Introduction to Lesson 9

This lesson contains some memory work that may appear disconnected at first. Examples include the kinds of minor planets based upon composition, the types of meteors, and the classes of comets. However, many of these disparate facts are tied together in the course of the lesson. Discover how these facts will be tied together, and know their relationship.

Be aware that comet tails do not trail behind comets, but instead always point away from the sun. Throughout history, people thought that comets were portends of disasters, such as plagues and the fall of kingdoms and empires. For instance, Halley's Comet was prominent at the time of the destruction of Jerusalem in a.d. 70 and at the Battle of Hastings in 1066. Additionally, at the time that the Spanish conquered the Aztecs, the leader of the Aztecs had a fatalistic attitude, because he had recently had a disturbing dream about losing his empire, which was confirmed in his mind by a bright comet.

You should realize that there is no evidence for the Oort cloud, so it really is not a scientific idea.

Know the difference between the terms *meteor*, *meteorite*, and *meteoroid*. These words are very similar and have related meanings, but they are very different. For that matter, many people confuse comets with meteors. When they see a meteor, many people exclaim, "Oh! A comet!"

It is good to be aware of evolutionary ideas, such as the ones presented in this lesson concerning the Oort cloud and the origin of the solar system. You will encounter these ideas elsewhere, and you need to understand how and why they are contrary to the Bible.

Worldview: Through the Lens

CREATIONIST	EVOLUTIONIST
Was not surprised to learn that Pluto has few craters on portions of its surface	Was surprised to learn that Pluto has regions on its surface with few craters
Believes comets indicate the solar system is not billions of years old	Thinks that comets originate from the Kuiper belt and the Oort cloud
Believes that God made the small bodies of the solar system on day four, along with the rest of the solar system	Believes that the small bodies of the solar system are remains from the naturalistic origin of the planets
Believes that God specially formed the moon on day four to fulfill specific purposes	Believes that studying the natural satellites of the other planets may reveal how the moon came to be

Small Solar System Bodies

Astronomers recognize two types of Small Solar System Bodies (SSSBs), asteroids and comets. Let's begin our discussion of SSSBs with Pluto, the largest of the SSSBs.

The Discovery of Pluto

A few decades after the discovery of Neptune, both Uranus and Neptune appeared to have slight discrepancies in their orbits. This sounded like the circumstances that led to the discovery of Neptune, so some astronomers concluded that there must be a ninth planet beyond Neptune perturbing both Uranus and Neptune. But unlike before, the discrepancies were smaller than they had been with Uranus, so the problem was poorly defined. This meant that there was much uncertainty in the predicted location of Planet X, the unknown planet responsible for the discrepancies in the orbits of Uranus and Neptune. The search for this Planet X lasted many years, with most of the work done at Lowell Observatory in Arizona.

Clyde Tombaugh discoverer of Pluto shown with his homemade 9-inch telescope.

At one point, Lowell Observatory hired a young man from Kansas named Clyde Tombaugh to work on this problem. Researchers used photography in the search. The image of the new planet would be small, resembling a faint star. The only way that astronomers could detect the planet was for them to look for a change in position from one night to the next. The region of sky that they needed to search was along the Milky Way where there are many faint stars, so the search was very tedious. A special instrument called a **blink microscope** was invented for the search. A blink microscope allows a person to rapidly alternate views of two photographs made on separate nights. As the view switched back and forth, star images would remain fixed, but any moving objects would immediately become obvious as it jumped back and forth. This is very similar to how a movie or video projector works, except that the movie in a blink microscope is a looped, two-frame movie. Astronomers have often used the blink microscope to search for asteroids. In fact, the search for Planet X resulted in the discovery of many asteroids.

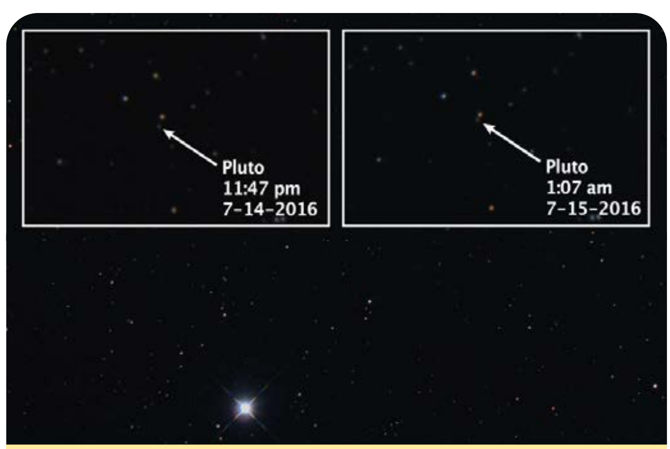
Early in 1930, Tombaugh blinked two photographs that showed another moving object. Calculation of an orbit for this new object revealed that it was

The author with the telescope Tombaugh used to discover Pluto.

The Frozen Canyons of Pluto's North Pole

orbiting beyond Neptune. Tombaugh had found Planet X. Astronomers chose the name Pluto, the god of the underworld. This was big news that generated much popular interest. Businesses cashed in on the craze, such as restaurants offering "Pluto burgers" on their menus. The up-and-coming cartoonist Walt Disney had decided to give his relatively new character Mickey Mouse a pet dog, and he chose the name Pluto to capitalize on the new planet craze.

Except that Pluto isn't a planet, at least since 2006 when the IAU said otherwise. As discussed in lesson 7, the IAU decided that Pluto wasn't a planet, primarily based upon the fact that it is too small to be a planet. At the time, the public largely disapproved, though opposition to the change seems to have waned considerably since. If Pluto isn't a planet, then what is it? Astronomers now classify Pluto as an asteroid, or minor planet.



Two photographs of Pluto taken only 80 minutes apart, showing the slight change in Pluto's position, indicating that it is not a star.

Asteroids

In 1801, the Sicilian astronomer Giuseppe Piazzi discovered a faint star-like object that appeared to move from night to night. A few nights of observations allowed calculation of an orbit for the object. The object followed a nearly circular path about 2.8 AU from the sun, between the orbits of Mars and Jupiter. This orbit was very similar to those of planets. In fact, many people thought that there should be a planet in just this kind of orbit (see **Feature 9.1**). Therefore, this discovery was hailed as a new planet. A planet-sized object in this orbit should have been very bright. However, this object generally was too faint to see without a telescope. Therefore, the object had to be much smaller than the other planets. At Piazzi's request, it was named after the Roman goddess Ceres. This followed the custom of naming planets after Roman Gods.

People continued to refer to Ceres as a planet for more than 40 years. Why was Ceres eventually reclassified, and what was it reclassified as being? Within a few years, astronomers discovered more small bodies between the orbits of Mars and Jupiter. As was realized with Pluto in 2006, astronomers gradually came to understand that these objects were too small to be planets. Eventually astronomers settled upon calling them asteroids, meaning "star-like," due to their similar appearance to stars when viewed through a telescope. An asteroid is a rocky object orbiting the sun in a planet-like orbit. Because they have planet-like orbits, we sometimes call them planetoids (planet-like). But now the preferred term is minor planet. Henceforth, we generally shall use this term rather than "asteroid." This modern term drives home the fact that minor planets have orbits very similar to those of planets, yet are very small.

By 1807, astronomers had discovered three additional minor planets, Pallas, Juno, and Vesta, all with similar orbits to Ceres. But it was not until 1845 when the fifth one was found. By 1890, astronomers had catalogued about 300 minor planets. Starting in 1891, photography became the tool used to search for new minor planets. Astronomers often used a blink microscope to search for minor planets. But now automated telescopes and search programs look for new minor planets. By the beginning of the 21st century, there were about 20,000 minor planets. Today there are more than a million.

Ceres' surface craters that are shallow and flattish

Ceres' surface craters with peaks at their center

Vesta

FEATURE 9.1

MYSTERIES OF THE ASTEROID BELT

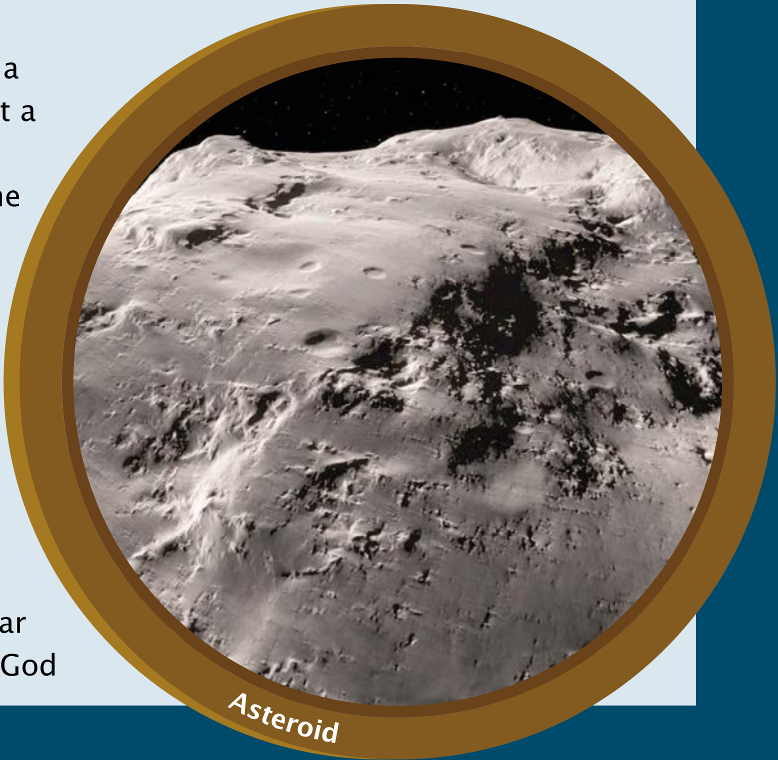
Start with the numbers 0.0 and 0.3 and then double the last number. If you repeatedly double the last number, the result is the sequence 0.0, 0.3, 0.6, 1.2, 2.4, 4.8…. If you add 0.4 to each number, the sequence gives the approximate distance of most of the planets from the sun in astronomical units. **Table 9.1** shows a comparison of the distances using this formula with the actual distances. Notice how well it fits the planets from Mercury to Saturn. We often call this formula Bode's law, after J.E. Bode, a German astronomer who popularized it in 1772. Another German astronomer named Titius had discovered the "law" six years earlier.

There are a couple of interesting things about Bode's law. It was formulated several years before the discovery of Uranus, and it "predicts" the distance of Uranus from the sun well. Second, Bode's Law predicts a planet between Mars and Jupiter that is not there, but the discovery of minor planets appeared to fill the predicted position. These two "predictions" convinced many people that Bode's law really was a law. The eventual discovery of Neptune far from its predicted position destroyed confidence in the "law." Pluto is even farther off. Today we do not think that Bode's law is a physical law in the sense that it is derived from basic principles. It is merely an approximation of planetary distances from the sun that just happens to work.

Planet	Bode's Law Distance	Actual Distance
Mercury	0.4	0.387
Venus	0.7	0.723
Earth	1.0	1.000
Mars	1.6	1.524
Vesta	2.8	
Jupiter	5.2	5.20
Saturn	10.0	9.58
Uranus	19.6	19.3
Neptune	38.8	30.2
Pluto	77.2	39.3

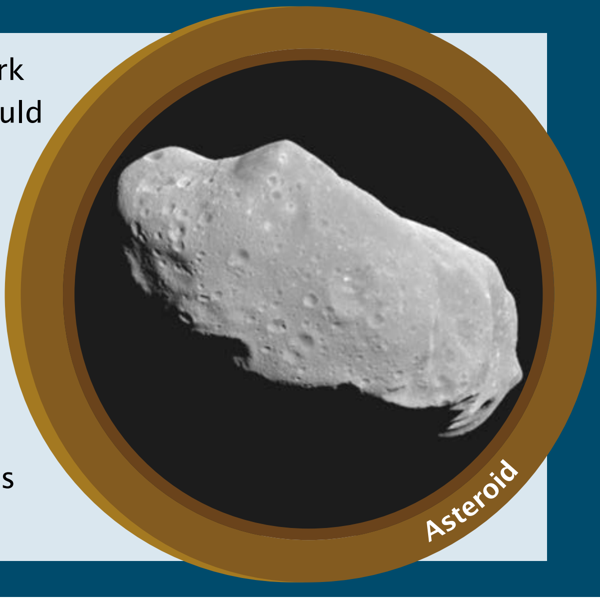
Table 9.1

Some creationists think that there used to be a planet where the asteroid belt is now, but that a catastrophe destroyed the planet. Generally, those creationists suggest that the catastrophe was a planetary collision about the time of the Flood. Some have very elaborate theories of planetary collisions and near collisions to explain the Flood, Joshua's long day, and other biblical miracles. There are at least two problems with this. One problem is that the mass of all the minor planets combined is less than 1/1000 of the earth's mass. This would hardly be enough material to make a respectable planet. Secondly, there are no clear biblical arguments for such a scenario. While God

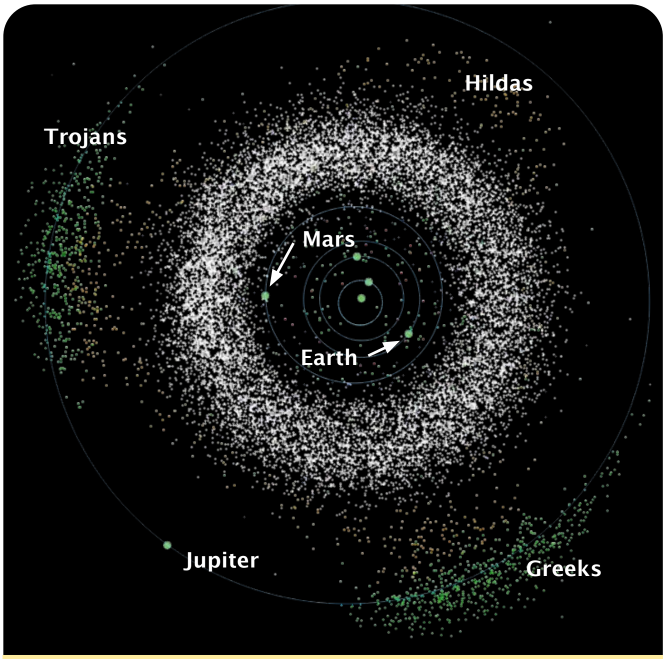

Asteroid

sometimes uses physical causes at peculiar times to work miraculous events, He often intervenes in a way that would violate normal physical law. The Flood could have had a physical mechanism that God brought on, or He could have made it happen in a way that violates the normal operation of the world.

Creation astronomers would like to have an explanation for the existence of asteroids and their different types. However, an explanation may not be necessary. It is possible that God merely created them as they are on day four of the creation week.



Following discovery of a minor planet, astronomers compute an orbit. After conjunction with the sun, if we find the asteroid in the position predicted by the orbit, then we say that we have confirmed the orbit. After confirmation, a minor planet receives a sequential number and a name. The discoverer usually chooses the name. Many of the early-discovered asteroids have names from characters in various mythologies. Today, most mythological names are exhausted. Various famous people and universities have been honored with names. In recent years, the IAU has tightened the rules for the naming of minor planets. When submitting a name, one generally must make a persuasive case that the person honored has made a significant contribution of some sort. Many scientists, authors, poets, and musicians have been so honored. The proper way to mention a minor planet is its number, followed by its name. For instance, the first minor planet discovered is 1 Ceres. With so many minor planets known today, relatively few of them have proper names. **Feature 9.2** explains how we refer to the minor planets without names.



The inner Solar System, from the Sun to Jupiter, including the Main Asteroid Belt (the white donut-shaped cloud). Just inside the orbit of Jupiter are the Hildas (the orange "triangle"). In Jupiter's orbit the "Greeks" are the group leading it. The group that leads Jupiter are called the "Greeks" and the trailing group are the "Trojans".

We can classify minor planets by the kinds of orbits that they follow. There are many different groups, so we will discuss only a few of them. Many asteroids orbit between the orbits of Mars and Jupiter in a region we know as the asteroid belt. Ceres is an example of a belt asteroid. Other minor planets have orbits that cross the earth's orbit. We call these minor planets, Near Earth Object (NEO) minor planets. Of course, the NEO's present a very real danger of collision (see **Feature 9.3**).

FEATURE 9.3

EARTH CROSSING ASTEROIDS

Astronomers know that a few dozen minor planets have orbits that cross the earth's orbit. These are the near-earth orbit (NEO) asteroids. This produces the remote possibility that these minor planets might collide with the earth. However, none of the known minor planets will collide with us for at least a few thousand years. However, for every such minor planet that we know about it, there are probably many others that we have not yet discovered. One of these asteroids could sneak up on us and provide no warning of its collision. During March 2004 a small minor planet, Asteroid 204 FH, passed within 42,700 km of the earth's surface (remember that the moon is about 380,000 km away, and the earth's diameter is about 13,000 km)! The LINEAR (Lincoln Near-Earth Asteroid Research) robotic telescope in New Mexico discovered this minor planet just a few days before the close pass. This near miss remains the record for close passage of a NEO. The LINEAR telescope's purpose is to look for such asteroids.


Arizona Meteor Crater

How serious would one of these collisions be? The asteroid that made the mile-wide Arizona Meteor Crater was probably no bigger than 100 meters. An impact of that size would have killed people within a few miles. Something a kilometer in diameter would produce a crater many kilometers across and could kill millions of people, depending upon where it struck. Not only would the impact kill people within the immediate area of the crater, but shock waves spreading outward would produce earthquake-like damage for some distance as well. An impact over an ocean would produce a huge tsunami that likely would kill people thousands of miles away.

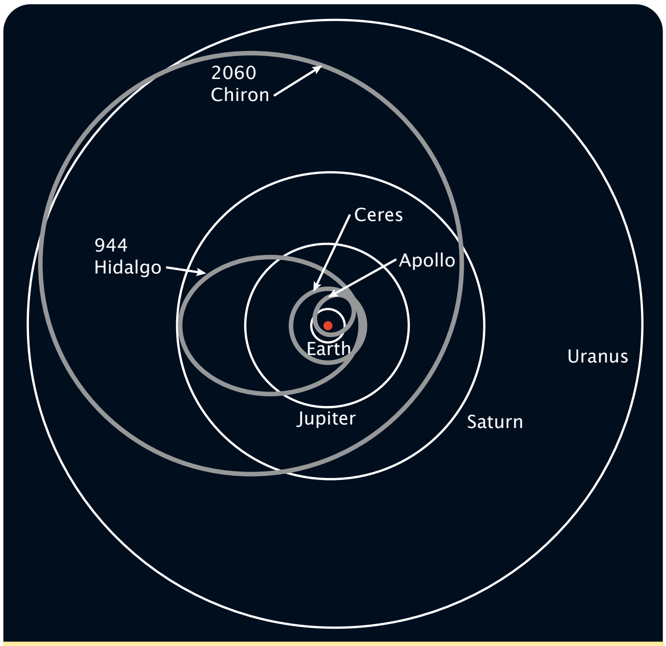
A larger impact could introduce fine particles into the upper atmosphere. These particles could remain aloft for more than a year, and they could block a significant amount of sunlight in that time. This might lead to drastic temperature drops that would destroy much plant life around the world.

In fact, just this kind of scenario is the most widely accepted theory of what happened to the dinosaurs. Many scientists think that an impact about 60 million years ago produced global cooling that directly killed many dinosaurs, while many other dinosaurs starved in the collapse of the food chain. Most scientists think that other rare catastrophic impacts were responsible for mass extinctions throughout time. Evolutionists even suggest that this sort of catastrophe allowed other animals, such as mammals, to evolve.

Some fear that this kind of event could destroy civilization. To better prepare for this possibility, some astronomers have embarked on a program to search for earth crossing minor planets. One of these efforts is the LINEAR robotic telescope in New Mexico. These efforts have discovered several such objects so far. We have witnessed a few minor planets passing within the moon's orbit. Passage this close is a near miss. Currently there are no plans to avoid such a catastrophe. In recent years, several Hollywood movies have explored this possibility. The solutions in these movies have not been very realistic.

Is there a Christian response to this? First, it is doubtful that any minor planets killed the dinosaurs 60 million years ago. We believe that most of them perished in the Flood a few thousand years ago. Second, we believe that civilization will end one day, but it will not be the result of a natural catastrophe. Instead, it will be the judgment of God. Whether He chooses to use an asteroid as part of this or not, we can be sure that there is nothing physically that we can do to stop it.

Another interesting group of minor planets is the Trojan group. We call them this because many of them have names from characters in Homer's account of the Trojan War. These minor planets follow in the same orbit as the planet Jupiter but are grouped either 60 degrees ahead or behind Jupiter. Jupiter's immense gravity traps the Trojan asteroids in this orbit in a type of resonance.



Orbits of Apollo, Ceres, Hidalgo, and Chiron

Another resonance occurs in the asteroid belt. There are certain regions in the asteroid belt where there are very few minor planets. These gaps are the Kirkwood gaps, named after Daniel Kirkwood, the Indiana astronomer who explained them. These gaps occur at distances corresponding to fractions ($\frac{1}{2}$, $\frac{2}{3}$, $\frac{2}{5}$, etc.) of the orbital period of Jupiter. You should recall that in Saturn's rings, gravitational perturbations of the satellites, such as Mimas, form gaps. The same sort of gravitational perturbations caused by Jupiter create the Kirkwood gaps.

In 1920, astronomers discovered 944 Hidalgo. Its orbit was most strange. Its eccentricity is quite high (0.66). Hidalgo's perihelion distance is 1.94 AU, placing it near the inside edge of the asteroid belt, but its aphelion distance is 9.5 AU, nearly as far from the sun as Saturn. At the time, astronomers considered 944 Hidalgo to be a unique object. But in 1977 astronomers discovered 2060 Chiron (kye'-ron), a minor planet with orbital eccentricity 0.38, and perihelion distance of 8.4 AU and aphelion distance of 18.9 AU. Chiron is the name of a centaur in Greek mythology. This name was carefully selected.

Centaurs were half man, half horse. Astronomers recognized that Hidalgo and Chiron had orbital characteristics intermediate between the two groups of SSSBs, minor planets and comets. Therefore, these two objects, along with others discovered since, are called Centaurs. Crossing the orbits of the very massive Jovian planets, the orbits of the Centaurs do not have long-term stability. Therefore, they cannot have followed the sort of orbits they have now for more than a few million years.

Since the early 1990s, astronomers have discovered hundreds of minor planets beyond the orbit of Neptune. Astronomers believe that these may be representatives of a more distant group of minor planets even more plentiful than the asteroid belt. These may be members of the hypothetical Kuiper (pronounced kye'-per) belt, which we will discuss shortly. Astronomers usually call these minor planets trans-Neptunian objects (TNOs) or Kuiper belt objects (KBOs). We shall return to our discussion of distant minor planets at the end of this lesson after we have studied comets.

In addition to classification based upon their orbits, we can group minor planets according to their composition. Spectroscopy reveals a minor planet's composition. There are several different classifications of minor planets, but there are three basic types. The C-type minor planets are most common (about $\frac{3}{4}$). Their name derives from the fact that they are carbon rich. The C-type minor planets are very dark in color. The S-type minor planets are rich in silicates. A silicate is a mineral containing SiO_4. Many rocks on earth are silicates. The **M-type minor planets** contain large amounts of metals, presumably iron and nickel. To many astronomers, the different compositions suggest that the different groups of minor planets have different origins.

A field of eye-catching craters that looks like a cluster of bright halos

Icy mountains of Pluto

Features of possible cryovulcanic eruption of ices from beneath Pluto surface

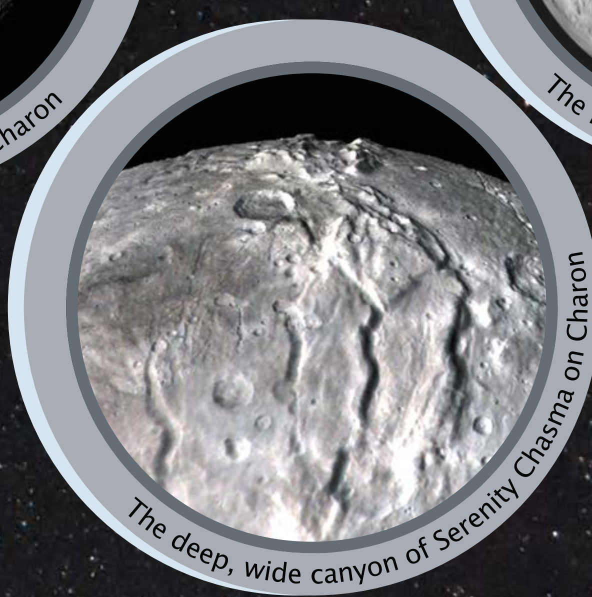
The Former Planet Pluto

Once astronomers officially decided to reclassify Pluto as a minor planet, it required assigning it a number. Normally, the number is assigned in order of discovery, but since its official recognition as a minor planet came 76 years after its discovery, it wasn't possible to give it a number appropriate for its discovery. Therefore, Pluto was given the first available number, making its official designation 134340 Pluto.

For nearly 60 years after its discovery, we knew relatively little about Pluto. From its faintness, astronomers deduced that Pluto was very small, and that it likely didn't have enough mass to cause significant perturbations on the orbits of Uranus and Neptune. If Pluto wasn't causing slight irregularities in the orbits of those two planets, what was? That isn't entirely clear. Some astronomers have suggested that there is an additional planet farther out, but there have been extensive searches for any such planets. If they are there, they would have been found by now. Other astronomers have suggested that galactic tides may have been responsible. However, the most likely answer is that there weren't any orbital irregularities to explain in the first place. The discrepancies were on the order of the errors of measurement, so the discrepancies may have not been real. In other words, the discovery of Pluto may have been entirely an accident.

Our ignorance of Pluto's properties began to change in 1978, when an astronomer discovered Charon (share'-on), a satellite orbiting Pluto. The orbit permitted measurement of Pluto's mass for the first time, as well as Charon's mass. Astronomers quickly realized that Pluto and Charon would undergo a series of mutual eclipses a few years later, in the 1980s. The eclipse season lasts a few years, with the next eclipse season being 120 years later.


A view of Pluto's moon Charon


The deep, wide canyon of Serenity Chasma on Charon


The Mordor dark region near Charon north pole

To take advantage of this fortuitous opportunity, there was a concerted effort to observe these eclipses. The data allowed accurate measurement of the diameters of both Pluto and Charon. Their diameters, along with their masses, permitted computation of the densities of Pluto and Charon. In addition to Charon, we now know that Pluto has four additional small satellites.

Our understanding of Pluto improved dramatically with the arrival of the New Horizons mission to Pluto in the summer of 2015. For the first time, we had close-up photographs of both Pluto and Charon. Since the New Horizons was a flyby mission, we have photographs of only one-half of Pluto and Charon. The images revealed some heavily cratered regions. However, wide portions of their surfaces have relatively few craters. This suggests that there has been much reworking of their surfaces. But if Pluto and Charon are billions of years old, this is difficult to explain. What is the source of heat that drove the geological processes?

When astronomers reclassified Pluto as a minor planet, they also created a new category of minor planets: **dwarf planets**. Because most minor planets are so small, they lack the gravity to pull themselves into spherical shapes. However, a few of the larger minor planets do have enough gravity to be spherical. These are dwarf planets. Besides Pluto, there are four other dwarf planets, 1 Ceres, 136108 Haumea, 136199 Eris, and 136472 Makemake. It is likely that more will be added to the group. You may have noticed from the photograph of Charon earlier that it is spherical, and so you may wonder why Charon isn't a dwarf planet. Being a satellite of Pluto, it isn't eligible for the classification as a dwarf planet. Remember, a planet (even if it's a dwarf planet) orbits the sun, while a satellite orbits a planet (or another minor planet).

FEATURE 9.2

WHAT'S IN A NAME?

With so many minor planets, many of them have not yet received names and likely never will. When this is the case, a minor planet is designated with its sequential number, plus its provisional designation. The provisional designation is the year of discovery, followed by a (capitalized) two-letter code and usually a subscripted number. The first letter indicates which half-month of the year the minor planet was discovered. The letter I is omitted because it can be confused with J, and the letter Z is not needed. The second letter indicates the order of discovery within the half month (again omitting the letter I). This will allow for 25 minor planets to be discovered in the half month. More than 25 minor planets now are discovered every half month, so the second letter is recycled starting with A. The subscripted number indicates how many times the second letter has been recycled. The subscripted numbers begin with 2, because if the letters have not been recycled, there is no need for a subscripted number. For instance, 90377 Sedna was given the provisional designation 2003 VB12. This means that Sedna was the 302nd object discovered in the first half of November 2003 ($12 \times 25 + 2 = 302$). Retroactively, 1 Ceres would have been given the provisional designation 1801 AA. There was no need for a subscripted number, because the second letter hadn't been recycled yet. Confusing? You bet. Don't worry, this won't be on the test!

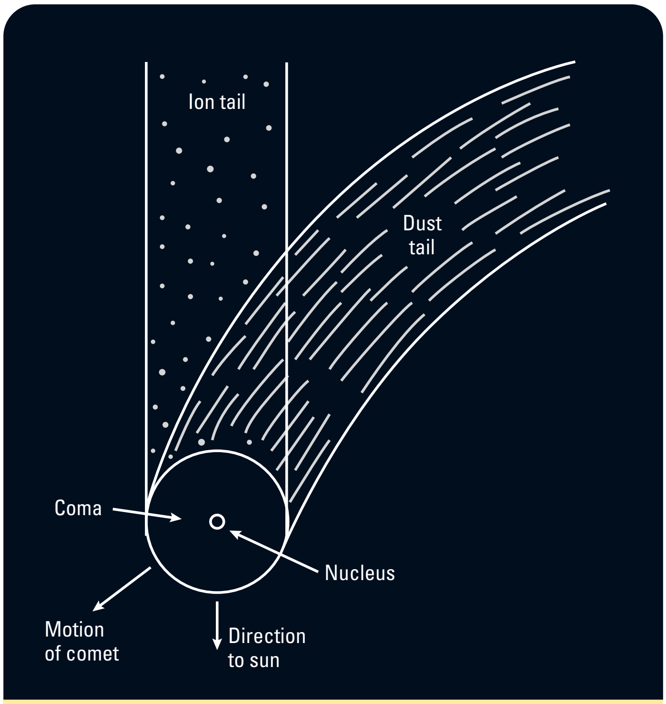


FIGURE 9.1 The structure of a comet. The nucleus is a few kilometers in diameter. The coma often is tens of thousands of kilometers in diameter. The tails may be tens of millions of kilometers long. Notice that the tails point away from the sun.

Comets

Comets are very mysterious objects. The word "comet" comes from the Latin word for "hair" from which we get the word comb. Thus, very loosely, a comet is a hairy star. **Figure 9.1** shows the structure of a comet. The **nucleus** is a chunk of ice a few kilometers across. The ices involved are water ice, carbon dioxide, and other materials with low temperature melting points. Mixed in with this ice are small bits of solid material. Much of this solid material is in the form of microscopic particles that astronomers call dust.

When the nucleus gets close to the sun, the heat of the sun evaporates much of the ice and turns it into a gas. The gas rapidly expands into space to form a **coma**. The coma can be tens of thousands of kilometers in diameter. The solar wind (an outrush of charged particles from the sun) blows the gas particles outward from the sun to form the **gas tail**. Solar radiation pushes dislodged dust particles outward to form the **dust tail**. The dust tail glows by reflected sunlight. The gas tail glows because the gas is ionized by the sun's radiation. As electrons recombine with the ions, the electrons emit light. Another name for the gas tail is the ion tail. The molecules in the gas tail move more quickly than the particles in the dust tail. The difference in speed usually makes the dust tail curved while the gas tail is straight. Either tail can extend for tens of millions of kilometers.

It is important to note that comet tails always point away from the sun. A common misconception is that a comet tail trails behind a comet as the comet moves. As a comet approaches the sun, the tail does appear to trail behind the comet. However, when a comet moves away from the sun, its tail leads the coma.

Comets are subject to the same law of gravity as the planets, so comets follow Kepler's laws of planetary motion. Recall that Kepler's second law dictates that orbiting bodies move most quickly at perihelion and slowest at aphelion. Comets follow very elliptical orbits around the sun. Therefore, comets spend most of their time near aphelion where they move very slowly. Conversely, comets spend very little time at perihelion where they move most quickly. Only during the very brief time near perihelion is the sun's heat able to form a coma and tail. For most of its orbit, a comet is too small and too faint to be visible. The orbits of comets are often highly inclined to the ecliptic. These are very different from planet and minor planet orbits, which are nearly circular and lie nearly in the same plane as the earth's orbit. **Figure 9.2** shows a typical comet orbit.

Astronomers classify comets as either long period or short period. A long period comet has a period of more than 200 years while a short period comet is less than 200 years. This is not an arbitrary distinction in time. The orbits of the two groups of comets are very different. Most short period comets have low inclinations and revolve in the same direction as the planets. Long period comets

The round coma around Comet ISON's nucleus is blue and the tail has a redder hue. Ice and gas in the coma reflect blue light from the Sun, while dust grains in the tail reflect more red light than blue light.

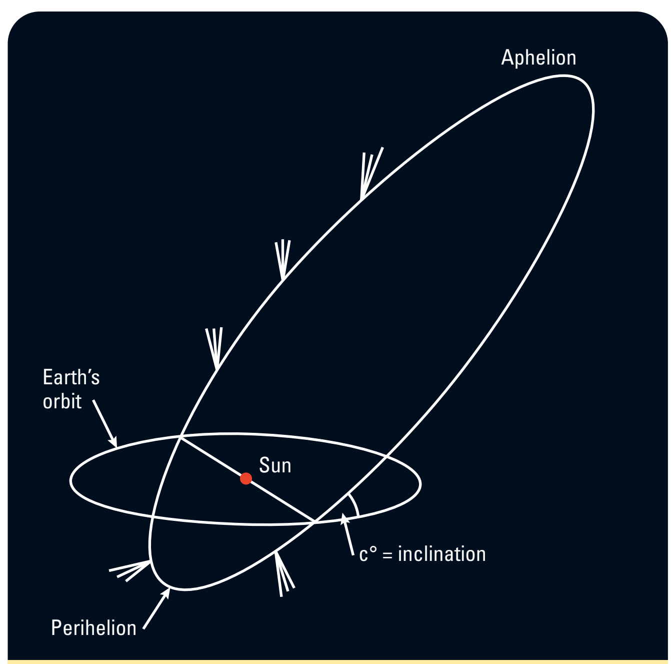


FIGURE 9.2 A typical comet orbit. Notice that the orbit is very elliptical, and that it is inclined quite a bit to the earth's orbit. The comet is brightest near perihelion.

can have any inclination, and about half revolve in the same direction as the planets, while the other half revolve the other direction. There are a few thousand known long period comets. There are about 100 short period comets. Three of the short period comets break the rule about orbiting in the same direction of the planets. Halley's Comet is the best-known exception.

If the solar system is 4.6 billion years old, there should be no comets left.

Being so small and made of ice, comets are flimsy objects. During each perihelion passage, a large amount of material is lost. Estimates vary, but a typical comet cannot survive more than a few hundred trips around the sun, if that many. The C type minor planets may be the burned-out remains of comets that have lost most of their volatiles.

Coming too near the planets is another way that comets may be lost. Since most comets cross most, if not all, the orbits of the planets, they risk having their orbits affected by the gravity of the planets. Because it has so much mass, Jupiter is particularly dangerous to comets. These gravitational interactions may shorten comet orbits, or they can increase the sizes of the orbits. If one of these perturbations increases a comet's orbit too much, the comet will permanently leave the solar system. On the other hand, if a gravitational perturbation shortens a comet's orbit, the comet will encounter perihelion passage more frequently.


Comet Shoemaker-Levy 9 impacting Jupiter

More frequent perihelion passage leads to more rapid loss of material as previously described. Therefore, a comet that undergoes a period decrease will more rapidly evaporate and cease to exist. Lastly, gravitational interactions can alter a comet's orbit so that the comet collides with a planet. This happened to Comet Shoemaker-Levy 9 in 1994 when it collided with Jupiter. The collision was set up two years earlier when the comet passed very close to Jupiter and Jupiter greatly perturbed the orbit.

All these mechanisms of destruction eliminate comets. We can estimate how long a typical comet can survive. An average lifetime is far less than the supposed 4.6 billion years of the solar system. Therefore, if the solar system is 4.6 billion years old, there should be no comets left. Creationists have long used this as an argument for the recent origin of the solar system.

Of course, evolutionists are aware of this problem, and they have proposed a solution. In 1950, the Dutch astronomer Jan Oort suggested that billions of comet nuclei orbit the sun at great distances from the sun. If the perihelion distances are hundreds or thousands of AUs, then we will not see them. Being so far from the sun, these comet nuclei will last indefinitely. Astronomers call these billions of comet nuclei far from the sun the **Oort cloud**. Oort supposed that occasional gravitational perturbations of passing stars could change the orbits to cause the comets to enter the inner solar system. Thus, as old comets fade or are lost to the solar system, new comets from the Oort cloud replace them. If new comets continuously enter the inner solar system at a rate that is slow enough, then there would still be billions of comets after billions of years.

It is conceivable that the Oort cloud exists, but simple conception is not how science works. Science requires evidence. If we cannot see, measure, or otherwise detect something, then that something is not scientific. There is no evidence that the Oort cloud exists. Consider this quote by the late Carl Sagan, a famous, secular Cornell University astronomer:

> *Many scientific papers are written each year about the Oort Cloud, its properties, its origin, its evolution. Yet there is not yet a shred of direct observational evidence for its existence.*

Many scientific papers are written each year about the Oort Cloud, its properties, its origin, its evolution. Yet there is not yet a shred of direct observational evidence for its existence.
~ Carl Sagan

This is not to say that the Oort cloud does or does not exist. It merely means that its existence is not a scientific question any more than the question of God's existence is a scientific question. Until we can test for the existence of the Oort cloud, it is not a scientific concept.

For many years, astronomers thought that gravitational perturbations of the planets could convert long period comets into short period ones. During the 1980s, computer simulations revealed that this is not so. The transformation of long period comets into short period ones proceeds too slowly: the length of time required greatly exceeds the lifetimes of individual comets. To answer this problem, astronomers began to conclude that while long period comets come from the Oort cloud, short period comets come from the Kuiper belt.

Gerard Kuiper suggested his belt about the time Oort devised his cloud. The **Kuiper belt** is a hypothetical doughnut-shaped distribution of comets just beyond the orbit of Neptune. Therefore, Kuiper belt comets are much closer to the planets of the solar system. Many scientists think that the accumulated perturbations of the outer planets slowly pull Kuiper belt comets inward toward the inner solar system. Since these comets are already orbiting in the same direction of the planets with low inclinations, scientists expect that these orbital properties are preserved as the orbits are shortened further. **Figure 9.3** is a sketch of the hypothesized Oort cloud and Kuiper belt.

Interestingly, Kuiper didn't develop his idea of the Kuiper belt to explain the origin of short period comets. Rather, Kuiper suggested that a belt of debris left over from the origin of the solar system existed beyond the orbit of Neptune billions of years ago, but that it was no longer was there. Gravitational perturbations in the early solar system would have removed this

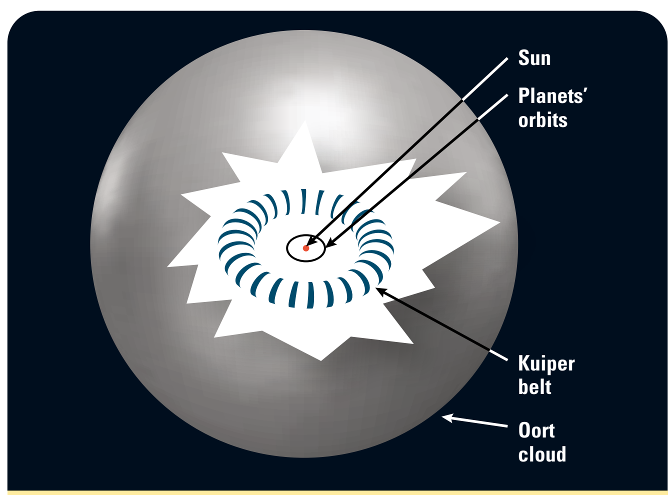
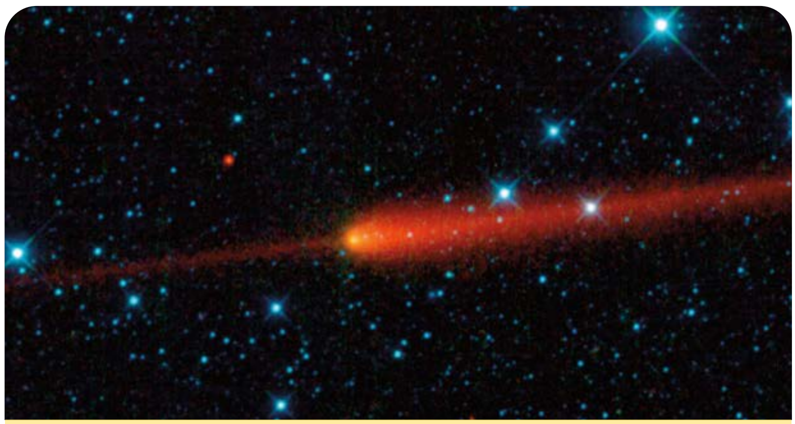


FIGURE 9.3 The relationship between the orbits of the planets and the Oort cloud and Kuiper belt. The diagram is not to scale. The Kuiper belt is a doughnut-shaped distribution of comet nuclei in the same plane as the planets' orbits. The Kuiper belt begins just beyond the orbit of Neptune. The Oort cloud is a far larger spherical distribution of comet nuclei.

debris, with many of the particles originally in the Kuiper belt populating the Oort cloud. It was only after astronomers realized the Oort cloud could not account for short period comets that they resurrected the Kuiper belt to explain the origin of short period comets.

Unlike the Oort cloud, there may be evidence that the Kuiper belt exists. In 1988, astronomers observed the distant asteroid Chiron brighten significantly and develop a faint coma. This suggested that Chiron was not rocky but is an icy body (i.e., a comet nucleus). In the early 1990s, two astronomers in Hawaii pioneered the use of a large telescope to look for objects orbiting just beyond Neptune. They have used techniques like those used to search for Pluto and minor planets. They and other astronomers have found hundreds of objects beyond the orbit of Neptune so far. These are the KBOs and TNOs previously mentioned.



This image from NASA Wide-field Infrared Survey Explorer features comet 65/PGunn. Comets are balls of dust and ice left over from the formation of the solar system. The comet tail is seen here in red trailing off to the right of the comet nucleus.

What is the difference between KBOs and TNOs? The term TNO is descriptive in that it reflects what we know about TNOs: they orbit the sun beyond the orbit of Neptune. However, the term KBO is laden with evolutionary ideas about where short period comets come from. Therefore, the author of this textbook prefers the more descriptive term, TNOs. Among astronomers in general there has been a shift in recent years away from KBOs toward TNOs. This may reflect a recognition that even within the evolutionary paradigm there is a difference between simply orbiting beyond Neptune and being the source of short-period comets. Astronomers increasingly are discovering TNOs that extend beyond the bounds of what is thought to be the Kuiper belt. One example is 2014 FE72. It follows a very elliptical orbit (e = 0.976) with a perihelion distance of 36.3 (within the hypothetical Kuiper belt) and aphelion distance of 3060 AU (well beyond the hypothetical Kuiper belt). These objects with very distant aphelia are considered intermediate between the Kuiper belt and the Oort cloud.

It is not yet possible to determine the composition of TNOs, but since they are so far from the sun astronomers assume that they are icy and hence match the composition of comets. Recall from the previous lesson that most objects far from the sun are icy. One problem with these objects being comet nuclei is their sizes. The largest comet nucleus ever observed was that of Comet Hale-Bopp in 1997. It had a diameter estimated to be about 40 km (25 miles). Many of the Kuiper belt objects allegedly discovered so far are far bigger than this. If these are comet nuclei, one must ask why we have never seen such large comets before. Furthermore, the composition of some of the larger TNOs (Pluto and Charon) as inferred from their densities do not match the compositions of comets. While they must have much ice to account for their densities, the densities of both Pluto and Charon indicate that they have far more refractory elements than comets.

FEATURE 9.4

HOW ARE COMETS NAMED?

There have been several systems for naming comets. Each one of the systems attempts to convey some information about the named comets. In 1995, astronomers adopted a single new way of naming comets. The first part of a name begins with one of four letters and a slash. The prefix P/ stands for a periodic or short period comet, C/ for long period comet, D/ for a defunct comet, and X/ for a questionable comet. Additionally, the more than 100 periodic comets are numbered sequentially starting with Halley's Comet. Therefore, Halley's Comet has the designation 1P.

The next part of the name is the year of discovery, or in the case of a periodic comet, recovery. After the year is a code for the half month of discovery or recovery. The letter A is the code for the first half of January, B the second half of January, and so forth (the letters I and Z are not used). After the half-month code, we use a number to indicate the order in which a comet was discovered in the half-month. Lastly, the name of the discoverer is in parenthesis. In the case of a near simultaneous discovery by more than one person, the names are hyphenated. As an example of the naming system, consider C/1996 B2 (Hyakutake). It was a long period comet discovered by someone named Hyakutake in late January of 1996. It was the second comet discovered in the second half of January that year.

There are strict rules governing the selection of names of astronomical bodies. Comets are the only astronomical objects that are named after the people who discover them. Until recently, amateur astronomers discovered most comets. Amateur comet hunters invest huge amounts of time scanning the skies looking for comets. Professional astronomers usually do not search for comets and observe a very small part of the sky in their research, and so they are far less likely to find new comets when there are others looking for them. Many of the comet hunters live in places with dark skies and climates that allow many clear nights. Comet hunters usually scan regions of the sky near the horizon after dusk and before dawn. Faint objects, such as very distant galaxies and star clusters, can be confused for comets. To avoid this confusion, many amateur comet hunters memorize the locations of many of these faint objects in the sky.

Notice that the system for naming comets is similar to the way that we give names to minor planets. Historically, comets and minor planets were considered distinct objects. However, in recent years astronomers have come to realize that comets and minor planets are extremes of a continuum of SSSBs. With improved detection, astronomers now occasionally see outgassing from objects once thought to be minor planets. When this occurs, the object is recognized as being a comet. However, the minor planet designation remains, but with a P/ prefix.

Meteors And Meteorites

A **meteor** is a brief streak of light in the sky due to release of kinetic energy as a piece of ice or rock entering the upper atmosphere of the earth at high speed. Interaction with molecules of air rapidly slows the particle down. The particle's kinetic energy must go somewhere, usually into heating the air around the particle and the particle itself. Though they are incorrect, common names for meteors are shooting stars and falling stars. Since stars are very far away and much larger than the earth, a star obviously cannot fall to the earth. Before striking the earth's atmosphere, the debris of rock or ice moving through space is a **meteoroid**. If a solid piece of material survives to the ground, we call it a **meteorite**. Meteors burn about 100 kilometers (60 miles) above the earth.

Most meteoroids are very small. One the size of a pea would appear quite bright. One originally the size of a baseball would light the night sky. How can this be? Though meteoroids may be very small, they are moving very fast (tens of kilometers/second). The fact that we see meteors against the dark of the night sky makes them easier to see. Many meteors visible to the naked eye result from meteoroids not much bigger than a grain of sand.

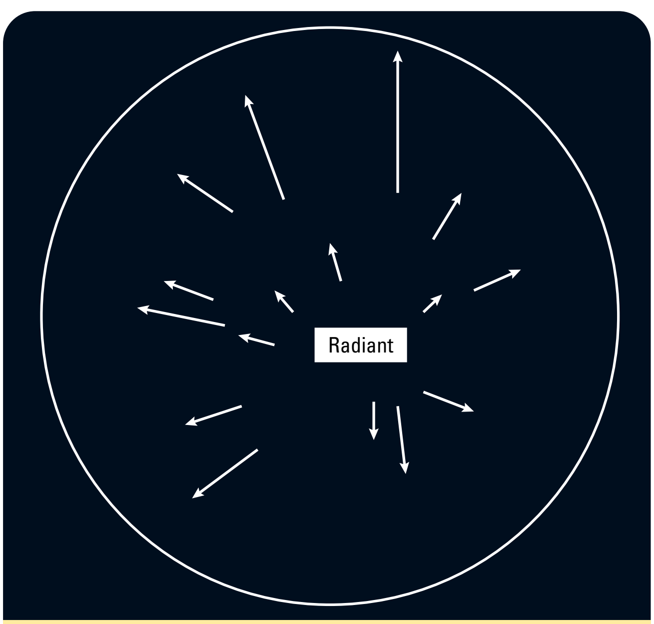


FIGURE 9.4 The radiant of a meteor shower. The circle represents the sky, and the arrows indicate the lengths and directions of meteor trails. Notice that while a meteor trail may be in any part of the sky, the tracks of all shower members diverge from the radiant if we trace the trails backward.

On any dark, clear night, a person may see several meteors per hour. However, several times per year, the earth encounters a swarm of meteoroids and a **meteor shower** results. During a meteor shower, we see far more meteors than usual. Sometimes the number per hour can be several score (a score is 20). On rare occasions, we briefly can see thousands per hour. The meteors from a meteor shower may be seen anywhere in the sky, but if we extend the trails backward, all the meteors appear to diverge from one spot in the sky. See **Figure 9.4**. This point is the radiant. We name a meteor shower for the location of its radiant. For instance, the Perseid shower each August has its radiant in the constellation Perseus. The Leonid meteor shower each November has its radiant in the constellation Leo. The meteoroids that cause a meteor shower travel in parallel paths in their common orbit around the sun. They appear to diverge from the radiant because of perspective. The parallel rails of a railroad track or the sides of a straight road appear to converge in the distance for the same reason.

Even when there is no meteor shower, there is always a background of a few meteors per hour. These meteors come from random directions, and they usually are single. Since these meteors do not appear to be associated with any shower, we call them **sporadic meteors**.

What is the source of meteors? It appears that sporadic and shower meteors come from different sources. From the paths of meteors in our sky, we can find the orbits of their meteoroids. In the case of sporadic meteors, the meteoroids were following orbits like the earth-crossing asteroids.

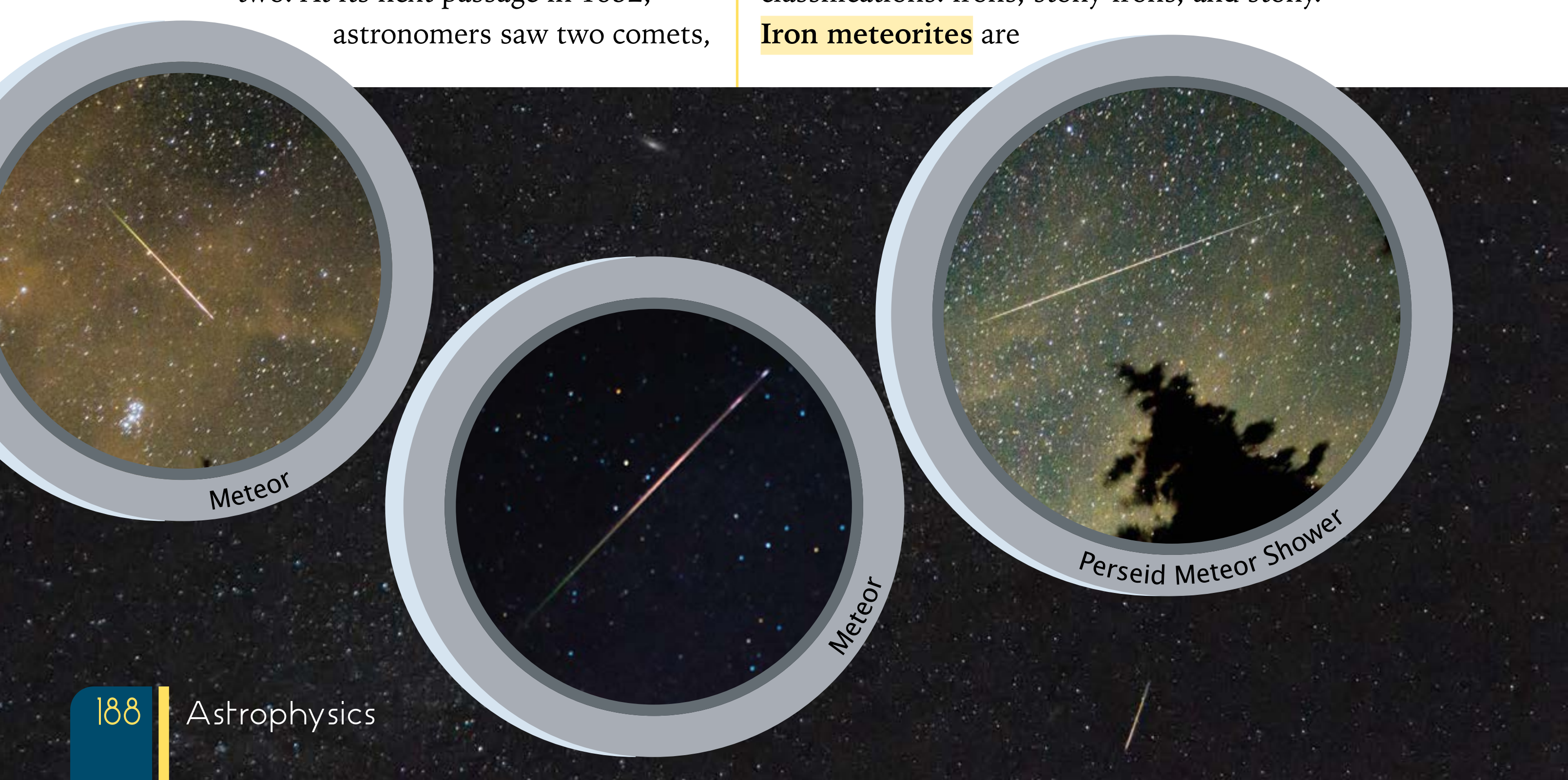
Therefore, sporadic meteors probably are fragments of asteroids that happen to collide with the earth. Nearly all sporadic meteors are single. That is, they do not occur in groups as the shower meteors do.

The meteoroids that cause meteor showers follow comet-like orbits. In fact, astronomers have identified several meteor showers with the orbits of known comets. For instance, a stream of meteoroids following the 133-year orbit of Comet Swift-Tuttle causes the Perseid meteor shower. Given the fragile nature of comets, it is not surprising that they break up into billions of debris that are scattered along their orbits. Since the particles are following the same orbit, they travel parallel paths so that they appear to diverge from the radiant as we discussed earlier.

In most cases, we cannot identify a meteor shower with a known comet. This probably means that the parent comets of those showers have ceased to exist. An illustration of this may be the Andromedid meteor shower each November. We know that the meteoroids of this shower follow the orbit of the 6.7-year period Comet Biela. In 1846, astronomers watched Comet Biela break in two. At its next passage in 1852, astronomers saw two comets, but no one has seen any of these comets since. If Comet Biela had fallen apart a few centuries earlier, today we would not have known about it or its orbit, but the debris would have indicated its past existence by the meteor shower each fall.

Additional evidence as to the identification of the parent bodies of the two types of meteors comes from meteorites. When there is a particularly bright meteor, people occasionally have been able to find a meteorite fragment from the meteor. All such finds have come from sporadic meteors. No one has ever recovered a meteorite from a meteor shower. This suggests that all meteorites found have come from sporadic meteors. Why do shower meteors fail to produce meteorites? The best answer is that the meteoroids that cause meteor showers are very fragile, while those that cause sporadic meteors are more substantial. We have already seen that comets are made of ice and dust. One would not expect such material to survive the fiery trip through the earth's atmosphere. On the other hand, we have seen that minor planets are made of rocky and metallic material, things that could survive the plunge to the earth's surface.

Meteorites fall into one of three basic classifications: irons, stony-irons, and stony. **Iron meteorites** are

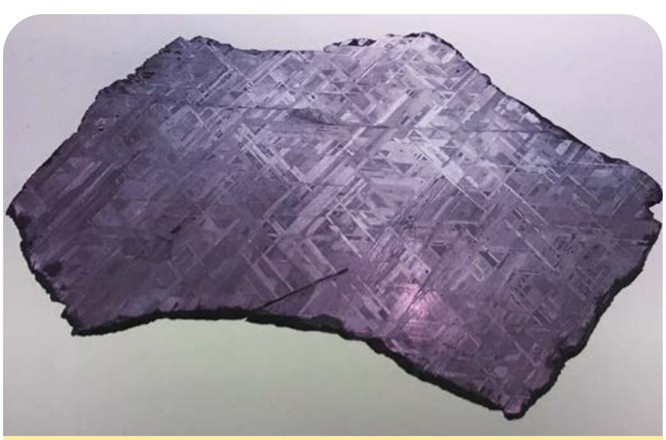


made almost entirely of iron and nickel. When cut and polished, an iron meteorite displays Widmanstätten patterns. Astronomers think that this crystal structure reveals conditions under which the parent body formed. **Stony-irons** contain about equal proportions of rocky and iron material. These are the rarest meteorites, making up no more than 1% of the total. Stony meteorites obviously have a rocky composition, but they usually contain about 10–15% iron and nickel as well. Stony meteorites make up more than 90% of all meteorites, but they represent only about half of those found. How can that be? Irons are very heavy and so they easily stand out from other rocks. If you found one, you would know that it was peculiar. On the other hand, the other types of meteorites are not that different from any other kind of rock that you might find, so they usually escape notice.

People often find unusual rocks and guess that they might be meteorites. As mentioned above, the great weight of an iron meteorite makes for easy identification. How can one tell if a rock is a stony type meteorite? Since nearly all meteorites contain some iron and nickel, magnets usually attract meteorites. If a strange rock fails magnetic attraction, it is probably not a meteorite.

One subclass of the stony type is the **carbonaceous meteorites**. They are very dark in color due to relatively high carbon content. Evolutionary scientists think that carbonaceous meteorites come from the oldest and most primitive kind of meteoroids. These scientists think that all the other types of meteoroids have undergone some amount of reworking. This thinking leads many scientists to conclude that the carbonaceous meteorites are samples of the original material from which the solar system formed. If this were true, then the radiometric ages of carbonaceous meteorites give the age of the solar system. You should recognize that these ideas are very evolutionary and require the assumption of an evolutionary history of the solar system. We will discuss the implications of this in a moment. Some carbonaceous meteorites contain amino acids, basic building blocks of proteins. Since proteins are necessary for life, many scientists accept this as evidence of how the basic chemistry of life could have formed naturally, even in space. However, a few simple amino acids are very different from life itself.

It is most likely that carbonaceous meteorites are fragments of the C-type minor planets. Recall that those minor planets are dark, as are the carbonaceous meteorites. Most other stony type meteorites probably derive from the **S-type asteroids**. The M-type minor planets are probably the meteoroids that give rise to the iron type



Iron meteorite with Widmanstätten pattern

Carbonaceous chondrite Meteorite

meteorites. The direct identification of each of the basic types of minor planets with most of the classifications of meteorites further strengthens minor planets as the source of all meteorites.

Why are there different kinds of minor planets? Perhaps we should first answer the question of the origin of minor planets. Most astronomers believe that the planets formed from the assembly of many small parts called planetesimals. See the discussion of **Feature 9.6**. In this theory, the asteroids are planetesimals that never became part of a planet. Perhaps there are so many minor planets between Mars and Jupiter because while a planet may have started to form there, it failed to do so completely. Jupiter may have formed quickly, and the perturbing effect of its strong gravity kept the planetesimals there so agitated that they could not form a planet.

If minor planets are the remains of a planet that failed to form, one might expect that the planetesimals at least started the process of forming into a planet. The largest minor planets are hundreds of kilometers across, so they must have formed from the collection of many planetesimals. As they formed, their gravity would have pulled much of the iron and nickel to their centers, leaving a rockier mantle. In an earlier lesson, we called this process differentiation. This would leave some of the larger minor planets with structure very similar to the terrestrial planets.

Later, collisions between these bodies could have fragmented the differentiated minor planets. The fragments that had been in the cores would be mostly iron and nickel, and today we would recognize these as M-type minor planets. Any meteorites from these bodies would be the iron type. The fragments from the mantle would be the S-type minor planets. Many of the stony type meteorites would be from this group of fragments. The much rarer stony-iron meteorites would result from fragments that came from near the core-mantle boundary of the differentiated planetesimals. All these types would have undergone heavy reworking, so they would not represent material from the very beginning of the solar system. Any planetesimals that managed to escape becoming part of these larger bodies would have experienced less reworking, and thus they would be samples of the early solar system. These would be the C-type minor planets and the carbonaceous meteorites. Most astronomers assume that the C-type minor planets are exhausted nuclei of comets. Evolutionists argue that **C-type asteroids** escaped reworking, because they spent much of the time since the beginning of the solar system far from the sun where there were few collisions.

You should recognize that this is an evolutionary origin of the solar system over a long time. This explanation is not consistent with a recent creation viewpoint. However, there is no single, clear creationary interpretation of minor planet types. Many creationists assume that God simply made different kinds of minor planets on the fourth day. Others think that some rapid process on the fourth day or at some other time in the recent past may have played a role in producing the various types of asteroids. Some creationists even suggest that the asteroids resulted from a catastrophe (see **Feature 9.1**). Parts of these ideas have some similarity to the evolutionary theory, except for the length of time involved and the fact that God directed the process or catastrophe that altered asteroids. Despite differences in detail, creationists generally can agree on several things. First, we agree that God created the matter that comprises minor planets during the creation week. Second, when God made the sun, moon, and planets on the fourth day, He chose not to include the material that is now in minor planets.

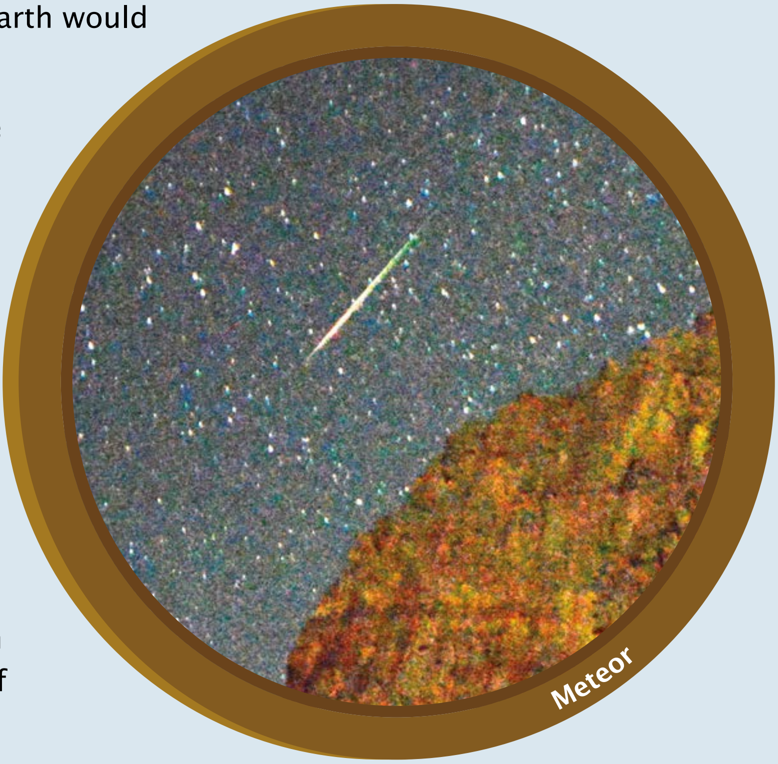
FEATURE 9.5

DO BIBLICAL PASSAGES ABOUT FALLING STARS REFER TO METEORS?

The synoptic gospels record the words of Jesus that before His return stars shall fall from heaven (Matthew. 24:29; Mark 13:25). While the parallel passage in Luke's gospel (21:25–26) does not specifically mention falling stars, it does, along with the other two, mention that the power of the heavens shall be shaken. This shaking of the heavens appears to be a reference to certain Old Testament passages about the day of the LORD (Isaiah 13:13; Haggai 2:6). Revelation 6:13 records that one of the things that happened after the opening of the sixth seal is that the stars of heaven fell to the earth.

In the original languages of the Bible, the words for star referred to any bright object in the sky other than the sun and moon. Without a telescope, planets look like stars. Even comets and meteors have the appearance of stars to the unaided eye, so usage such as this is quite understandable. The problem is, when the word for star appears in the Bible, does it mean what we mean by the word today, or does it have one of the other connotations? In a few lessons, we will find that stars are far larger and more massive than the earth, so stars cannot fall to the earth. If there were any falling, the earth would fall onto a star, and the earth would be destroyed.

It is reasonable to conclude that these falling stars are meteors. This is particularly the case if we consider Revelation 8:12. Revelation 6:13 implies that most of the stars fell from heaven, but here a couple of chapters later in Revelation 8:12, it states that $\frac{1}{3}$ of the stars were darkened when the fourth trumpet sounded. If most of the stars (as we understand the term today) fell earlier, how could there be enough left for $\frac{1}{3}$ to be darkened later? We can reasonably conclude that the falling of the stars is a reference to meteors.



Meteor

FEATURE 9.6

AN EVOLUTIONARY THEORY FOR THE ORIGIN OF THE SOLAR SYSTEM

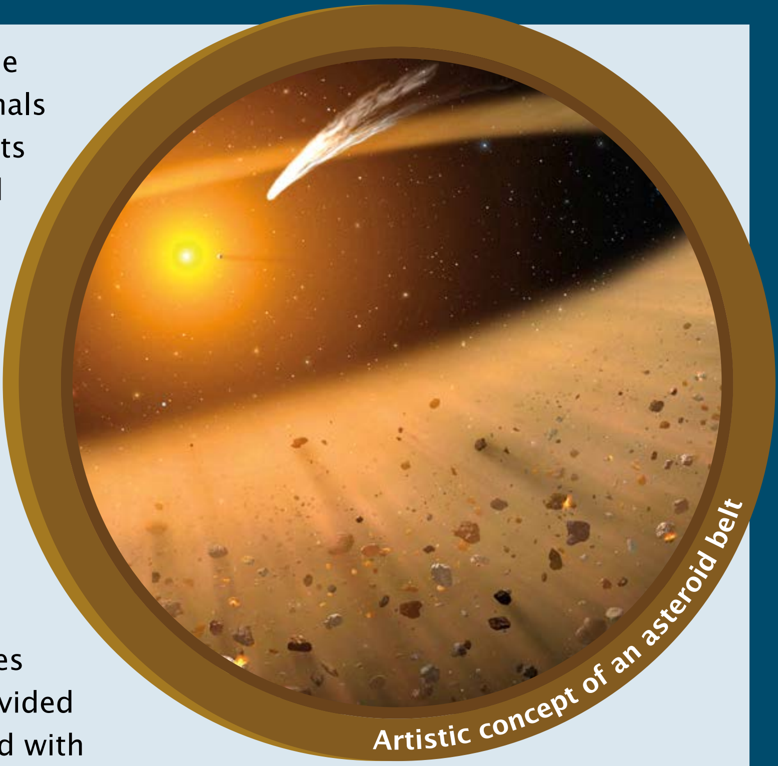
Evolutionists believe that the solar system formed from a large cloud of gas and dust about 4.6 billion years ago. We see clouds in space, and astronomers think that some of these are locations of star formation. We will discuss the topic of star formation in a few lessons. According to the theory, the original slow rotation of the cloud would have sped up as the cloud contracted. The increased rotation rate is a result of the conservation of angular momentum. A similar thing happens to a spinning ice skater as the skater pulls his arms inward. Most of the material would have fallen into the center to form what astronomers call the proto sun. The remaining material would have flattened into a disk orbiting the proto sun.

The material in the disk presumably began to stick together and coalesce into larger particles. How this process could have started is not clear. Some have suggested that static electricity allowed tiny particles to stick together. Others have suggested that sticky organic substances that coated the surfaces of solid particles got it started. Once solid particles began to form, they stuck together to form larger particles. These solid particles are called planetesimals. Once the planetesimals got large enough, their gravity became great enough to attract other planetesimals. Eventually a few planetesimals became large enough to become the dominant objects in their respective parts of the forming solar system. These large planetesimals became the planets.

While the amalgamation of planetesimals was going on, the proto sun would have heated up to form the sun. The early sun's radiation would have heated the planetesimals nearest the sun so that their volatile elements evaporated. The radiation would have blown the evaporated material outward away from the sun, but the refractory elements would have remained in orbit close to the sun. Therefore, the inner planets are rocky in composition and have little of the lighter elements. Farther from the sun, the planetesimals would have retained their volatile material. That is why the Jovian planets have retained so much of their lighter elements. Astronomers think that the Jovian planets and the sun have about the same composition.


Artistic illustration of planetesimal collision around Star HD 166191

The satellites might have resulted from the capture of some of the smaller planetesimals by the gravity of the planets. As the planets and satellites formed, the energy released in the process would have heated and melted the material. This would have allowed the heavier material to sink toward the centers of the bodies. This explains the differentiation that exists in many bodies. After much of the material had accumulated to form the planets and satellites, the surfaces would have cooled enough to become solid. There were still plenty of planetesimals left over, and their falling onto the surfaces of the moons and planets would have provided the heavy bombardment that we discussed with the moon in an earlier lesson. During the late heavy bombardment, the last few large planetesimals collided with planets and satellites to form impact basins. Since that time, there have been much fewer impacts.


Artistic concept of an asteroid belt

Most of the planetesimals were swept up in forming the planets, but there are a couple of locations where planets failed to form. One is the asteroid belt, and the other is the Kuiper belt. Being much closer to the sun, the asteroid belt planetesimals would have lost their volatile elements and so were left with a rocky composition. The much more distant Kuiper belt planetesimals would have kept their volatile elements, and so would be mostly icy in composition. The Kuiper belt objects would become comet nuclei. Gravitational perturbations of the planets would slowly change the orbits of both groups of leftover planetesimals. Asteroids orbiting in the inner solar system are presumably from the asteroid belt. The gravity of the outer planets either pulled Kuiper belt objects into the inner solar system to form short period comets or pushed the KBOs to higher orbits to populate the Oort cloud. Once in the Oort cloud, perturbation from outside the solar system would work to either remove comet nuclei from the sun's grasp or send the nuclei into the inner solar system as long period comets.

How does a Christian respond to this? Unfortunately, all too many accept this theory as the method by which God created the solar system. While this theory gives a qualitative understanding of some features of the solar system, a more important test is how well it squares with the Genesis account of creation. There are several failings here. First, this theory is a purely physical, natural explanation for the solar system. No Creator is necessary, so His introduction at any point is unwarranted. Second, it is in direct contradiction of several clear statements from Scripture. One is the fact that creation took six days and is complete. This natural theory took millions or billions of years; in fact, it is an ongoing process today. Another biblical problem is that it has the sun forming before the earth, and the moon and earth forming about the same time. We know that the earth came first and that the sun and moon came on the fourth day. To accommodate the evolutionary theory, the Christian must be very creative in interpreting what Genesis is telling us. This is a very dangerous thing to do. It seems to elevate science above God's word.

The evolutionary theory does explain some things, such as the two types of planets and the existence of comets and asteroids, but it fails at other points. For instance, no one knows how a cloud of gas and dust can begin to contract to start the process. In fact, well-understood physical processes argue against this. We will discuss this further in a later lesson. Another problem involves angular momentum. Angular momentum is a quantity possessed by rotating or revolving objects. The sun has more than 99% of the mass of the solar system, but only about 1% of the angular momentum. The planets have less than 1% of the mass, but have 99% of the angular momentum. This should not be; most of the mass should contain most of the angular momentum. It is not clear how the sun could have shed nearly all its angular momentum.

Other problems include some of the oddities of the solar system. Two planets rotate backwards, while the other six planets rotate in the same direction that nearly everything else moves. How did this happen? Uranus has a peculiar axial tilt, and Neptune's moon Triton has a strange backward orbit. The usual explanation is that all of these resulted from late, large impacts, but the details are difficult. Satellites are common in the solar system, and yet the earth's moon is very strange. Most of the moons in the solar system orbit in the equatorial plane of their respective planets. Only the earth's moon orbits near the ecliptic. Most astronomers think that studying the rest of the solar system should allow us to learn about how our moon came to be. However, if our moon is unique, it is doubtful that the study of other satellites would tell us much about the moon's history.

Most creationists believe that God recently created the solar system for His glory and man's enjoyment. While this is true, it would be helpful if we could develop more quantitative explanations about creation of the solar system. Much work remains to be done here.


Earth's moon