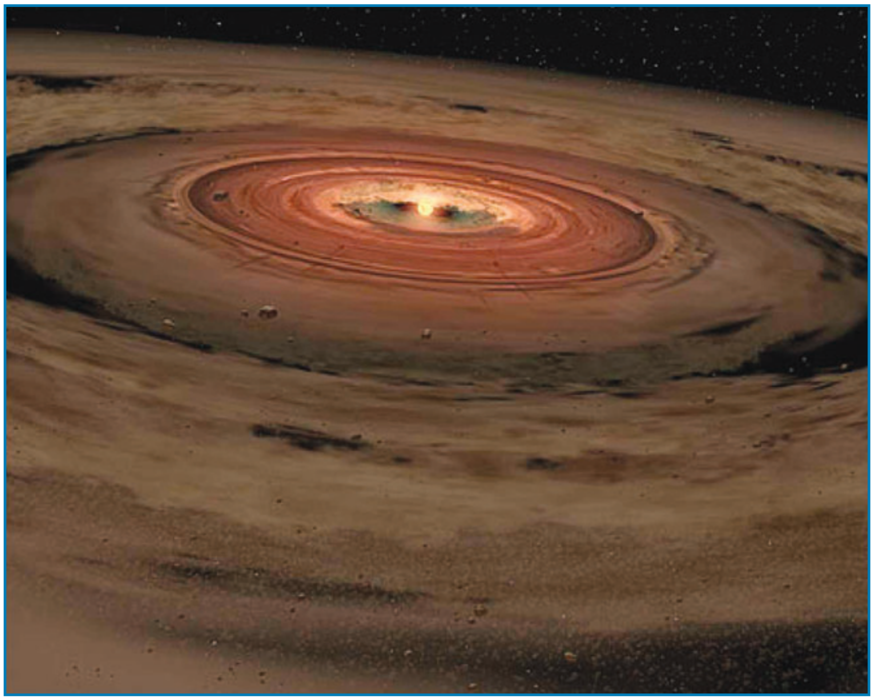
3.5 Explore

Where in the Solar System Are Smaller Objects Found?

In *Learning Set 1,* you read about some of the other objects in the solar system. You learned about dwarf planets and smaller solar system objects such as asteroids, comets, and meteoroids. Now that you have developed a model of the sizes and distances of the planets in the solar system, you can use that model as a map to help you understand where the other solar-system objects are found. You must know where those solar system objects can be found to know if solar-system objects will collide.



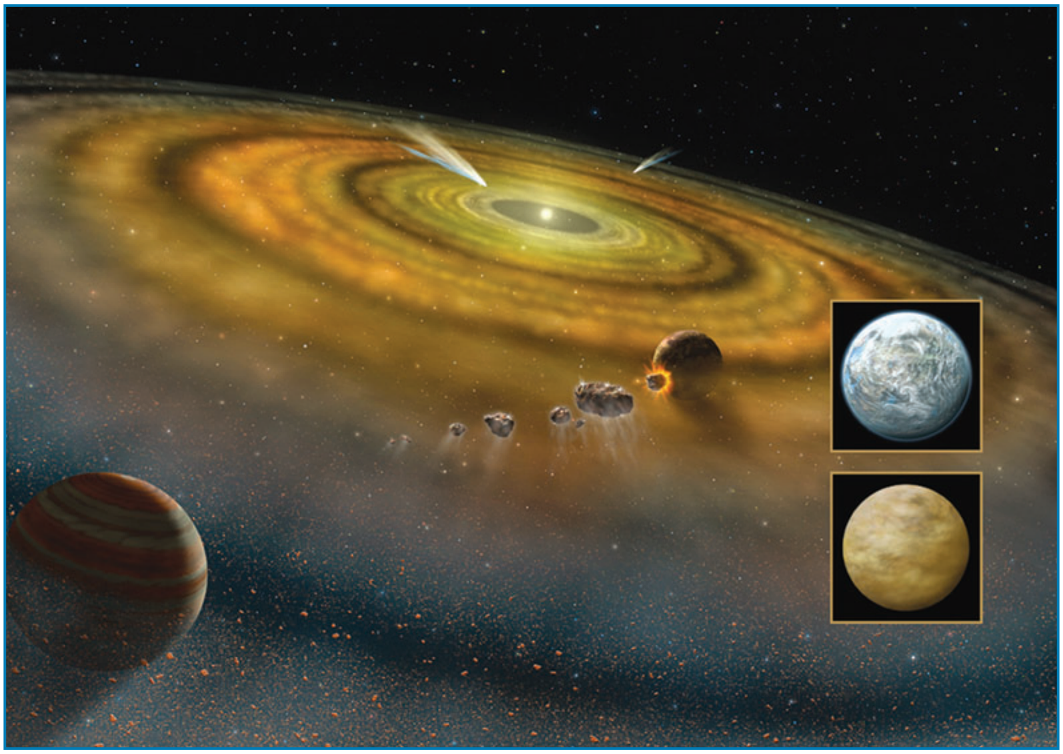
The universe most likely started as a large collection of gas and dust, as this artist's rendering illustrates.

Answering the question of where the other solar-system objects are located is easier if you understand how the solar system was formed. The solar system has not existed forever. The universe is about 14 billion years old, but the solar system formed less than 5 billion years ago.

Formation of the Solar System

Scientists have several theories about how the solar system formed. There are small differences in the theories, but they are all the same in many ways. All of the current theories say that the universe started as a large collection of gas and dust in space. This gas and dust was in a cloud much greater in size than the orbit of Neptune. The gas and dust started to spin and collapse in on itself. As parts of the cloud spun faster and faster around the center, and different pieces collided with each other, the cloud became a flattened disk with a bulge at the center. The center of the bulge became very hot, and as soon as it was hot enough for fusion to occur, the Sun was officially born.

According to current theories, most of the mass in the cloud collapsed inward to form the Sun. But the parts that remained outside the bulge in the disk continued to collide and combine with each other. Eventually, eight little balls formed within the disk, sweeping up everything in their path. These eight balls eventually became the eight planets.



According to scientists, the parts of the mass that did not become part of the Sun continued to collide and combine with one another. As in this illustration, the remaining eight balls became the eight planets in our solar system. Not to scale.

This theory of the solar system's formation accounts for two important facts about the way the planets orbit the Sun. The planets all travel in the same direction around the Sun, counterclockwise, as seen from above. The planets orbit in the same direction around the Sun because the original disk was spinning in that direction. Also, all of the planets lie within the same *orbital plane* because they all formed within the flattened disk of matter surrounding the new Sun. You can think of the orbital plane of the solar system as a tabletop. The planets all orbit the Sun as if they were marbles rolling on the tabletop. Most solar-system objects have orbits that are tilted a little bit. This means that part of the orbit is above the orbital plane and part is below the orbital plane. Some objects have orbits that are tilted much more, but these orbits most likely were the result of collisions or near misses.

Remember the story of the Moon's formation that you read about in *Learning Set 2.* In this scenario, the Moon came into being after Earth had already formed. Because a collision probably brought about the Moon's formation, the Moon does not quite lie in the orbital plane of the planets. In fact, the Moon's orbit is tilted 5° away from the orbital plane.

An artist imagines the asteroid belt.

According to these theories, even after the planets formed, there was still material left over from the formation of the solar system. The early history of the solar system was filled with collisions, the records of which still exist on the Moon and other objects in the solar system. Other bits of leftover material formed the other smaller objects in the solar system. For example, some rocky, iron-rich material collected in between the orbits of Mars and Jupiter. This collection of over one million rocky objects, each over a kilometer in diameter, is now called the *asteroid belt.*

Most asteroids are found in the asteroid belt. However, asteroids can be found throughout the solar system. Some of these other asteroids may have formed in the asteroid belt and then their orbits changed because they passed too close to Jupiter.

A million asteroids in one area seems like a lot. It may seem that collisions would occur all the time, at least within the asteroid belt. Have you ever watched a science fiction film with a "chase scene" through the asteroids? There are no doubt collisions among the asteroids as they tumble through space, which makes for exciting special effects. However, one thing to remember is that there is a lot of space in space! The area between the orbits of Mars and Jupiter is over two quintillion square kilometers (2,000,000,000,000,000,000 km^2) in size. If you assume that there are a million asteroids in the asteroid belt, and they all lie in the orbital plane, then there is only one asteroid per two trillion square kilometers (2,000,000,000,000 km^2) of the orbital plane. This means that in an area that is four times the area of Earth's surface, you would only find one rock about a kilometer in diameter.

Astronomers have investigated whether the asteroid belt could be debris left over from destruction of a planet between Mars and Jupiter. Scientists now think, though, that there is not enough debris in the asteroid belt to account for the destruction of such a planet.

Astronomers learn about the solar system through the use of telescopes in space, such as the Hubble, and on Earth. This telescope is part of NASA's Catalina Sky Survey in Arizona.

You know there is evidence on the Moon's surface of many impacts that occurred in the past. You also know that the Moon may have formed in a collision that occurred after the planets formed. Scientists think that the early solar system had much more debris than there is now. There may have been several periods of intense bombardment in the early solar system. During these periods, collisions would have occurred much more frequently than they do now. One way of thinking about this is that collisions are less likely now because most of the objects that would collide have already done so.

In science, a theory is the best explanation that scientists have at any given time. The best explanation is one that has lots of data to support it. To learn more about the formation of the solar system and about how objects in the solar system move, scientists collect data using telescopes and space probes. They also use computer models and simulations to help them test their theories. Scientists build computer models to match their theories, and they use them to simulate what happens in the universe over billions of years.

If a model is good, then the simulation will show solar-system objects moving in space the way we see them move today. The data astronomers collect from observing the sky and the data collected from computer simulations should match. If a theory about the formation of the solar system is accurate, the computer simulation should predict where astronomers would find other solar-system objects that have never been sighted before. When astronomers find solar-system objects they have not seen before, they gain evidence to support their theories. In science, the best theory is the one that explains available data and makes the best predictions.

Stop and Think

1. Describe the events that led to the formation of the solar system.
2. Why do the planets all move in the same direction around the Sun?
3. The asteroid belt contains over a million objects 1 kilometer or more in diameter and countless smaller objects. Why is it still correct to describe the asteroid belt as a relatively empty place?

Near-Earth Objects

Knowing about the formation of the solar system may give you some clues about where other smaller objects in the solar system might be found and how they move. Smaller objects that orbit around larger objects are called **satellites**. Many of the objects in the solar system lie in well-defined orbits that do not cross Earth's orbit, so they are unlikely to collide with Earth. Other objects are moons of other planets. These moons will never stray far from the planet they orbit. Gravity from the planet they orbit will keep them far from the orbits of other planets.

Some of the smaller solar-system objects, such as comets, have flattened elliptical orbits. When they are far from the Sun, beyond the orbit of Neptune, comets travel slowly. Some take thousands of years to orbit once around the Sun. But because their orbits are very elliptical, their path is more likely to cross the path of a planet, similar to the way the Shoemaker-Levy 9 comet crossed paths with Jupiter.

satellite: a smaller object that is in orbit around a larger object.

Near-Earth Objects (NEOs): asteroids and comets that cross the orbit of Earth.

Another factor in determining whether an object will collide with a solar-system object is whether the object's orbit is *inclined.* Some dwarf planets, such as Pluto, have orbits that are inclined at a great angle from the orbital plane of the solar system. This means that they are much less likely to cross the path of another planet because they do not spend much time in the orbital plane.

Any asteroids and comets that cross the orbit of Earth are tracked by the governments of the world. These objects are classified as **Near-Earth Objects (NEOs)**. Once an NEO is detected, it is reported and monitored. In the United States, NASA catalogs all NEOs that have the potential to be catastrophic if they collided with Earth. Scientists monitor the orbits of NEOs and investigate questions such as how many there are, their origins, and their threat to Earth.

Stop and Think

1. Does a space object have to have an Earth-crossing orbit in order to collide with Earth? Why or why not?
2. Do you think the number of objects listed as Near-Earth Objects is always increasing, or could the list become shorter?

Reflect

1. Look back to the kinds of objects listed on your *Solar System* page. Which of these objects do you think are most likely to have a collision with another solar-system object?
2. Which solar-system objects do you think are very unlikely to collide with Earth? Why?
3. Which solar-system objects do you think would be most likely to collide with Earth? Why?

Update the *Project Board*

You have read a little about the formation of the solar system and the location of small solar-system objects. Your *Project Board* may have questions like *Where did all of these solar-system objects come from?* and *How did the solar system form?* You can now start to answer these questions in the *What we are learning?* and *What is our evidence?* columns.

Your reading may have raised more questions. For example, you might wonder *Where do comets come from?* If there are still things you are unsure about, or things that, if answered, would increase your confidence about what you think you know, record them in the *What do we need to investigate?* column.

What's the Point?

The solar system formed from a cloud of gas and dust a little less than 5 billion years ago. The Sun formed in the middle, and the planets formed from the leftover gas and dust that had collected in a disk around the Sun. Material that did not go into the formation of planets made up the asteroids, comets, and other objects that travel around the solar system. Near-Earth Objects (NEOs) are those objects that cross Earth's orbit.