1.1 A Modern View of the Universe

Our goals for learning:

- 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?
- Can we see the entire universe?

What Objects Do We Find in The Universe?

- The Universe contains everything we see around us.

Stars

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

Planets

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

Moons (or satellites)

An object that orbits a planet.

Asteroids

A relatively small and rocky object that orbits a star.

Comets

A relatively small and icy object that orbits a star.

Solar (Star) System(s)

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

Nebulas

An interstellar cloud of gas and/or dust

Galaxies

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

M31, The Great Galaxy in Andromeda

The Universe

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

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	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.

Light-year

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

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

What have we learned?

- What is our physical place in the universe?
  - Earth is part of the Solar System, which is the Milky Way galaxy, which is a member of the Local Group of galaxies in the Local Supercluster
- 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 star and then recycled into new star systems, including our solar system

What have we learned?

- How can we know that the universe was like in the past?
  - When we look to great distances we are seeing events that happened long ago because light travels at a finite speed
- Can we see the entire universe?
  - No, the observable portion of the universe is about 14 billion light-years in radius because the universe is about 14 billion years old

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?

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 big is the Milky Way Galaxy?

The Milky Way has about 100 billion stars.

On the same ten billion-to-one scale….

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…

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 big is Earth compared to our solar system?
  - The distances between planets are huge compared to their sizes—on a scale of 1-to-10 billion, Earth is the size of a ball point and the Sun is 15 meters away
- How far away are the stars?
  - On the same scale, the stars are thousands of km away
- How big is the Milky Way galaxy?
  - It would take more than 3,000 years to count the stars in the Milky Way Galaxy at a rate of one per second, and they are spread across 100,000 light-years

What have we learned?

- How big is the universe?
  - The observable universe is 14 billion light-years in radius and contains over 100 billion galaxies with a total number of stars comparable to the number of grains of sand on all of Earth's beaches
- How do our lifetimes compare to the age of the universe?
  - On a cosmic calendar that compresses the history of the Universe into one 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 in our solar system?
- How is our solar system moving in the Galaxy?
- How do galaxies move within the Universe?
- Are we ever sitting still?

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.

What have we learned?

- How is Earth moving in our solar system?
  - It rotates on its axis once a day and orbit the Sun at a distance of 1 A.U. = 150 million km
- How is our solar system moving in the Milky Way galaxy?
  - Stars in the Local Neighborhood move randomly relative to one another and orbit the center of the Milky Way in about 230 million years

What have we learned?

- How do galaxies move within the universe?
  - All galaxies beyond the Local Group are moving away from us with expansion of the Universe: the more distant they are, the faster they're moving
- Are we ever sitting still?
  - No!

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?

- 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"

What have we learned?

- How has the study of astronomy affected human history?
  - Throughout history, astronomy has provided an expanded perspective on Earth that has grown hand in hand with social and technological developments

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