Chapter 1: Our Place in the Universe

1.1 A Modern View of the Universe

Our goals for learning:
- What is our physical place in the Universe?
- How did we come to be?
- How can we know what the Universe was like in the past?
- Can we see the entire universe?

What is our physical place in the universe?

- Our “Cosmic Address”

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.

- Mars
- Neptune

**Moon (or satellite)**

An object that orbits a planet.

- Ganymede (orbits Jupiter)

**Asteroid**

A relatively small and rocky object that orbits a star.

- Eros

**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
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

Universe
The sum total of all matter and energy; that is, everything within and between all galaxies
How did we come to be?
• Our Cosmic Origins

How can we know what the universe was like in the past?
• Light travels at a finite speed (300,000 km/s).

<table>
<thead>
<tr>
<th>Destination</th>
<th>Light travel time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moon</td>
<td>1 second</td>
</tr>
<tr>
<td>Sun</td>
<td>8 minutes</td>
</tr>
<tr>
<td>Sirius</td>
<td>8 years</td>
</tr>
<tr>
<td>Andromeda Galaxy</td>
<td>2.5 million years</td>
</tr>
</tbody>
</table>

• 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:
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?

Definition: a light-year
• The distance light can travel in one year.
• About 10 trillion km (6 trillion miles).
  - 6,000,000,000,000 miles
• Review: name the number
  - 1,000
  - 1,000,000
  - 1,000,000,000
  - 1,000,000,000,000
  - 1,000,000,000,000,000
Look Back Time

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

Can we see the entire universe?

Light from the distance shown as the universe was only 2 billion years old.

Thought Question

Why can’t we see a galaxy 15 billion light-years away? (Assume universe is 14 billion years old.)

A. Because no galaxies exist at such a great distance.
B. Galaxies may exist at that distance, but their light would be too faint for our telescopes to see.
C. Because looking 15 billion light-years away means looking to a time before the universe existed.

1.2 The Scale of the Universe

Our goals for learning:

- How big is Earth compared to our solar system?
- How far away are the stars?
- How big is the Milky Way Galaxy?
- How big is the Universe?
- How do our lifetimes compare to the age of the Universe?
Relative Sizes of Planets

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

The scale of the solar system

- On a 1-to-10 billion scale:
  - Sun is the size of a large grapefruit (14 cm)
  - Earth is the size of a ball point, 15 meters away.

How far away are the stars?

On our 1-to-10 billion scale, it’s just a few minutes walk to Pluto.

How far would you have to walk to reach Alpha Centauri?
A. 1 mile
B. 10 miles
C. 100 miles
D. the distance across the U.S. (2500 miles)
How big is the Milky Way Galaxy?

The Milky Way has about 100 billion stars. On the same ten billion-to-one scale, the universe contains about 100 billion galaxies. As many stars as grains of (dry) sand on all Earth’s beaches.

How big is the Universe?

- The Milky Way is one of about 100 billion galaxies.
- 100 billion stars/galaxy \times 100 billion galaxies = \text{10,000,000,000,000,000,000 stars}

As many stars as grains of (dry) sand on all Earth’s beaches.

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.

Are we ever sitting still?

1. Formation
2. Beginning
3. Expansion
4. Evolution
5. Future

- Expansion: cosmological expansion of the universe, causing galaxies to move apart.
- Evolution: evolution of the universe, from the Big Bang to the present day.