travel time
Moon	1 second
Sun	8 minutes
Sirius	8 years
Andromeda Galaxy	2.5 million years

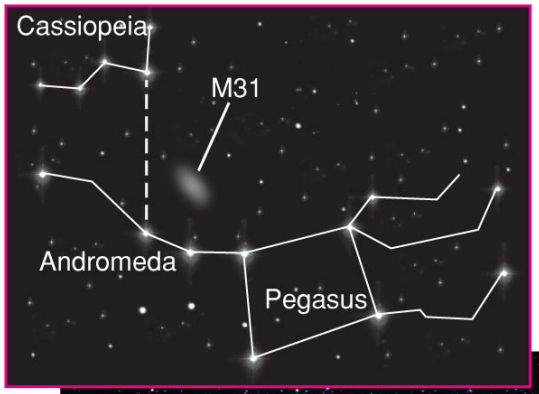
- Thus, we see objects as they were in the past:

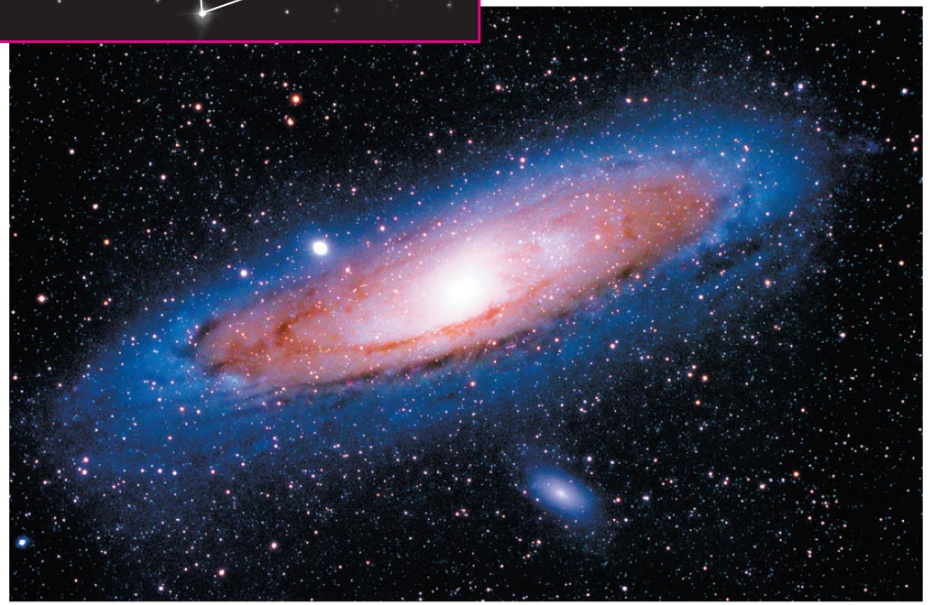
The farther away we look in distance,
the further back we look in time.

Far away means back in time?

Example:

- This photo shows the Andromeda Galaxy as it looked about 2 1/2 million years ago.
- **Question: When will we be able to see what it looks like now?**





Scientific Notation

$10^0 = 1$ (one)
$10^1 = 10$ (ten)
$10^2 = 100$ (one hundred)
$10^3 = 1000$ (one thousand)
$10^4 = 10{,}000$ (ten thousand)
$10^6 = 1{,}000{,}000$ (one million)
$10^9 = 1{,}000{,}000{,}000$ (one billion)
$10^{12} = 1{,}000{,}000{,}000{,}000$ (one trillion)

$10^0 = 1$ (one)
$10^{-1} = 1/10 = 0.1$ (one tenth)
$10^{-2} = 1/10 \times 1/10 = 1/10^2 = 0.01$ (one hundredth)
$10^{-3} = 1/10 \times 1/10 \times 1/10 = 1/10^3 = 0.001$ (one thousandth)
$10^{-4} = 1/10 \times 1/10 \times 1/10 \times 1/10 = 1/10^4 = 0.0001$ (one ten-thousandth)

Scientific Notation

Express Numbers in the form :

$$A \times 10^n$$

This is referred to as the powers-of-ten notation.

Some rules:

$10^{-n} = 1/10^n$

$10^{a+b} = 10^a \times 10^b$ example: $10^2 \times 10^3 = 10^{2+3}$

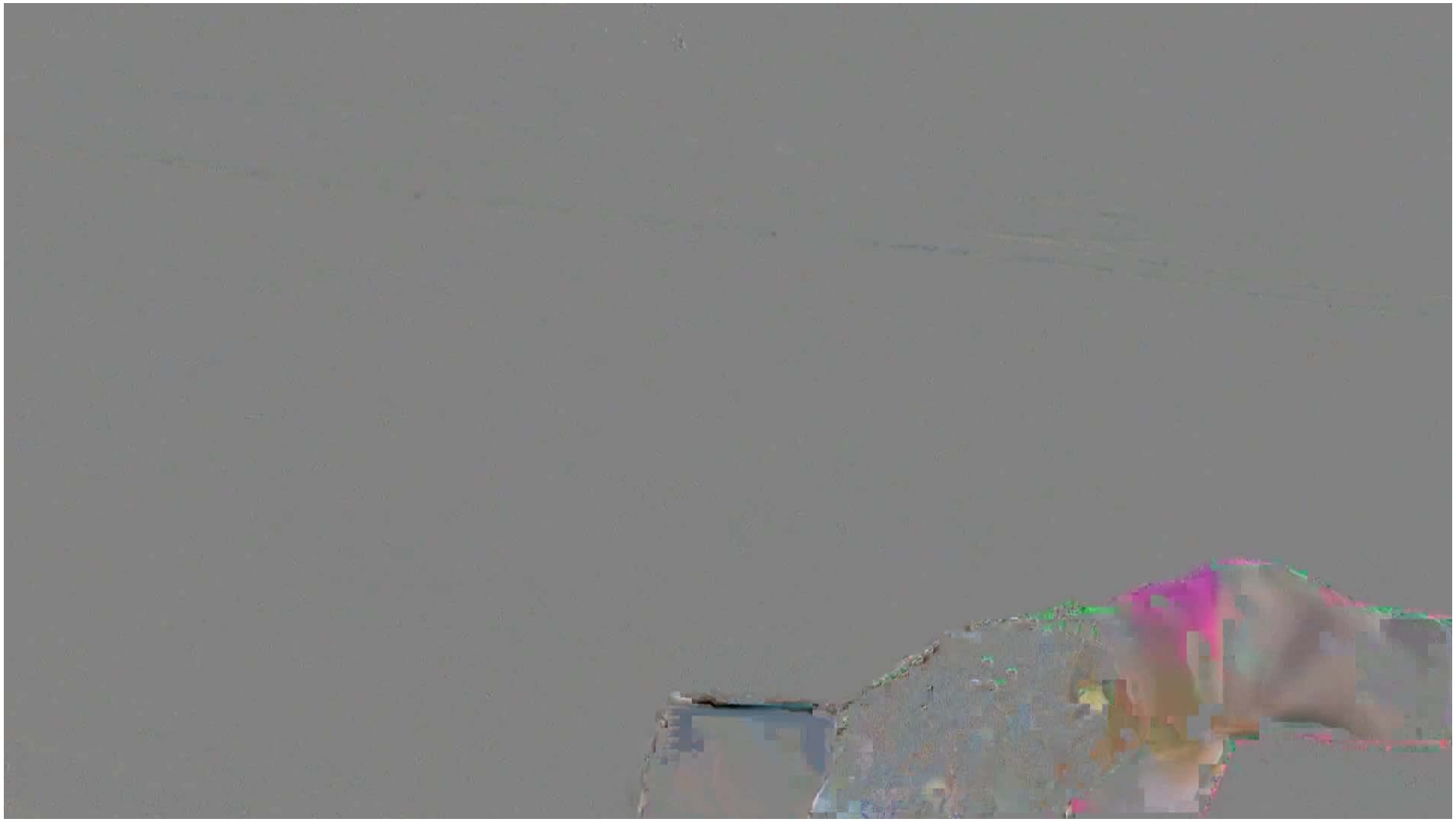
$(10^a)^b = 10^{ab}$ example: $(10^2)^3 = 10^{2\times 3} = 10^6$

Examples:

$3500 = 3.5 \times 10^3$, $0.0035 = 3.5 \times 10^{-3}$

12900000. = ?, 0.000000129 = ?

$10^6 \times 10^3 = ?$, $10^2 \times 10^{-2} = ?$, $(10^2)^{-3} = ?$



Scientific Numerical Prefixes

SI prefixes

10^n	Prefix	Symbol	Decimal
10^{12}	tera	T	1 000 000 000 000
10^{9}	giga	G	1 000 000 000
10^{6}	mega	M	1 000 000
10^{3}	kilo	k	1000
10^{2}	hecto	h	100
10^{1}	deca	da	10
10^{0}	*(none)*	*(none)*	1
10^{-1}	deci	d	0.1
10^{-2}	centi	c	0.01
10^{-3}	milli	m	0.001
10^{-6}	micro	μ	0.000001
10^{-9}	nano	n	0.000000001

International System Of Units

SI units:
length is measured in meters (m)

time is measured in seconds (s)

and mass is measured in kilograms (kg)

Light-year

The light-year (abbreviated ly) is the distance that light travels in one year.

The speed of light in empty space is $c = 3\times10^5$ km/s

1 light-year = 1ly = 9.46×10^{12} km (derive this)

1 Astronomical Unit = 1 AU = Average distance between Sun and Earth = 149,598,000 km $\approx 1.5\times10^8$ km

Light year

$$1 \text{ light-year} = (\text{speed of light}) \times (1 \text{ year})$$

$$= \left(300{,}000 \frac{\text{km}}{\cancel{s}}\right) \times \left(\frac{365 \text{ d}\cancel{\text{ays}}}{1 \cancel{\text{yr}}} \times \frac{24 \cancel{\text{hr}}}{1 \text{ d}\cancel{\text{ay}}} \times \frac{60 \text{ m}\cancel{\text{in}}}{1 \cancel{\text{hr}}} \times \frac{60 \cancel{s}}{1 \text{ m}\cancel{\text{in}}}\right)$$

$$= 9{,}460{,}000{,}000{,}000 \text{ km}$$

Example: Estimate the time it takes for light to reach us from the sun

Example: Estimate the time it takes for light to reach us from the sun

$$speed = \frac{\text{Distance}}{\text{time}}, \text{ If we denote } c \text{ as the speed of light we can write:}$$

$$c = \frac{\text{Distance}}{\text{time}} \Rightarrow \text{time} = \frac{\text{Distance}}{c} = \frac{1.5 \times 10^{8}\, km}{3 \times 10^{5}\, km/s} = 500\,\text{sec}$$

How big is the universe?

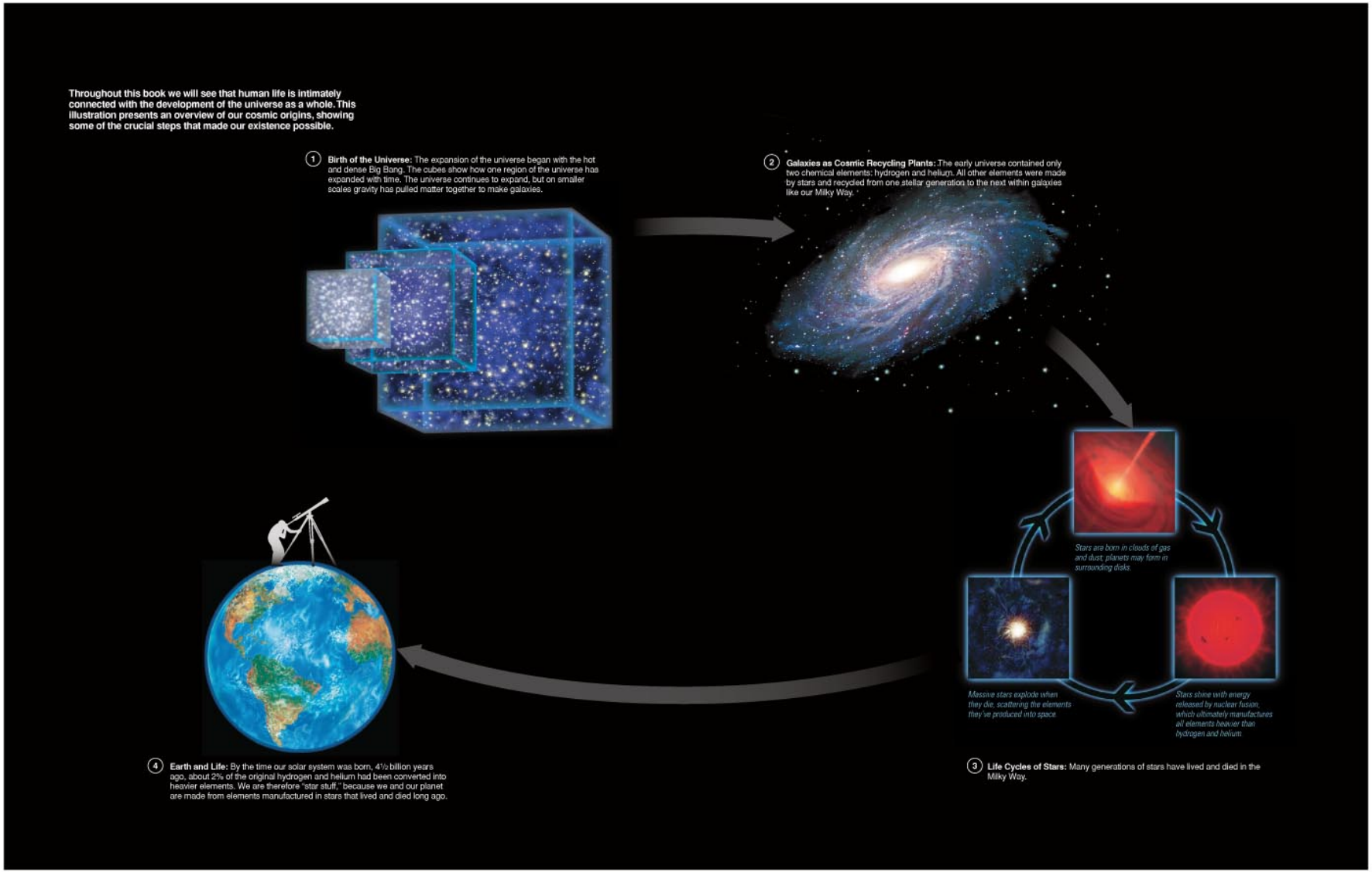
- The Milky Way is one of about 100 billion galaxies.
- 10^{11} stars/galaxy x 10^{11} galaxies = 10^{22} stars

- There are as many stars as grains of (dry) sand on *all* Earth's beaches.

1.2 The History of the Universe

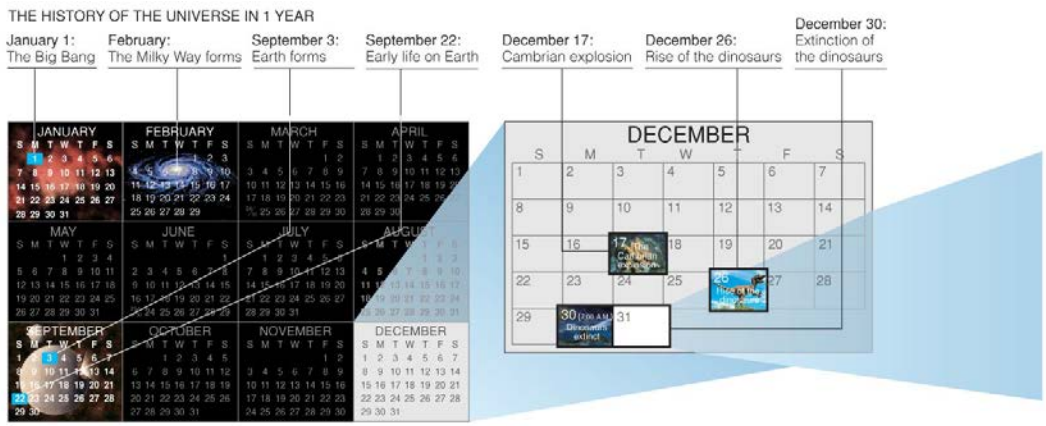
- Our goals for learning:
  - **How did we come to be?**
  - **How do our lifetimes compare to the age of the universe?**

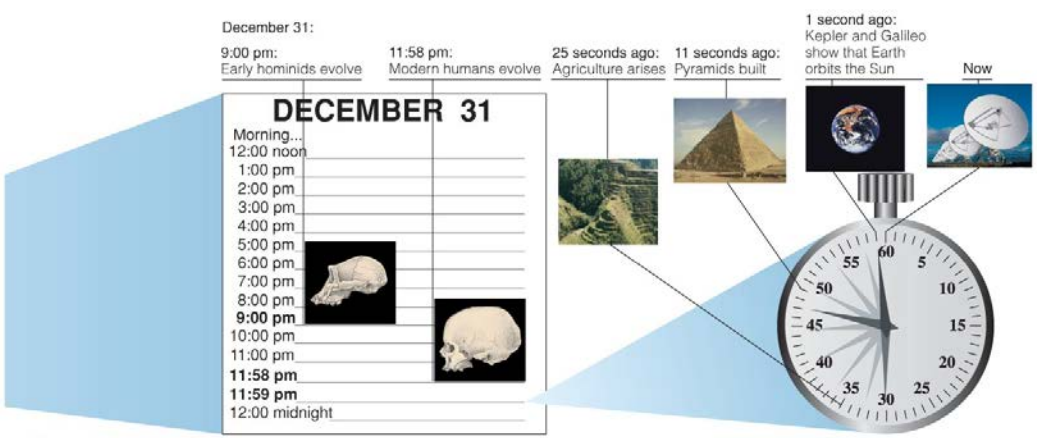
How did we come to be?



How do our lifetimes compare to the age of the universe?

- The cosmic calendar: a scale on which we compress the history of the universe into 1 year.





What have we learned?

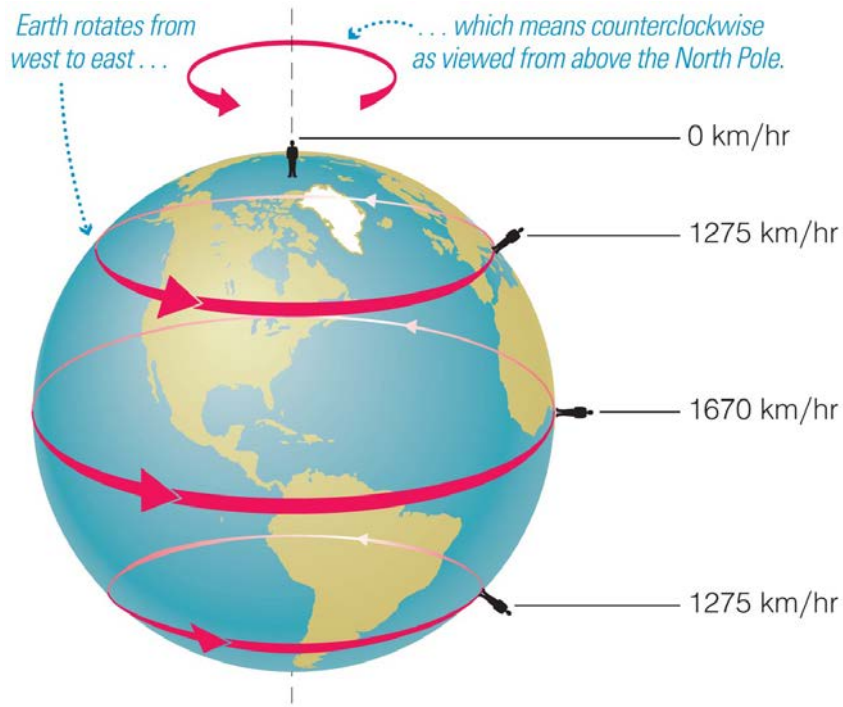
- **How did we come to be?**
  - The matter in our bodies came from the Big Bang, which produced hydrogen and helium.
  - All other elements were constructed from H and He in stars and then recycled into new star systems, including our solar system.
- **How do our lifetimes compare to the age of the universe?**
  - On a cosmic calendar that compresses the history of the universe into 1 year, human civilization is just a few seconds old, and a human lifetime is a fraction of a second.

1.3 Spaceship Earth

- Our goals for learning:
  - **How is Earth moving through space?**
  - **How do galaxies move within the universe?**

How is Earth moving through space?

- Contrary to our perception, we are not "sitting still."
- We are moving with Earth in several ways, and at surprisingly fast speeds.

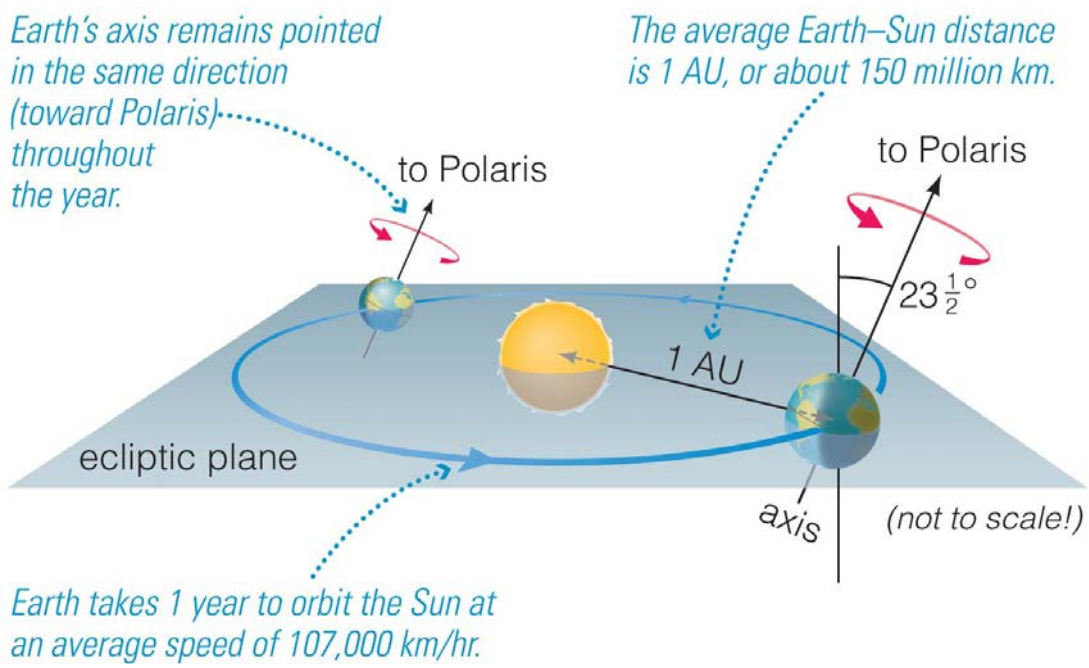


The Earth **rotates** around its axis once every day.

How is Earth moving through space?

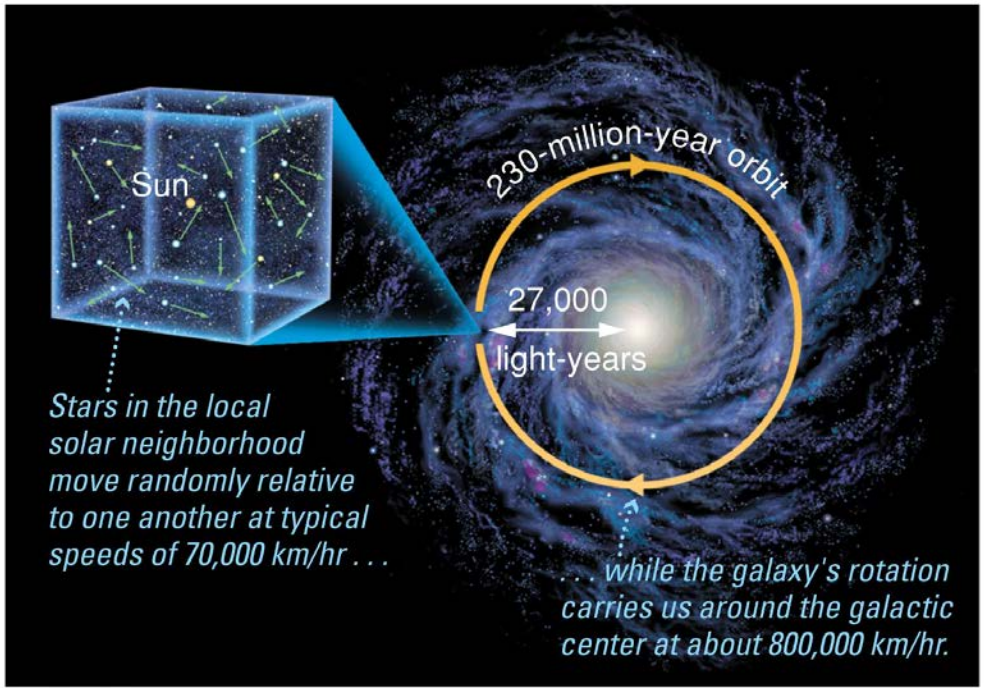
- Earth **orbits** the Sun (revolves) once every year:
  - at an average distance of 1 AU ≈ 150 million kilometers.
  - with Earth's axis tilted by 23.5º (pointing to Polaris)

- It rotates in the same direction it orbits, **counterclockwise** as viewed from above the North Pole.



How is our Sun moving in the Milky Way Galaxy?

- Our Sun moves randomly relative to the other stars in the local solar neighborhood…
  - typical relative speeds of more than 70,000 km/hr
  - but stars are so far away that we cannot easily notice their motion
- … and orbits the galaxy every 230 million years.

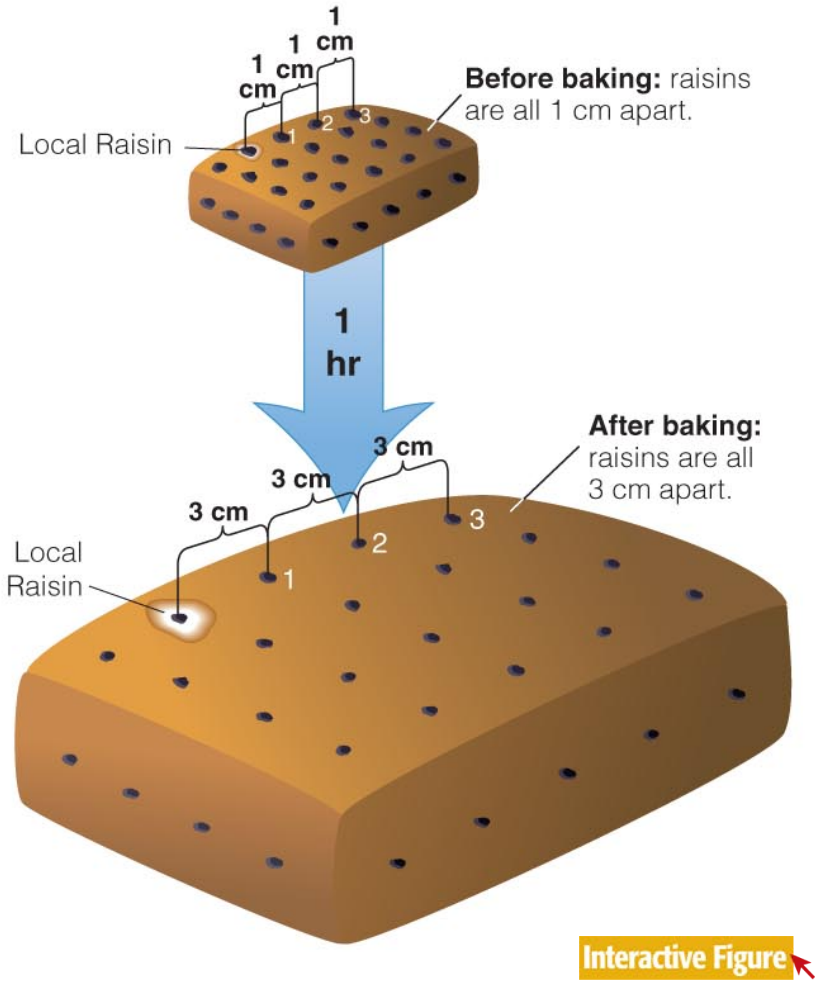


How is our Sun moving in the Milky Way Galaxy?

- More detailed study of the Milky Way's rotation reveals one of the greatest mysteries in astronomy:

How do galaxies move within the universe?

- Galaxies are carried along with the expansion of the universe. But how did Hubble figure out that the universe is expanding?

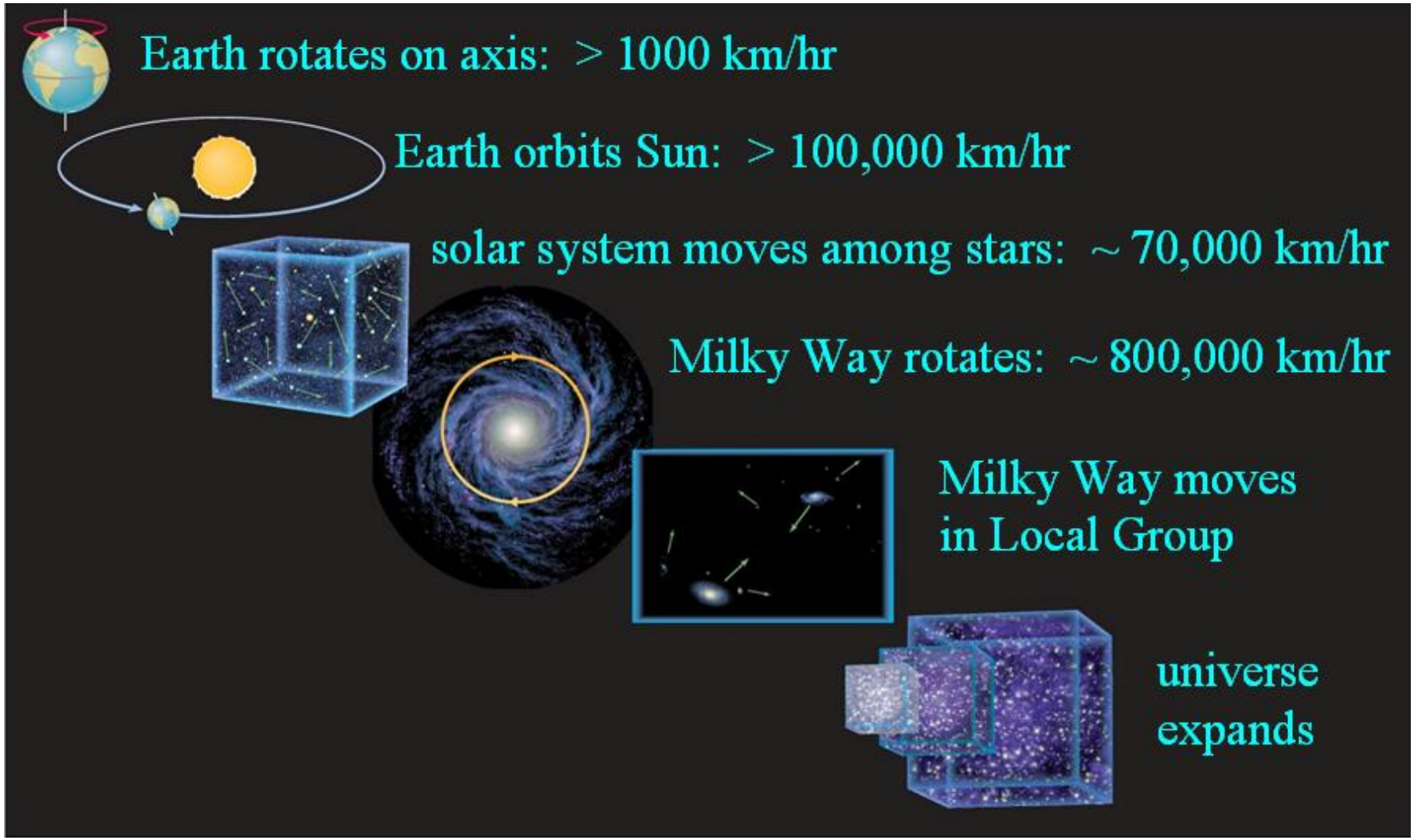


Hubble discovered that

- All galaxies outside our Local Group are moving away from us.
- The more distant the galaxy, the faster it is racing away.

- Conclusion: We live in an expanding universe.

Are we ever sitting still?



1.4 The Human Adventure of Astronomy

- Our goals for learning:
  - **How has the study of astronomy affected human history?**

How has the study of astronomy affected human history?

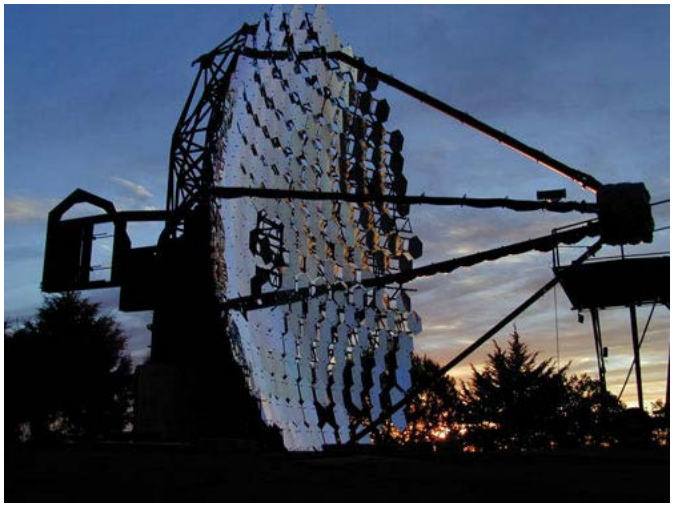
- The Copernican revolution showed that Earth was not the center of the universe (Chapter 3).
- Study of planetary motion led to Newton's laws of motion and gravity (Chapter 4).
- Newton's laws laid the foundation of the industrial revolution.
- Modern discoveries are continuing to expand our "cosmic perspective."

Multi-Wavelength Observations of the Universe

The Hubble Space Telescope (near-infrared, ultraviolet and optical)

The Chandra X-ray Observatory (X-ray)

The Very Large Array (Radio)



Gamma-ray Astronomy at the Whipple Observatory