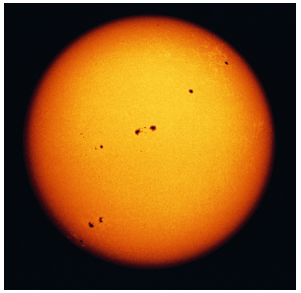
Chapter 1
Our Place in the Universe

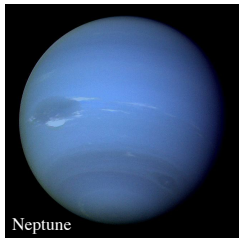
1) What is this?

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



2) What is this?

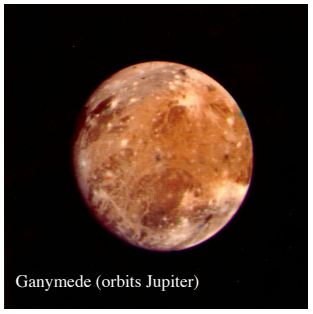
Mars



Neptune

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

3)What is this?

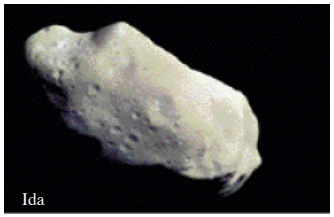


Ganymede (orbits Jupiter)

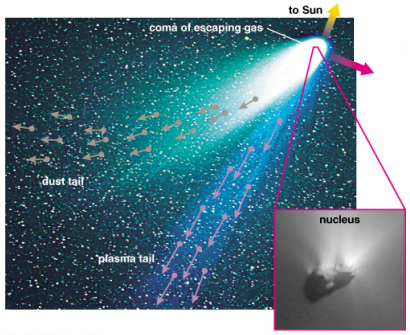
An object that orbits a planet.

4) What is this?

A relatively small and rocky object that orbits a star.



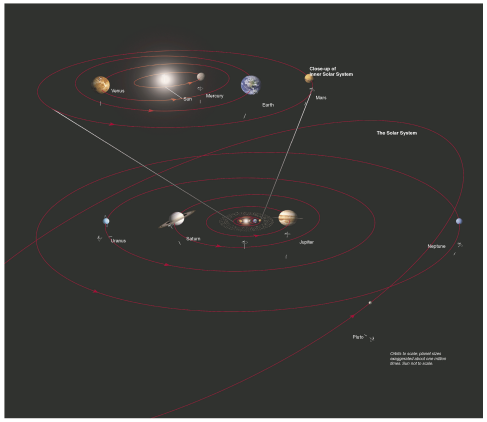
5) What is this?



A relatively small and icy object that orbits a star.

6)What is this?

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

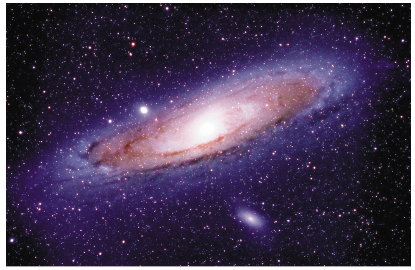


7) What is this?

An interstellar cloud of gas and/or dust

8) What is this?

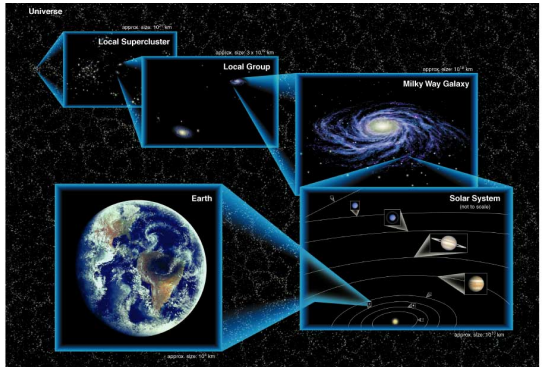
A great island of stars in space, all held together by gravity and orbiting a common center



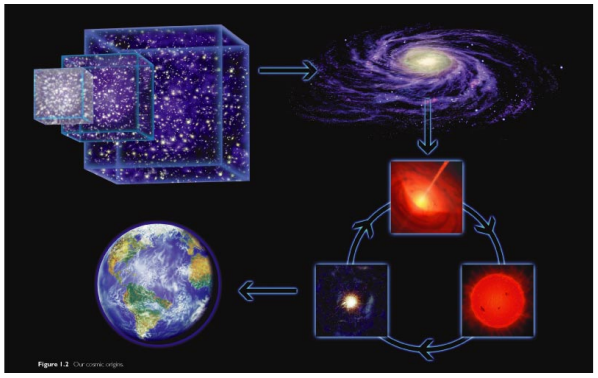
9) What is this?

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

What is our place in the universe?



How did we come to be?



How can we know what the universe was like in the past?

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

Destination	Light travel time
Moon	
Sun	
Nearest Star	
Andromeda Galaxy	

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

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

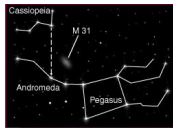
Example:

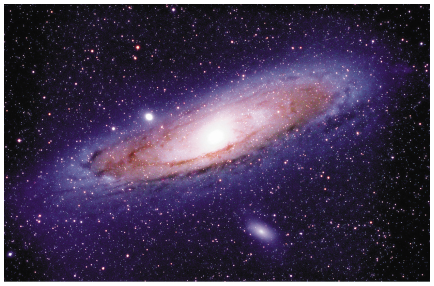
We see the Orion Nebula as it looked 1,500 years ago.

Example:

This photo shows the Andromeda Galaxy as it looked about 2 1/2 million years ago.

Question: When will be able to see what it looks like now?





Light-year

- The **distance** light can travel in one year.
- About 10 trillion km (6 trillion miles).

How far is a light-year?

$$1\,\text{light - year} = (\text{speed of light}) \times (1\ \text{year})$$
$$= \left(300{,}000\,\frac{\text{km}}{\text{s}}\right) \times \left(\frac{365\ \text{days}}{1\ \text{yr}} \times \frac{24\ \text{hr}}{1\ \text{day}} \times \frac{60\ \text{min}}{1\ \text{hr}} \times \frac{60\ \text{s}}{1\ \text{min}}\right)$$

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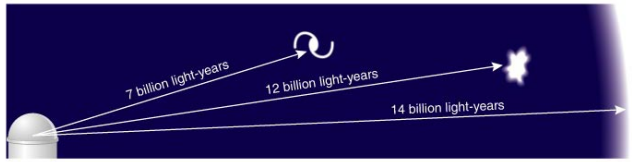
$$= 9{,}460{,}000{,}000{,}000\ \text{km}$$

What is that number in scientific notation?
→ 9.46×10^{12} km

- At great distances, we see objects as they were when the universe was much younger.



The universe is about 14 billion years old.

How big is Earth compared to our solar system?

Let's reduce the size of the solar system by a factor of 10 billion; the Sun is now the size of a large grapefruit (14 cm diameter).

How big is Earth on this scale?

A. an atom
B. a ball point
C. a marble
D. a golf ball

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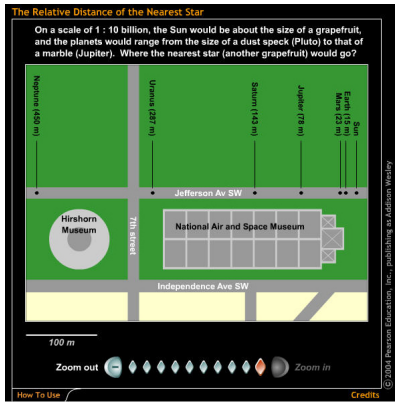
What is the distance between the Earth and the Sun?

- about 100 solar diameters

The scale of the solar system



How big is the Milky Way Galaxy?

Thought Question

Suppose you tried to count the more than 100 billion stars in our galaxy, at a rate of one per second…

How long would it take you?

A. a few weeks
B. a few months
C. a few years
D. a few thousand years

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How big is the Universe?

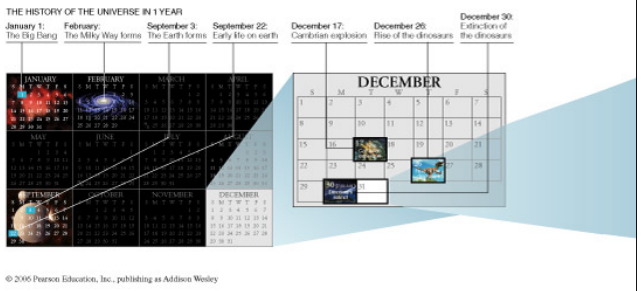
- The Milky Way is one of about 100 billion galaxies.
- 10^{11} stars/galaxy x 10^{11} galaxies = 10^{22} stars

As many stars as grains of (dry) sand on *all* Earth's beaches…

- Now let's step through the Universe in powers of 10:

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.



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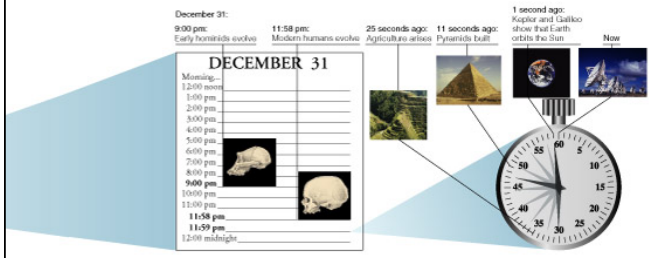
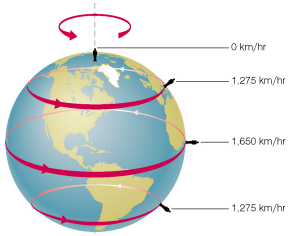


How is Earth moving in our solar system?

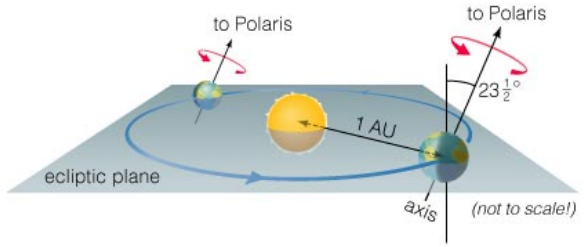
- Contrary to our perception, we are not "sitting still."
- We are moving with the Earth in several ways, and at surprisingly fast speeds…



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

Earth **orbits** the Sun (revolves) once every year:

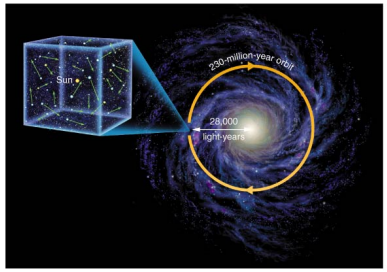
- at an average distance of 1 AU ≈ 150 million km.
- with Earth's axis tilted by 23.5º (pointing to Polaris)
- and rotating in the same direction it orbits, **counter-clockwise** as viewed from above the North Pole.



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

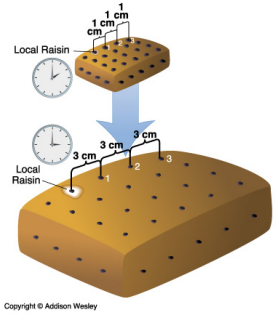
- typical relative speeds of more than 70,000 km/hr
- but stars are so far away that we cannot easily notice their motion

… And orbits the galaxy every 230 million years.



How 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?