Introduction to the Solar System

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CHAPTER 1

Introduction to the Solar System

Lesson Objectives

- Describe some early ideas about our solar system.
- Name the planets, and describe their motion around the Sun.
- Explain how the solar system formed.

Vocabulary

- astronomical unit
- dwarf planet
- nebula
- nuclear fusion
- planet
- solar system

Introduction

We can learn a lot about the universe and about Earth history by studying our nearest neighbors. The solar system has planets, asteroids, comets, and even a star for us to see and understand. It's a fascinating place to live!

Changing Views of the Solar System

The Sun and all the objects that are held by the Sun's gravity are known as the **solar system**. These objects all revolve around the Sun. The ancient Greeks recognized five planets. These lights in the night sky changed their position against the background of stars. They appeared to wander. In fact, the word "planet" comes from a Greek word meaning "wanderer." These objects were thought to be important, so they named them after gods from their mythology. The names for the planets Mercury, Venus, Mars, Jupiter, and Saturn came from the names of gods and a goddess.

Earth at the Center of the Universe

The ancient Greeks thought that Earth was at the center of the universe, as shown in **Figure** 1.1. The sky had a set of spheres layered on top of one another. Each object in the sky was attached to one of these spheres. The object moved around Earth as that sphere rotated. These spheres contained the Moon, the Sun, and the five planets they recognized: Mercury, Venus, Mars, Jupiter, and Saturn. An outer sphere contained all the stars. The planets appear to move much faster than the stars, so the Greeks placed them closer to Earth. Ptolemy published this model of the solar system around 150 AD.

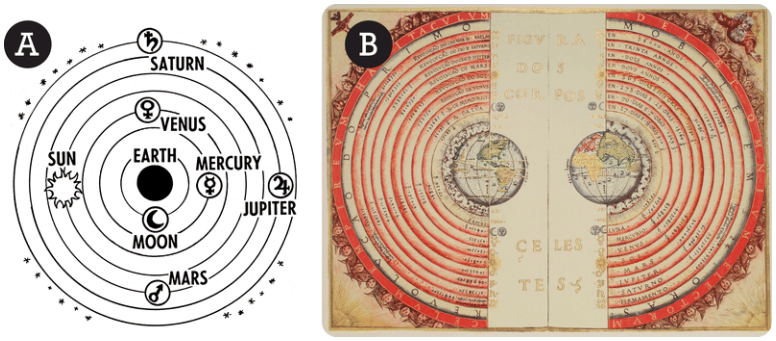

FIGURE 1.1

On left is a line art drawing of the Ptolemaic system with Earth at the center. On the right is a drawing of the Ptolemaic system from 1568 by a Portuguese astronomer.

The Sun at the Center of the Universe

About 1,500 years after Ptolemy, Copernicus proposed a startling idea. He suggested that the Sun is at the center of the universe. Copernicus developed his model because it better explained the motions of the planets. **Figure** 1.2 shows both the Earth-centered and Sun-centered models.

FIGURE 1.2

Copernicus proposed a different idea that had the Sun at the center of the universe

Copernicus did not publish his new model until his death. He knew that it was heresy to say that Earth was not the center of the universe. It wasn't until Galileo developed his telescope that people would take the Copernican model more seriously. Through his telescope, Galileo saw moons orbiting Jupiter. He proposed that this was like the planets orbiting the Sun.

Planets and Their Motions

Today we know that we have eight planets, five dwarf planets, over 165 moons, and many, many asteroids and other small objects in our solar system. We also know that the Sun is not the center of the universe. But it is the center of the solar system.

FIGURE 1.3
This artistic composition shows the eight planets, a comet, and an asteroid.

Figure 1.3 shows our solar system. The planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. **Table** 1.1 gives some data on the mass and diameter of the Sun and planets relative to Earth.

TABLE 1.1: Sizes of Solar System Objects Relative to Earth

Object	Mass (Relative to Earth)	Diameter of Planet (Relative to Earth)
Sun	333,000 Earth's mass	109.2 Earth's diameter
Mercury	0.06 Earth's mass	0.39 Earth's diameter
Venus	0.82 Earth's mass	0.95 Earth's diameter
Earth	1.00 Earth's mass	1.00 Earth's diameter
Mars	0.11 Earth's mass	0.53 Earth's diameter
Jupiter	317.8 Earth's mass	11.21 Earth's diameter
Saturn	95.2 Earth's mass	9.41 Earth's diameter
Uranus	14.6 Earth's mass	3.98 Earth's diameter
Neptune	17.2 Earth's mass	3.81 Earth's diameter

What Is (and Is Not) a Planet?

You've probably heard about Pluto. When it was discovered in 1930, Pluto was called the ninth planet. Astronomers later found out that Pluto was not like other planets. For one thing, what they were calling Pluto was not a single object. They were actually seeing Pluto and its moon, Charon. In older telescopes, they looked like one object. This one object looked big enough to be a planet. Alone, Pluto was not very big. Astronomers also discovered many objects like Pluto. They were rocky and icy and there were a whole lot of them.

Astronomers were faced with a problem. They needed to call these other objects planets. Or they needed to decide that Pluto was something else. In 2006, these scientists decided what a planet is. According to the new definition, a **planet** must:

- Orbit a star.
- Be big enough that its own gravity causes it to be round.
- Be small enough that it isn't a star itself.
- Have cleared the area of its orbit of smaller objects.

If the first three are true but not the fourth, then that object is a **dwarf planet**. We now call Pluto a dwarf planet. There are other dwarf planets in the solar system. They are Eris, Ceres, Makemake and Haumea. There are many other reasons why Pluto does not fit with the other planets in our solar system.

The Size and Shape of Orbits

FIGURE 1.4

The Sun and planets with the correct sizes. The distances between them are not correct.

Figure 1.4 shows the Sun and planets with the correct sizes. The distances between them are way too small. In general, the farther away from the Sun, the greater the distance from one planet's orbit to the next.

Figure 1.5 shows those distances correctly. In the upper left are the orbits of the inner planets and the asteroid belt. The asteroid belt is a collection of many small objects between the orbits of Mars and Jupiter. In the upper right are the orbits of the outer planets and the Kuiper belt. The Kuiper belt is a group of objects beyond the orbit of Neptune.

In **Figure** 1.5, you can see that the orbits of the planets are nearly circular. Pluto's orbit is a much longer ellipse. Some astronomers think Pluto was dragged into its orbit by Neptune.

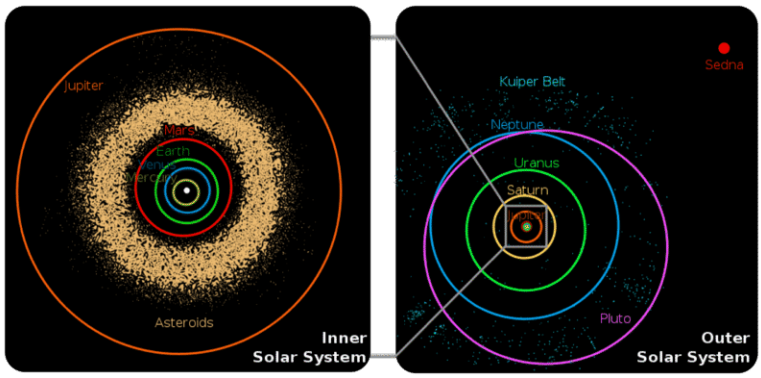

FIGURE 1.5
In this image, distances are shown to scale.

Distances in the solar system are often measured in **astronomical units** (AU). One astronomical unit is defined as the distance from Earth to the Sun. 1 AU equals about 150 million km (93 million miles). **Table** 1.2 shows the distance from the Sun to each planet in AU. The table shows how long it takes each planet to spin on its axis. It also shows how long it takes each planet to complete an orbit. Notice how slowly Venus rotates! A day on Venus is actually longer than a year on Venus!

TABLE 1.2: Distances to the Planets and Properties of Orbits Relative to Earth's Orbit

Planet	Average Distance from Sun (AU)	Length of Day (In Earth Days)	Length of Year (In Earth Years)
Mercury	0.39 AU	56.84 days	0.24 years
Venus	0.72	243.02	0.62
Earth	1.00	1.00	1.00
Mars	1.52	1.03	1.88
Jupiter	5.20	0.41	11.86
Saturn	9.54	0.43	29.46
Uranus	19.22	0.72	84.01
Neptune	30.06	0.67	164.8

The Role of Gravity

Planets are held in their orbits by the force of gravity. What would happen without gravity? Imagine that you are swinging a ball on a string in a circular motion. Now let go of the string. The ball will fly away from you in a straight line. It was the string pulling on the ball that kept the ball moving in a circle. The motion of a planet is very similar to the ball on a string. The force pulling the planet is the pull of gravity between the planet and the Sun.

Every object is attracted to every other object by gravity. The force of gravity between two objects depends on the mass of the objects. It also depends on how far apart the objects are. When you are sitting next to your dog, there is a gravitational force between the two of you. That force is far too weak for you to notice. You can feel the force of gravity between you and Earth because Earth has a lot of mass. The force of gravity between the Sun and planets is also very large. This is because the Sun and the planets are very large objects. Gravity is great enough to hold the planets to the Sun even though the distances between them are enormous. Gravity also holds moons in orbit around planets.

Extrasolar Planets

Since the early 1990s, astronomers have discovered other solar systems. A solar system has one or more planets orbiting one or more stars. We call these planets "extrasolar planets," or "exoplanets". They are called exoplanets because they orbit a star other than the Sun. As of June 2013, 891 exoplanets have been found. More exoplanets are found all the time. You can check out how many we have found at http://planetquest.jpl.nasa.gov/.

planets orbit in the same direction around the Sun. These two features are clues to how the solar system formed.

A Giant Nebula

Scientists think the solar system formed from a big cloud of gas and dust, called a **nebula**. This is the solar nebula hypothesis. The nebula was made mostly of hydrogen and helium. There were heavier elements too. Gravity caused the nebula to contract (**Figure** 1.6).

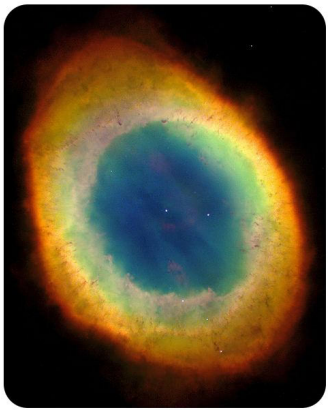

FIGURE 1.6

The nebula was drawn together by gravity.

As the nebula contracted, it started to spin. As it got smaller and smaller, it spun faster and faster. This is what happens when an ice skater pulls her arms to her sides during a spin move. She spins faster. The spinning caused the nebula to form into a disk shape.

This model explains why all the planets are found in the flat, disk-shaped region. It also explains why all the planets revolve in the same direction. The solar system formed from the nebula about 4.6 billion years ago

Formation of the Sun and Planets

The Sun was the first object to form in the solar system. Gravity pulled matter together to the center of the disk. Density and pressure increased tremendously. **Nuclear fusion** reactions begin. In these reactions, the nuclei of atoms come together to form new, heavier chemical elements. Fusion reactions release huge amounts of nuclear energy. From these reactions a star was born, the Sun.

Meanwhile, the outer parts of the disk were cooling off. Small pieces of dust started clumping together. These clumps collided and combined with other clumps. Larger clumps attracted smaller clumps with their gravity. Eventually, all these pieces grew into the planets and moons that we find in our solar system today.

The outer planets — Jupiter, Saturn, Uranus, and Neptune — condensed from lighter materials. Hydrogen, helium, water, ammonia, and methane were among them. It's so cold by Jupiter and beyond that these materials can form solid particles. Closer to the Sun, they are gases. Since the gases can escape, the inner planets — Mercury, Venus, Earth, and Mars — formed from denser elements. These elements are solid even when close to the Sun.

Lesson Summary

- The Sun and all the objects held by its gravity make up the solar system.

- There are eight planets in the solar system: Mercury, Venus, Earth, Mars, Jupiter, Saturn, and Neptune. Pluto, Eris, Ceres, Makemake and Haumea are dwarf planets.
- The ancient Greeks believed Earth was at the center of the universe and everything else orbited Earth.
- Copernicus proposed that the Sun at the center of the universe and the planets and stars orbit the Sun.
- Planets are held by the force of gravity in elliptical orbits around the Sun.
- The solar system formed from a giant cloud of gas and dust about 4.6 billion years ago.
- This model explains why the planets all lie in one plane and orbit in the same direction around the Sun.

Lesson Review Questions

Recall

1. What are the names of the planets from the Sun outward? What are the names of the dwarf planets?

2. How old is the Sun? How old are the planets?

Apply Concepts

3. Describe the role of gravity in how the solar system functions. Why don't the planets fly off into space? Why don't the planets ram into the Sun?

4. Why does the nebular hypothesis explain how the solar system originated?

Think Critically

5. Why do you think so many people for so many centuries thought that Earth was the center of the universe?

6. People were pretty upset when Pluto was made a dwarf planet. Why do you think they were upset? How do you feel about it?

Points to Consider

- Would you expect all the planets in the solar system to be made of similar materials? Why or why not?
- The planets are often divided into two groups: the inner planets and the outer planets. Which planets do you think are in each of these two groups? What do members of each group have in common?

References

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