LESSON 4

Deep Space

Quick Write

Reflect on the story about Wylie Overstreet and Alex Gorosh's model of the solar system. What type of planning do you think was required to create an accurate model of the solar system?

Learn About

- the Milky Way galaxy
- other galaxies
- black holes, dark matter, nebulae, and pulsars
- big bang theory

The universe is so large that it can be hard to visualize. Many industries create models in order to visualize a concept. For example, architects may create models of a house or shopping mall before beginning the building process. But how do you create a model of the universe? Filmmakers Wylie Overstreet and Alex Gorosh decided it was a challenge they were up for. In their first project, To Scale: The Solar System, the duo created an accurately scaled model of the solar system. They used seven miles of dry lakebed in the Nevada desert to pull off this amazing model. In their model, the Earth was the size of a marble and the 140 million miles distance between Earth and Mars became 302 feet. The duo went a step further than just creating the model of the solar system, they used vehicles to create an accurate orbit for each planet. And when night arrived, the model came to life. Using lights attached to their vehicles, a time-lapse video was created showing an accurate model of the solar system and the orbits of each planet.

The project was so successful that they decided to move on to a larger project. Overstreet and Gorosh decided to build a scale model of time. In the project, To Scale: Time, the duo created a model to show the 13.8 billion years of the universe. Human life was a microscopic component of the model. The model itself spanned four miles, with 10 meters representing 20 million years. In the end, it took 12 minutes to film the entire 13.8 billion years of the universe's history.

The Milky Way Galaxy

A galaxy is *a group of stars, gas, and dust bound together by gravity*. The Earth and our entire solar system live in the Milky Way galaxy. And while it was originally assumed that our Sun was the center of the galaxy, our solar system is in fact closer to the edge of the galaxy. The Sun lies about 25,000 light years from the center of the galaxy. A light year is *the distance traveled by light in one year* (approximately 5,880,000,000,000 miles). American astronomer Harlow Shapley was the first to accurately determine the immense size of the galaxy and the location of our solar system. In 1917, Shapley used spatial distribution of globular clusters to determine the diameter of the galaxy. Globular clusters are *large compact spherical star clusters, typically of old stars in the outer regions of a galaxy*.

The image depicts the sun and the solar system in relation to the Milky Way galaxy. The white circle indicates the location of our solar system.

Courtesy of NASA/JPL-Caltech/T. Pyle

The Milky Way is a spiral galaxy. Think of it as a pinwheel, with a central bulge and four large spiral arms. The diameter of the galaxy is about 100,000 light years! In the spirals are glowing clouds that can be seen in the night sky. Inside the glowing clouds are gas and dust. This is where star formation occurs.

Vocabulary

- galaxy
- light year
- globular clusters
- galactic year
- Population II stars
- dwarf star
- dark matter
- interstellar medium (ISM)
- supernova
- charge exchange
- exoplanets
- elliptical galaxy
- lenticular galaxy
- irregular galaxy
- spiral galaxy
- starburst
- galaxy clusters
- superclusters
- black hole
- event horizon
- gravitational lensing
- nebulae
- emission nebulae
- reflection nebulae
- dark nebulae
- planetary nebulae
- supernova remnant
- neutron star
- pulsar
- cosmic microwave background (CMB)

While the diameter of the galaxy is 100,000 light years, the galaxy is only about 2,000 light years thick, so it forms a thin disk.
StarDate.org

Astronomers estimate that 200-400 billion stars live in the Milky Way galaxy. On a clear night, in a rural area away from light pollution, you can see the Milky Way galaxy. You will see faint light with dark patches. The dark patches are clouds of dust and gas that are lit by the many stars in the galaxy. It looks almost like milk spilt on the night sky, hence the name the Milky Way.

While our solar system orbits the Sun, the Sun orbits the center of the Milky Way galaxy. The galaxy is so big that *an entire orbit takes 250 million years*; this is known as a galactic year.

A view of the Milky Way galaxy in the night sky.
Fabio Lamanna/Shutterstock

Did You Know?

More than half of the stars in the galaxy are over 4.5 billion years old. It is believed that galaxies go through a stellar baby boom in which massive amounts of stars are produced. It is estimated that the stellar baby boom occurred over 10 billion years ago for the Milky Way.

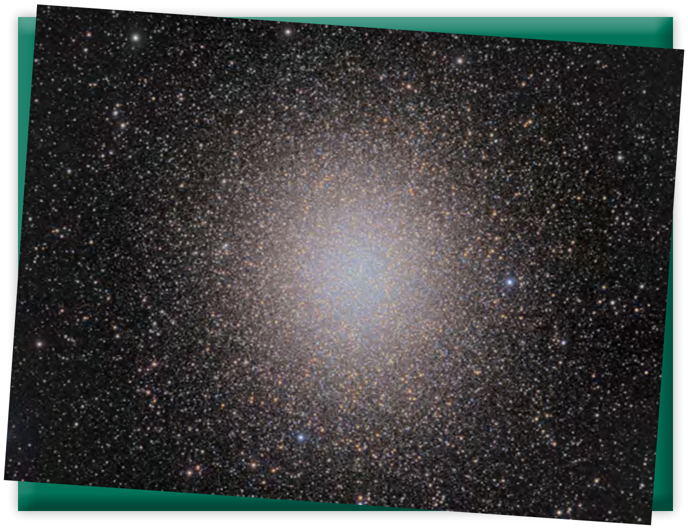
Structure of the Milky Way

The structure of the Milky Way galaxy is similar to other spiral galaxies. It consists of six separate parts:

- Nucleus
- Central bulge
- Disk
- Spiral arms
- Spherical component
- Halo

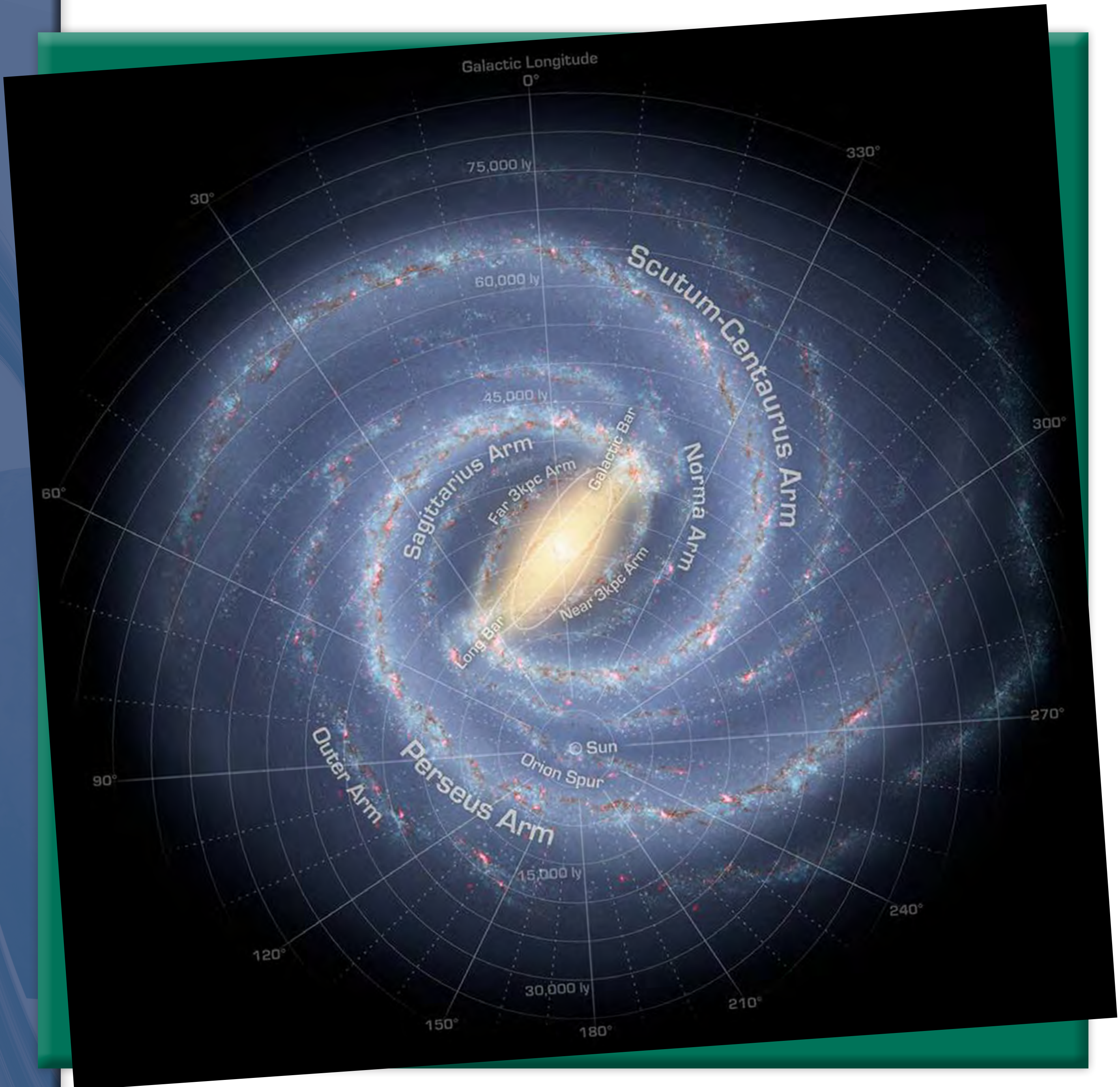
The nucleus is the center of the galaxy in which lies a gigantic black hole. The black hole in the center of the Milky Way is not your average black hole. It is a supermassive black hole that is 4,000,000 times the size of the Sun. This black hole may have started out small, but has grown exponentially with the ample amount of dust and gas available for it to consume. Although you cannot see a black hole, astronomers are able to locate black holes by observing the effects on nearby stars and gases. It is believed that most galaxies have a black hole in their center. We'll discuss black holes in further detail later in this lesson.

The central bulge is the area surrounding the nucleus. This area is almost perfectly spherical and contains mostly Population II stars. Population II stars are *older stars that are less luminous*. They are typically found in globular clusters.



Omega Centauri is the largest globular cluster in the sky.
Albert Barr/Shutterstock

The disk is the most difficult part of the galaxy to observe and extends out approximately 75,000 light years from the nucleus. Think of the disk as the area where the arms of the galaxy are attached. The disk contains stars and gas clouds. There are two components to the disk: the "thin disk," which contains dust, gas and the youngest stars; and the "thick disk," which contains older stars.



An illustration of the Milky Way galaxy and the spiral arms.
Courtesy of NASA/JPL-Caltech/R. Hurt (SSC/Caltech)

The spiral arms are probably the most noticeable feature of the galaxy. There are four main spiral arms: Norma and Cygnus, Sagittarius, Scutum-Crux, and Perseus. In addition to the main arms, there are several minor arms, or spurs. Our solar system is located on the Orion Spur. New stars are constantly being formed in the arms.

The galaxy is constantly moving. The material in the center of the galaxy moves faster, and, as it moves, the material in the center of the galaxy stretches out to create the spiral arms. Scientists believe the spiral arms remain as a result of density waves, or areas of greater density. The density wave model was proposed by C.C. Lin and Frank Shy in the 1960s to explain the spiral arms of the galaxy. Have you ever been in a traffic jam? Traffic slows down and you make your way past the cause of the traffic jam. But even after you have passed the cause of the traffic jam, traffic remains slower than normal. This is an example of density waves.

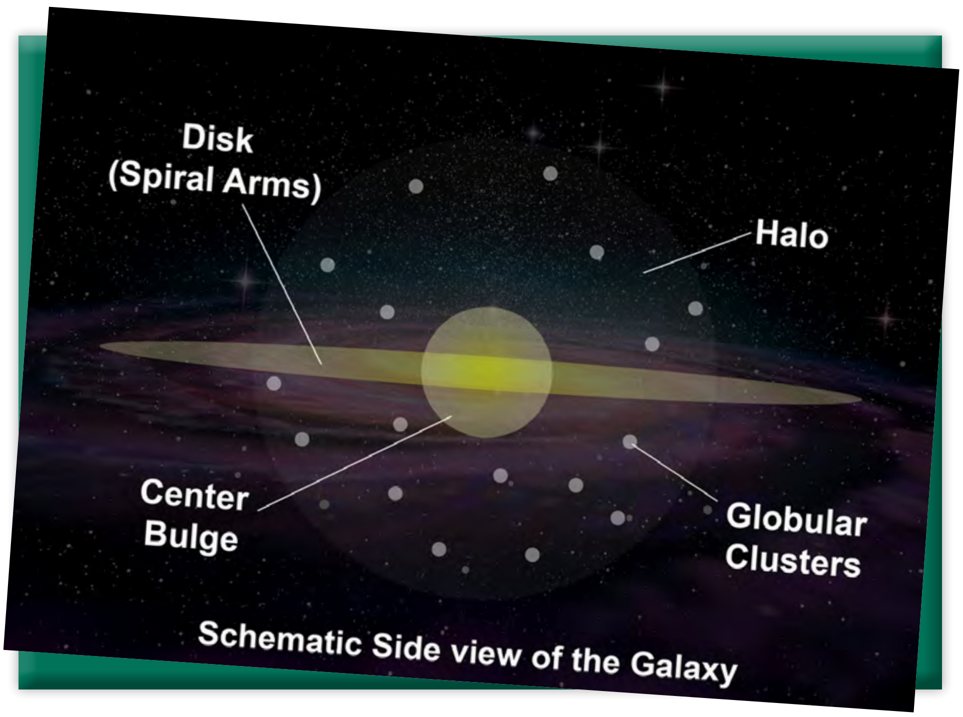
The spherical component of the galaxy extends above and below the disk and is really an extension of the central bulge. This region is populated by globular clusters of Population II stars and dwarf stars. A dwarf star is *a star with average or low luminosity, mass, and size.*

The halo, a spherical area that surrounds the Milky Way, is a massive component of the galaxy that may reach much farther than the 100,000 light year diameter of the galaxy. Not much is known about the halo other than its massive size. We do know that the halo only contains about two percent as many stars as found in the disk.

Dark matter is *invisible matter that can be detected through its gravitational pull* on the Milky Way's gas clouds. It is estimated that dark matter makes up 90 percent of the Milky Way. We'll discuss dark matter in further detail later in this lesson.

Did You Know?

The Milky Way galaxy gained its enormous size from devouring smaller galaxies throughout its existence.

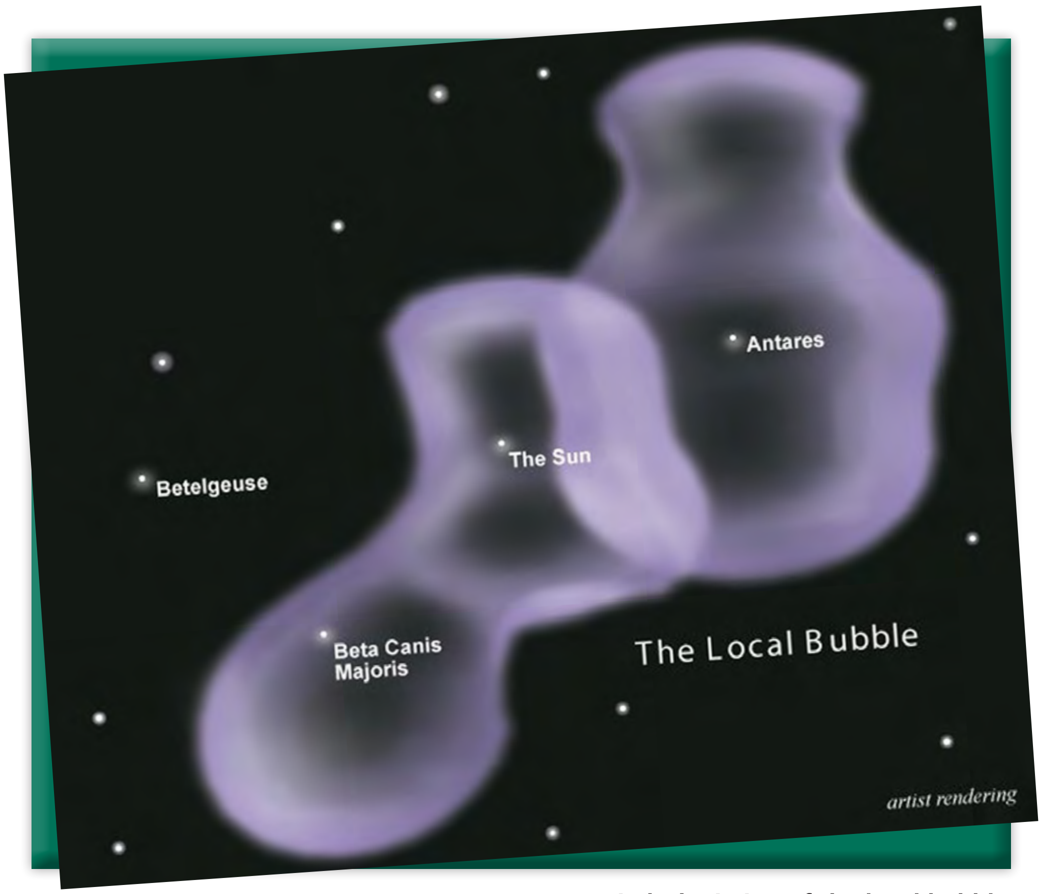


An illustration of the Milky Way galaxy and it's components.

The Local Bubble

Interstellar medium (ISM) is *the term used to describe the matter in galaxies that exists between solar systems*. This matter is made up of gases and dust. It is believed that "bubbles" exist in the ISM. Our solar system is located in one of the bubbles known as the Local Bubble. This region contains very hot gases, but is surrounded by cooler, dense air. The Local Bubble is about 300 lights years in diameter and surrounded by other bubbles.

It is believed that the Local Bubble was created by a supernova explosion over 10 million years ago. A supernova is *a massive explosion of a star*. A supernova explosion typically occurs once or twice every century in the Milky Way galaxy. However, 10 million years ago there was a plethora of supernova explosions. Think of when you make popcorn: after one kernel pops, many others start popping. This is what occurred around our solar system 10 million years ago.



An artist's depiction of the local bubble.

Courtesy of NASA

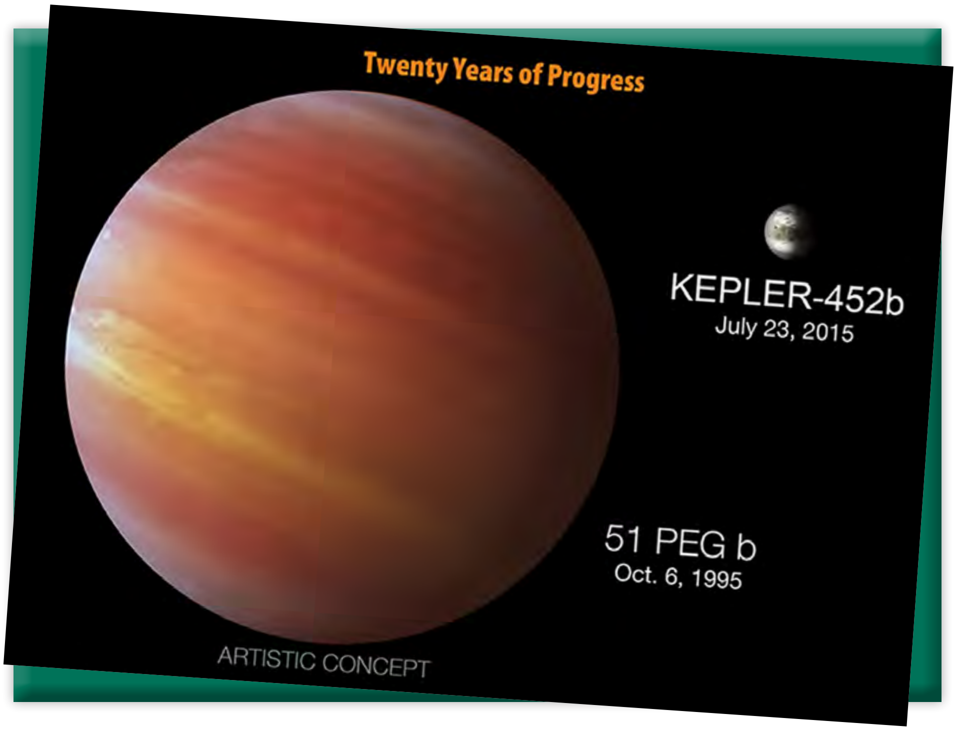
So how did scientists discover the bubble? Scientists have always been fascinated with the interstellar medium (ISM) and continue to study the gas and dust found in deep space. However, when scientists started aiming their telescopes to study matter in our solar system they found very little of the gas, dust, and ions they found in ISM. In addition, sensors outside of the Earth's atmosphere detected an abundance of x-ray radiation. The conclusion was the formation of the bubble.

The supernova explosions were so strong they blew away the dust and gas particles in our solar system. The remnants of the supernova are the x-ray radiation in our solar system.

In recent years, the Local Bubble model has been debated. Some scientists believe that the x-ray radiation is not necessarily all coming from inside our solar system as a result of the supernova. They speculate that the radiation may come from charge exchange, which is *the passing solar wind stealing electrons and emitting radiation*. Data suggests that only 40 percent of the x-ray radiation is emitted from our solar system and that the remaining radiation is most likely coming from the hot gas walls of the bubble.

Exoplanets

Many other planets live in the Milky Way galaxy outside of our solar system, these planets are called exoplanets. Exoplanets are *planets that orbit a star outside of our solar system*. To date, over 3,700 exoplanets have been discovered and the number is constantly growing.



This shows the first planet to be confirmed as an exoplanet, 51 Pegasi b, and the newest Earth-sized planet confirmed.

Courtesy of NASA Ames/W. Stenzel

So how does a planet form? Scientists and philosophers have pondered this question for centuries. As scientists collect data from advanced telescopes and probes, they can speculate on the process of planet formation. But scientists have never been able to observe a planet in the process of formation. The data collected provides clues as to how planets, such as Earth, were formed. Theories suggest that planets are formed by large collisions occurring in space. The gas and dust left over from a collision are pulled together by gravity. As larger and larger pieces form together, the universe slowly creates a planet.

The Kepler spacecraft undergoing testing at Cape Canaveral, FL prior to launch in 2009.
Courtesy of NASA/Kim Shiflett

NASA has an entire division dedicated to exoplanet exploration called the Exoplanet Exploration Program (ExEP). For example, the Kepler mission is a NASA mission designed to study our region of the Milky Way for other planets that may be in the habitable zone. As a planet passes in front of a star, it is called a "transit." This event can be seen in the sky as a small black dot. The Kepler Space Telescope uses this phenomenon to detect other planets. Once a planet is detected, the orbital size and mass can be calculated to determine if the planet is in a habitable zone.

The Kepler Space Telescope was launched in 2009 and trailed Earth's orbit for four years. The data from the mission is still being analyzed and continues to reveal new planets. As a result of the four years of data, more than 2,000 exoplanets were confirmed. The Kepler Space Telescope mission ended in 2013 when two reaction wheels on the spacecraft failed.

This failure did not stop NASA's Kepler team. They had an innovative fix for the spacecraft. They used the pressure of sunlight to stabilize the axis of the telescope. The telescope was renamed the K2 and continues its path in Earth's orbit, sending data that may help scientists discover new exoplanets.

Did You Know?

The Transiting Exoplanet Survey Satellite (TESS) is the next step in the search for planets outside of our solar system, including those that could support life. The mission will find exoplanets that periodically block part of the light from their host stars, events called transits. TESS will survey 200,000 of the brightest stars near the Sun to search for transiting exoplanets. TESS was launched on April 18, 2018, aboard a SpaceX Falcon 9 rocket. The stars TESS will study are 30 to 100 times brighter than those the Kepler and K2 missions surveyed, which will enable far easier follow-up observations with both ground-based and space-based telescopes. TESS will also cover a sky area 400 times larger than that monitored by Kepler.

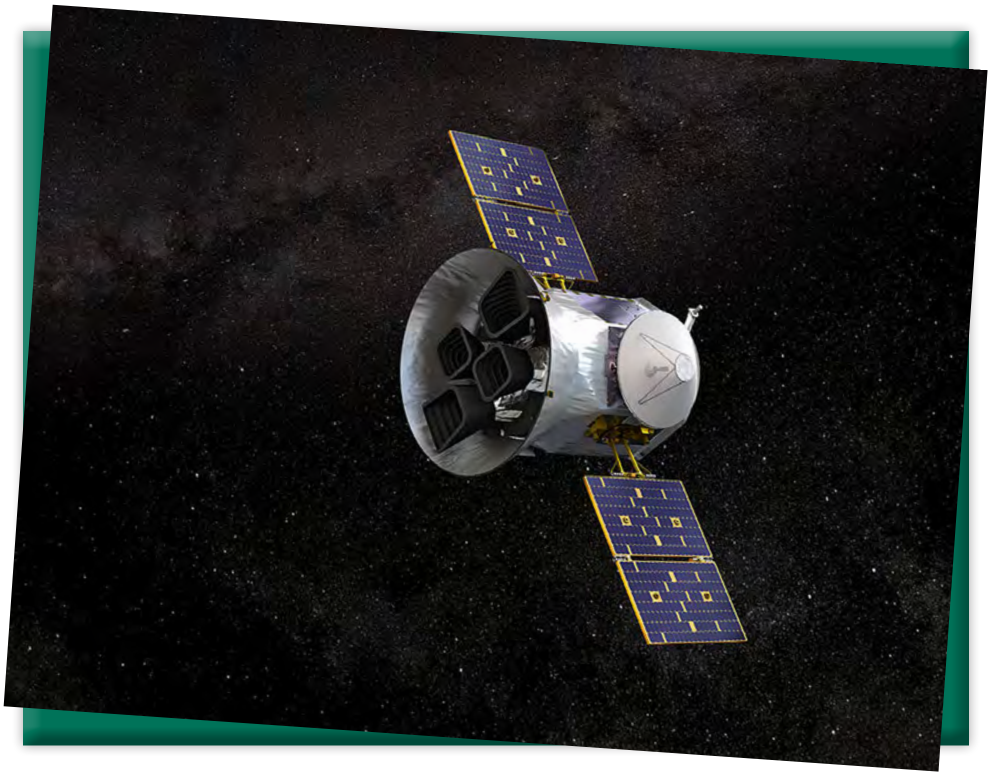
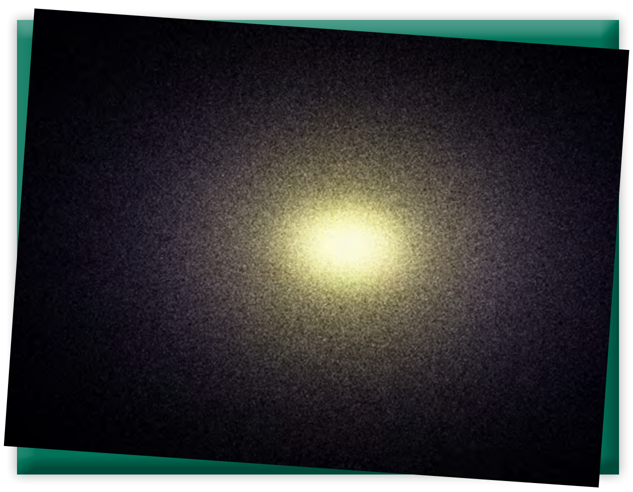


Illustration of NASA's Transiting Exoplanet Survey Satellite — TESS.
Courtesy of Goddard Space Flight Center/NASA

Other Galaxies

The universe is home to many other galaxies. Scientists theorize that galaxies are first formed with a small group of stars. The galaxy then merges with other galaxies and became a larger galaxy, like the Milky Way. Galaxies can come in different sizes and shapes. There are four known galaxy shapes: elliptical, lenticular, irregular, and spiral.

An elliptical galaxy is *elliptical in shape and does not have spiral arms or gas and dust particles as seen in the Milky Way*. Elliptical galaxies are typically home to older stars.



An elliptical galaxy appears to be mostly a big ball of light from the massive number of stars it contains.
Courtesy of Shutterstock/Diego Barucco

Figure 2.1: Lenticular galaxy NGC 4565
Courtesy of NASA/JPL-Caltech

A lenticular galaxy is a *spherically shaped galaxy with a disk of stars and gas around a nucleus*. The disk is similar to spiral galaxies, but does not have spiral arms or areas of star formation.

Figure 2.1 from NASA Galaxy Evolution Explorer shows NGC 4565, one of the nearest and brightest galaxies not included in the famous list by 18th-century comet hunter Charles Messier.

Figure 2.2: irregular galaxy IC 3583
Courtesy of NASA/JPL-Caltech

Irregular galaxies do not have a clear shape. These types of galaxies have large groupings of stars and areas of star formation.

This delicate blue group of stars in Figure 2.2 is an irregular galaxy named IC 3583 and sits some 30 million light years away in the constellation of Virgo (The Virgin).

Figure 2.3: Barred spiral galaxy M83
Courtesy of NASA/JPL-Caltech

Spiral galaxies are *spiral in shape and have long spiral arms with young stars and star formation areas*. Spiral galaxies are easily recognizable and mesmerizing to see. As discussed earlier, the Milky Way galaxy is a spiral galaxy.

Figure 2.3 shows vibrant magentas and blues in a Hubble image of the barred spiral galaxy M83. The image reveals that the galaxy is ablaze with star formation.

Observing Galaxies from Earth

You may not realize it, but you can observe many galaxies from Earth in the night sky. You just need to know where to look to locate these magnificent sites.

Andromeda Galaxy

The Andromeda galaxy is 2.5 million light years away, yet it is the closest big galaxy to the Milky Way, and you can see it without a telescope! The Andromeda galaxy is a spiral galaxy that is slightly larger than the Milky Way. It is also referred to as M31, Messier 31, or NGC 224.

When observing the galaxy in the night sky, it will appear as a long, hazy smudge of light. The Andromeda galaxy is located just north of the Andromeda constellation. It is best to observe the galaxy in a dark sky, away from urban light pollution in November in the Northern Hemisphere. The Andromeda galaxy will be about the same width as the full moon in the night sky.

In 2015, the Hubble Space Telescope took a mosaic of images of the Andromeda galaxy that resulted in an immense amount of information for scientists. Some of the key features of Andromeda are two supermassive black holes that orbit each other, and a ring of dwarf galaxies around Andromeda.

This image from NASA Galaxy Evolution Explorer is an observation of the large galaxy Andromeda, also known as Messier 31.

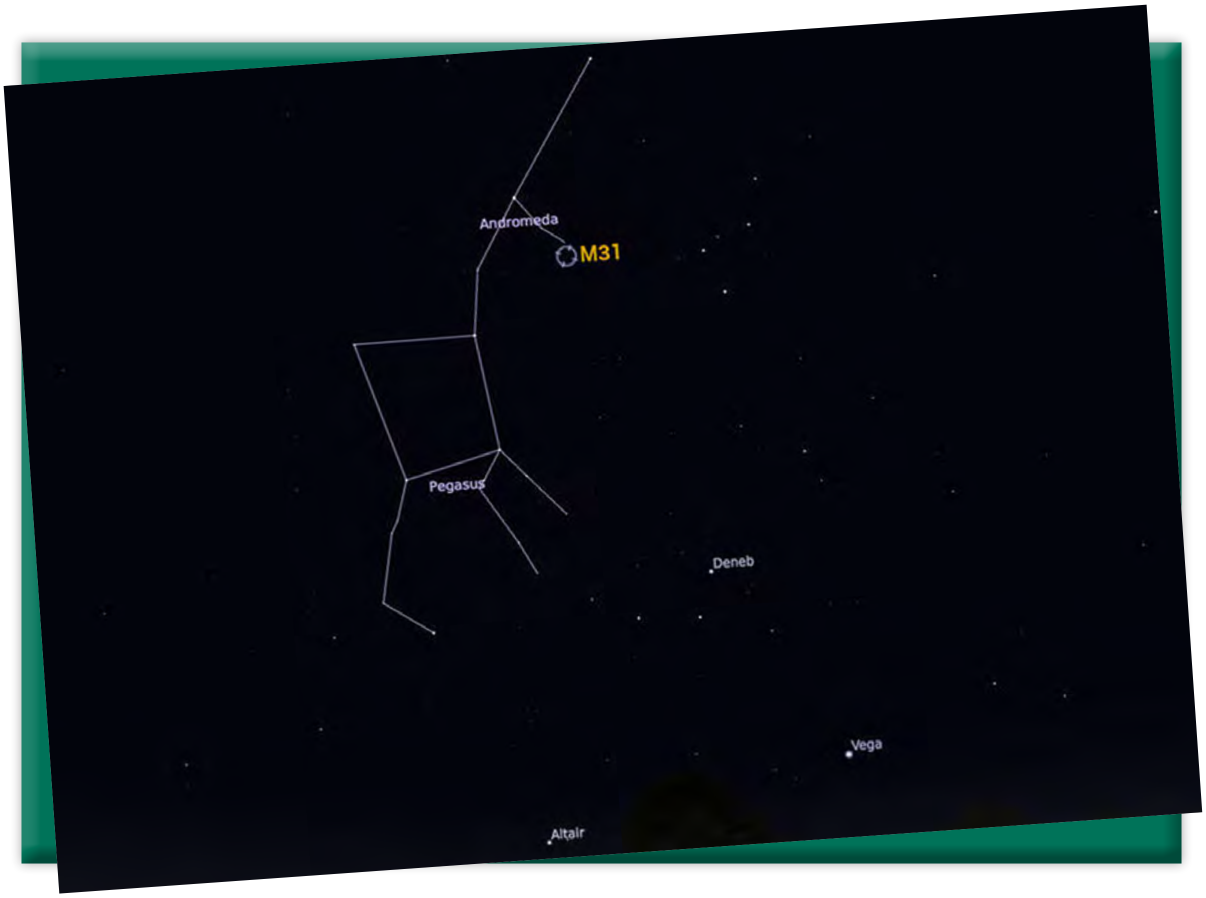
Courtesy of NASA/JPL/California Institute of Technology

This is a real image of the Andromeda galaxy in the night sky.

Courtesy of Shutterstock/Anze Furlan

Did You Know?

The Andromeda Galaxy is currently on a collision course with the Milky Way galaxy. In about four billion years, the two galaxies will collide, creating a new "Milkomeda" elliptical galaxy. Of course, the process of combining these two galaxies will take almost two billion years.



This star chart shows the location of M31 in the Northern Hemisphere in November around 10 p.m. EST.
Courtesy of Stellarium

Waypoints

How are Galaxies Named?

Galaxies usually have many different names. The Messier catalog of objects was maintained by Charles Messier. It was a list of 110 fuzzy objects observed in the sky. When an object is identified, it is often referred to by its Messier number.

In addition, many galaxies are given an NGC number. The NGC is the New General Catalogue that contains a list of 7,840 interesting night sky objects. As each object is identified, it may be referred to using its NGC number.

A third way of naming galaxies is based on their location in the sky in relation to constellations. For example, the Andromeda galaxy is named for the constellation in which it is located, the Andromeda constellation. But in the Messier catalog, the Andromeda galaxy is designated as M31. And in the New General Catalogue, the Andromeda galaxy is designated as NGC 224.

The International Astronomical Union maintains the official names for astronomical objects, so you cannot name a galaxy or star after yourself even if you discover it!

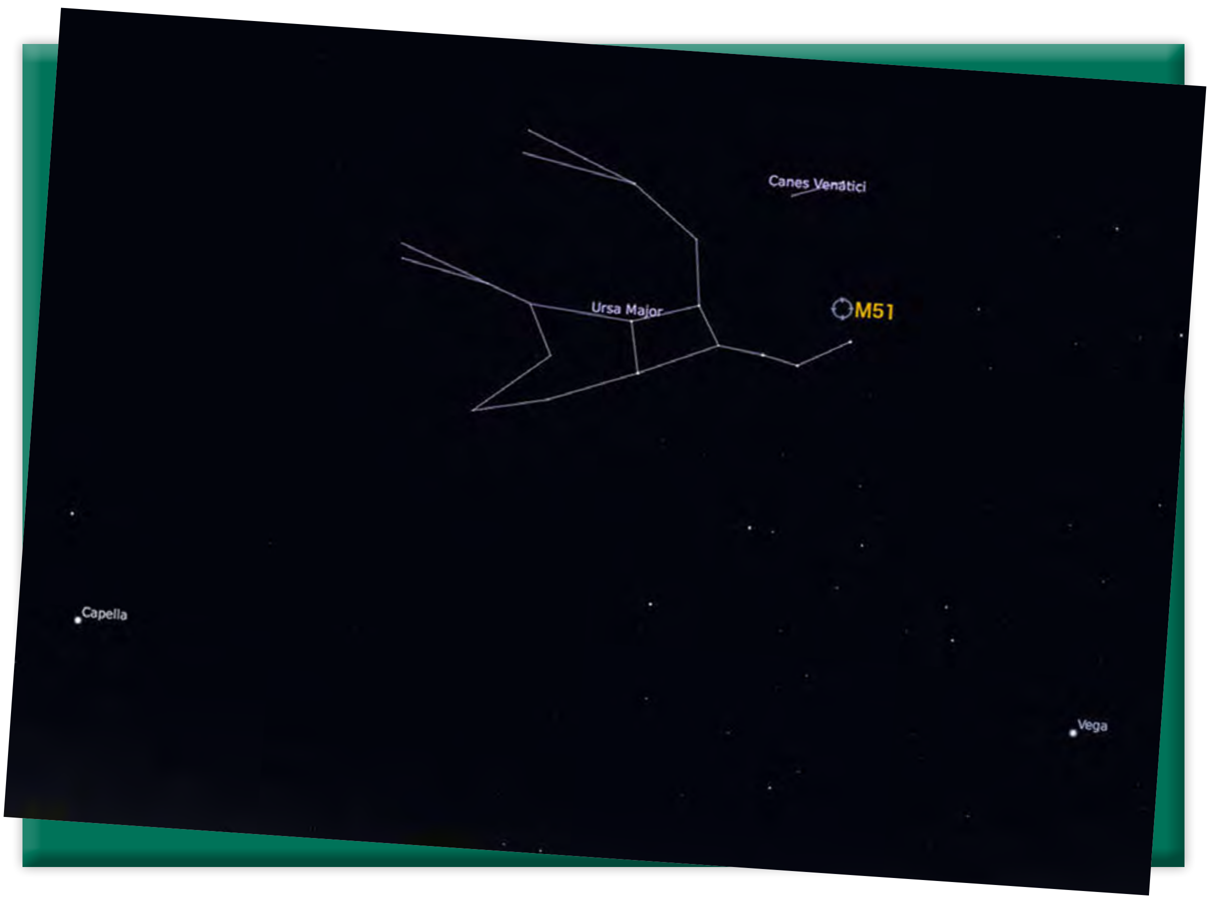
The Whirlpool Galaxy

The Whirlpool galaxy is a majestic spiral galaxy more than 23 million light years from the Milky Way. The Whirlpool galaxy is also known as M51 and is in the constellation Canes Venatici.

Each of the spiral arms of the Whirlpool galaxy has long lanes of stars, gas, and dust producing clusters of new stars. Some astronomers believe that the arms on the Whirlpool galaxy are more prominent because of the tidal force from its companion galaxy, NGC 5195. The Whirlpool galaxy can be spotted with a small telescope in May.

The Whirlpool galaxy is situated facing the Milky Way, which provides stunning images. This image of the Whirlpool Galaxy shows its companion galaxy, NGC 5195, to the right.

Courtesy of NASA, ESA, Beckwith (STScI) and the Hubble Heritage Team (STScI/AURA)



This star chart shows the location of M51 in the Northern Hemisphere in May around 10 p.m. EST.

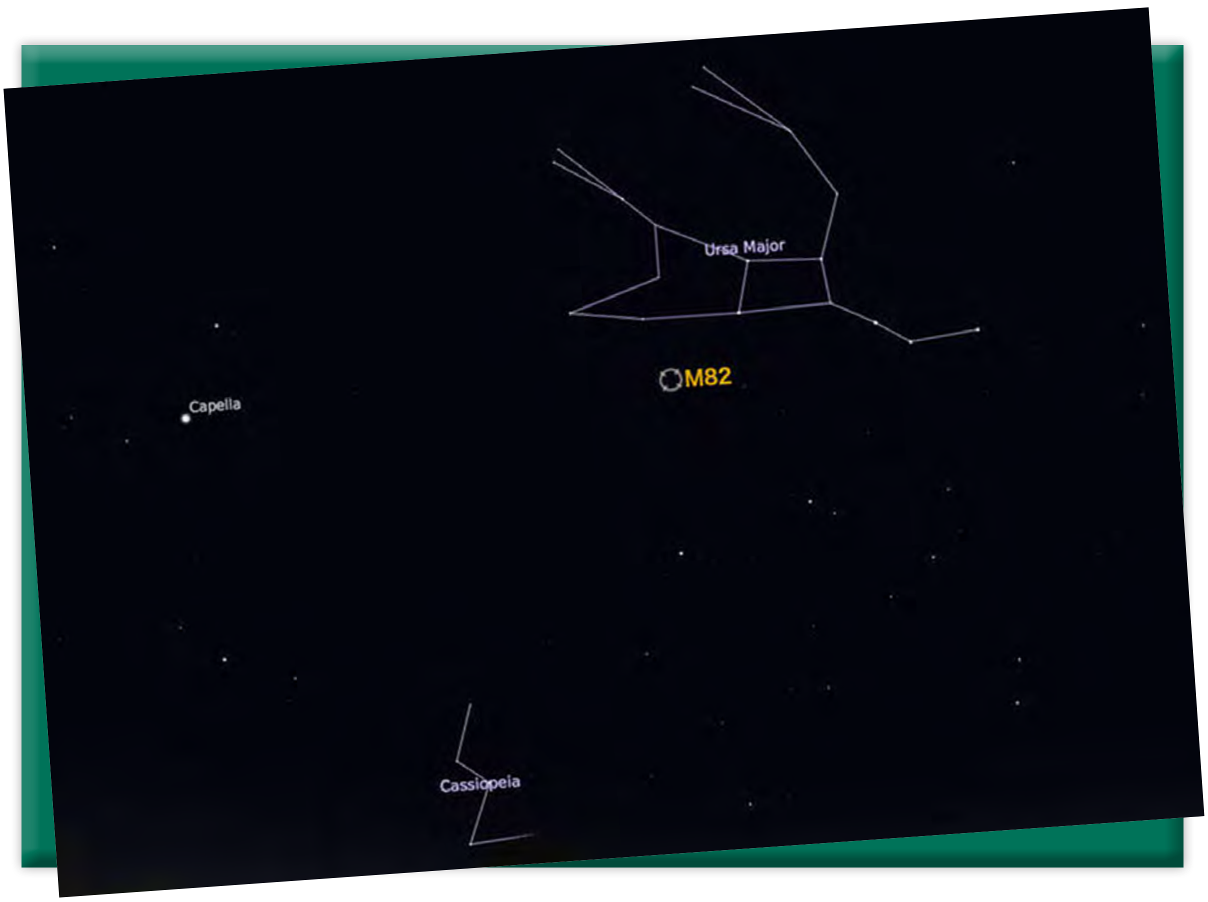
Courtesy of Stellarium

In this image of the Cigar galaxy, you can see the gas and dust in pink coming from the galaxy.

Courtesy of NASA, ESA, Beckwith (STScI) and the Hubble Heritage Team (STScI/AURA)

The Cigar Galaxy

The Cigar galaxy is a spiral galaxy 12 million light years away in the constellation Ursa Major. (Ursa Major is in The Big Dipper.) It is also referred to as M82. The Cigar galaxy has *a high rate of star formation* called a starburst. This phenomenon is attributed to its galactic neighbor M81. M82 produces new stars 10 times faster than the Milky Way galaxy. M82 can be seen with a telescope or binoculars in April in the Northern Hemisphere.



This star chart shows the location of M82 in the Northern Hemisphere in April around 10 p.m. EST.

Courtesy of Stellarium

Triangulum Galaxy

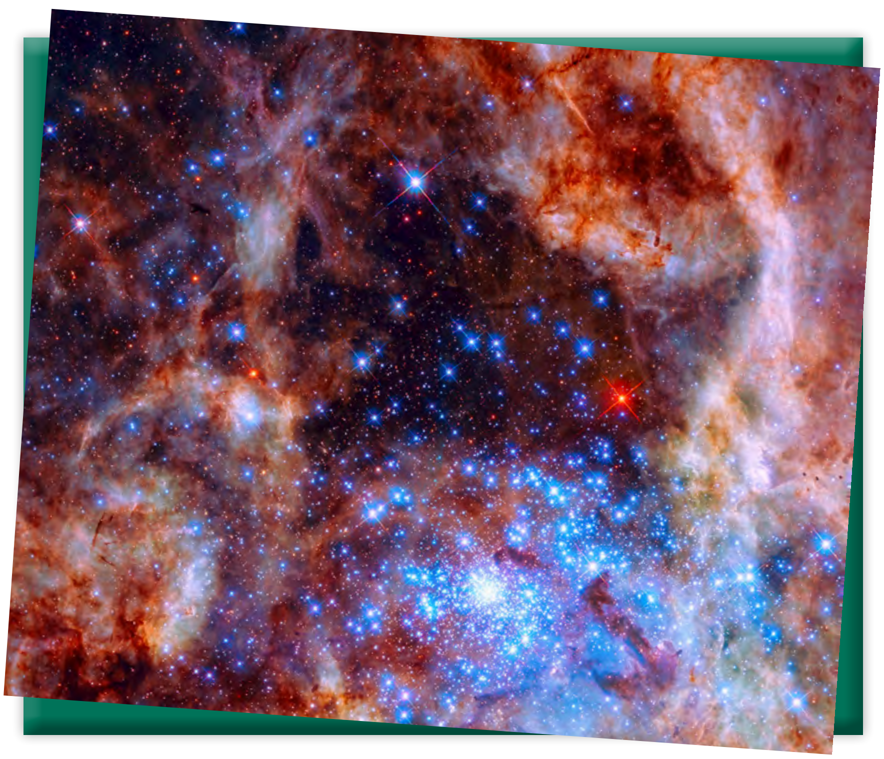
The Triangulum galaxy is a spiral galaxy about 2.8 million light years away. It is very close to the Andromeda galaxy and can also be seen unaided in the night sky away from light pollution. The Triangulum galaxy is also referred to as M33.

Triangulum galaxy, or M33.
Courtesy of Shutterstock/Antares_StarExplorer

The Magellanic Clouds

The Magellanic Clouds are a group of two irregular galaxies that live close to the Milky Way. The Large Magellanic galaxy is easy to find in the night sky and is visible to the unaided eye. It will appear as a small, faint smudge in the sky. It is often mistaken for the Milky Way. The Large Magellanic Cloud is between the Dorado and Mensa constellations. The Small Magellanic Cloud is in the Tucana constellation.

The Large Magellanic Cloud is almost 200,000 light years from Earth and contains vast clouds of gas and newly formed stars that present a magnificent display of colors in the night sky.

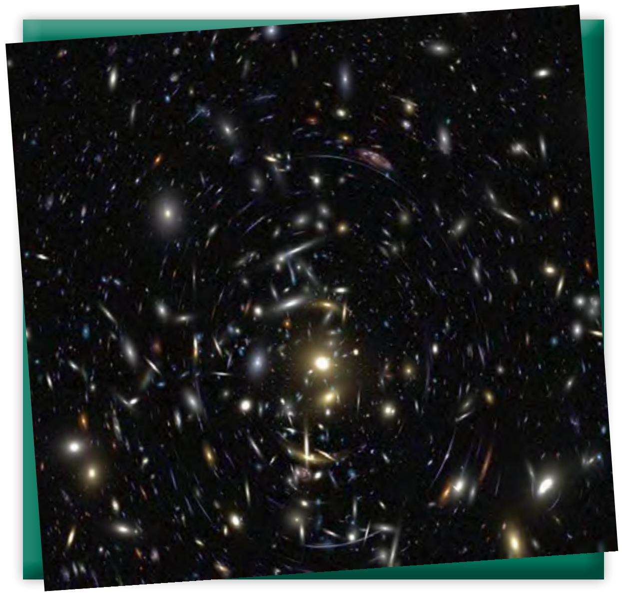


Central region of the Tarantula Nebula in the Large Magellanic Cloud. The young and dense star cluster R136. Retouched colored image.
Courtesy of NASA/Shutterstock

Galaxy Clusters

As you have seen from the images, many *galaxies form groups* or galaxy clusters. The Milky Way is part of a galaxy cluster called the Local Group. *Galaxy clusters can also group together* into superclusters.

The Local Group contains about 50 galaxies, including the Milky Way galaxy. The Andromeda galaxy and Magellanic Clouds are also included in the Local Group.



A computer-simulated view of a cluster of galaxies in the distant cosmos.

Courtesy of NASA, ACS Team, Rychard Bouwens (UCO/Lick Obs.)

Did You Know?

The universe is full of galaxy clusters in varying sizes. A galaxy cluster can contain a few galaxies or thousands of galaxies. They may be scattered over a large area or be packed tightly together.

Black Holes, Dark Matter, Nebulae, and Pulsars

Black Holes

Another intensely studied aspect of deep space is a black hole. A black hole is *an area of intense gravitational pull*. A black hole will suck objects in, and once inside, they cannot escape–even light can't escape a black hole.

Think of a black hole as a hungry toddler. Black holes are like toddlers in that they are a bit messy as they pull objects inside. Material being sucked into the black hole doesn't always get pulled directly in. The objects may miss the opening of the black hole, and their material is forced out at the speed of light. The black hole has powerful magnetic fields surrounding it, so when material is forced out it gets caught in the magnetic fields around the black hole. These magnetic fields act as jets to shoot the material away. In addition, they emit an enormous amount of energy, such as radio waves, visible light, and X-ray light.

There are three main types of black holes: primordial, stellar, and supermassive. Primordial black holes are extremely small black holes that have a large mass. It is thought that primordial black holes were formed early in the universe.

Stellar black holes form when a large star collapses into itself. At the final stage of a particularly massive star's life, it can detonate, or create a supernova, which is a massive explosion that scatters most of the star but leaves a cold remnant. The remnant has no energy or outward pressure to oppose the inward pull of gravity. The result is a black hole, with its immense gravitational pull.

Supermassive black holes are formed at the same time as the galaxy to which they belong. It is believed that the size of the black hole has a direct correlation to the size of the galaxy. Many galaxies have a black hole at their center, just as the Milky Way does. Black holes can grow to a massive size as they consume the matter and objects that pass by.

A black hole sucks in dust, gas, and even stars and planets. Objects and matter must pass fairly close to a black hole in order to be sucked into the black hole. Once *an object is pulled into a black hole to the point of no return*, the object has reached the event horizon. This is the point where the path into the black hole cannot be reversed.

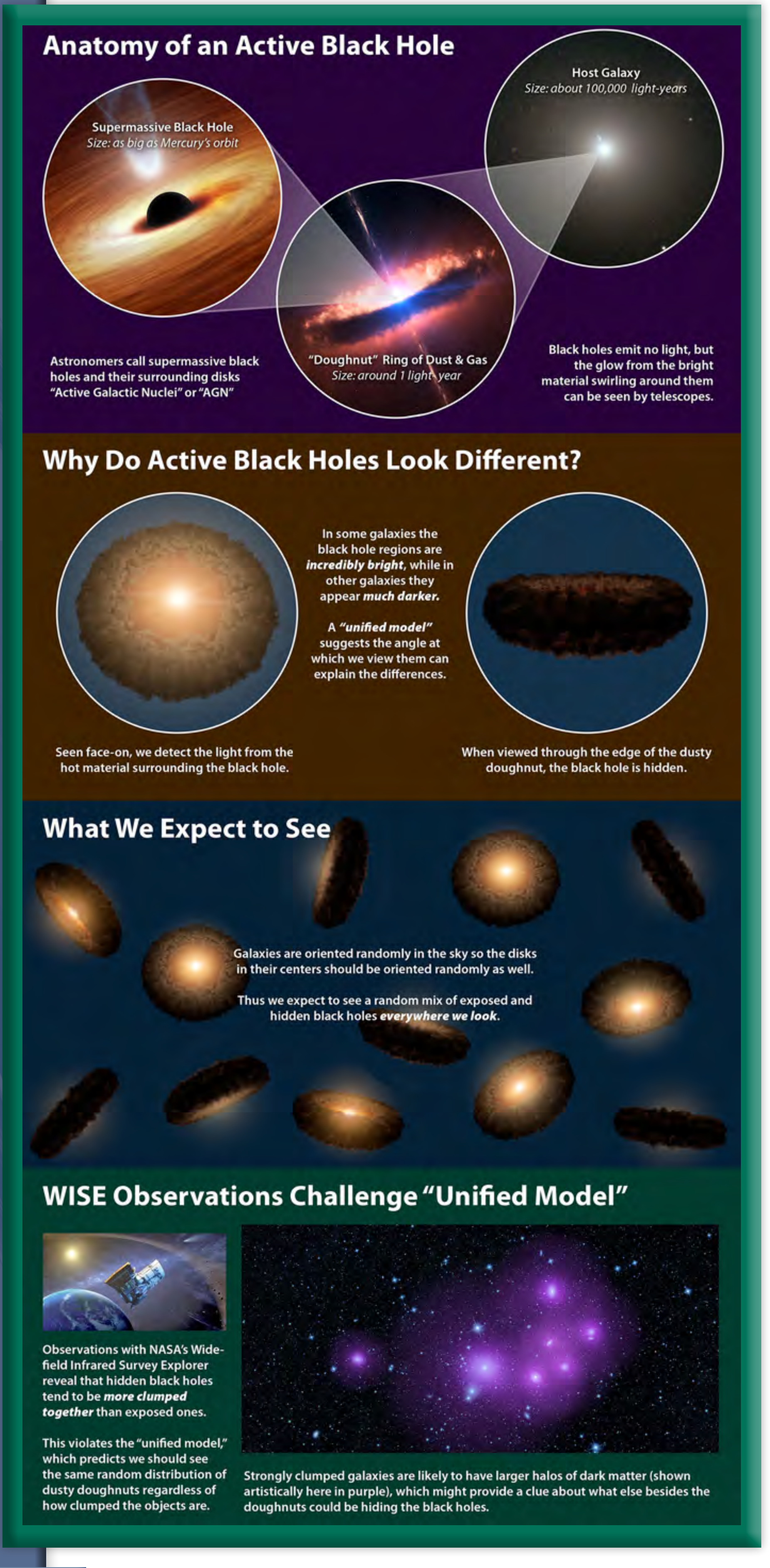
Did You Know?

Australian astronomers found the fastest-growing black hole known. The 20-billion-solar-mass black hole consumes the mass of the Sun every two days. If this black hole were at the center of the Milky Way, it would appear 10 times brighter than a full moon because of the massive amount of gases sucked in.

While black holes are very powerful, they are also very small. If you had a black hole the size of our Sun, the black hole would be approximately 2 miles in diameter. Because of their size and distance from Earth, it is impossible to directly observe a black hole. However, scientists are able to measure the mass in a specific area of the sky. When they locate dark mass, this equates to a black hole.

An artist's rendition of a black hole.

Jurik Peter/Shutterstock



There are still a lot of unknowns about black holes. However, much was learned by theoretical physicist, cosmologist, and author Stephen Hawking, who dedicated his time to researching them. Hawking developed a solid mathematical backing for Albert Einstein's Theory of Relativity and the concept of black holes proposed in Einstein's theory. Hawking applied the area of quantum mechanics to black holes and discovered that black holes emit radiation. The source of the radiation is virtual particles that jump in and out of the black hole. If a black hole consumes a negative particle, the black hole will shrink by a miniscule amount and radiation will be emitted. This is known as Hawking radiation. With the application of this theory, all black holes will eventually shrink away when there is no matter left for them to consume. This process would, of course, take an immensely long time to occur. Although no emissions have been spotted, most physicists do believe they exist.

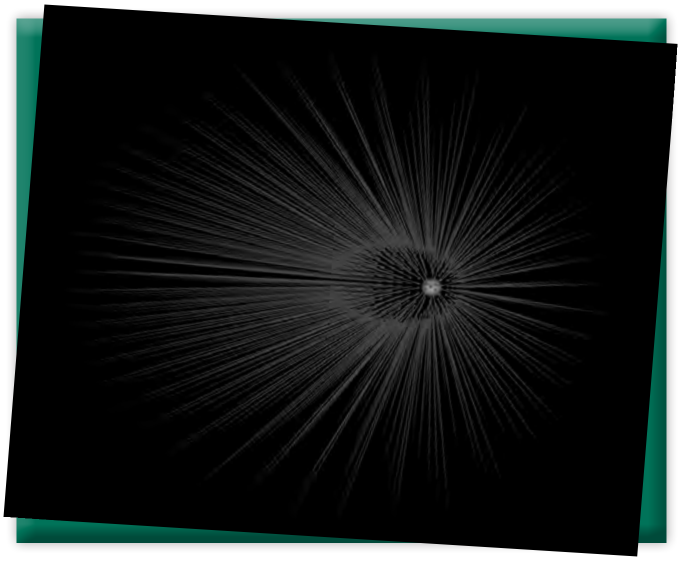
The anatomy of a black hole.

Courtesy of NASA/JPL-Caltech

Dark Matter

What is dark matter? Dark matter may be the biggest mystery of space. We have talked about galaxies containing dark matter, but what exactly is it? Well, astrophysicists don't really know. We know that it does not emit radiation like other matter. And we also know that it cannot be seen.

So, if you can't see dark matter, how do we know it exists? Let's first review how galaxies form. Over time, stars form and collect into galaxies. The galaxies then cluster together. Between the stars, galaxies, and solar systems, there is matter smashed together. Gravity is the glue that holds everything together. The matter between everything is filled with gas, dust and "stuff" that we just can't detect. This "stuff" is dark matter. It is the invisible matter between planets, solar systems, and galaxies.



This illustration shows Jupiter surrounded by filaments of dark matter called "hairs," which are proposed in a study in the Astrophysical Journal by Gary Prézeau of NASA's Jet Propulsion Laboratory, Pasadena, California. A hair is created when a stream of dark matter particles goes through the planet.

Courtesy of NASA/JPL-Caltech

Dark matter was discovered when scientists were studying the mass of objects in space. Using the observable light of a galaxy, they could estimate the mass of the galaxy. However, when looking at the weight, position, and speed of rotation, scientists learned that the mass calculation was far greater than the observable light would indicate. This finding established the existence of dark matter. Dark matter has a mass that contributes to the overall mass of the object, even though we cannot observe dark matter.

Because scientists cannot see dark matter, how do they go about studying it? They use gravitational lensing, which is *a technique used to study dark matter*. When light is passed through a gravitational lens, it will bend. The amount of bending can help scientists study dark matter.

Another way that scientists study dark matter is by using the Fermi Gamma-Ray Space Telescope. The telescope detects gamma rays, the highest energy form of light. It is believed that when dark matter particles collide they release gamma rays. The burst of gamma rays would be detected by the Fermi telescope. The Fermi Gamma-Ray Space Telescope was launched in June 2008 and maps the entire sky every three hours. It is still considered a new technology, and data from the telescope is continually being analyzed.

For now, dark matter continues to be a great mystery. Many theories surround dark matter, and little is known about it. But, through studies, scientists have been able to determine what dark matter is "not," thus getting them closer to discovering the mystery of dark matter.

Nebulae

A beautiful nebula and galaxy.
Courtesy of NASA/Shutterstock

We have discussed how dust and gas are present in the space between stars and planets. In some areas, the *dust and gas are very dense and create clouds* known as nebulae (nebula for singular). Within the nebulae clouds, star formation occurs. The combination of the dust, gas, and star formation produces magnificent displays of light from the nebulae clouds. There are many types of nebulae that are found in the universe, including emission nebulae, reflection nebulae, dark nebulae, planetary nebulae, and supernova remnant.

As young stars are born, they create strong stellar winds and interstellar gas. The solar winds create bubbles and canyons in the nebula. The interstellar gas creates light to form emission nebulae, which are *nebulae clouds lit up by interstellar gas*. With binoculars or a small telescope, you can witness emission nebulae in the night sky.

A reflection nebula in the star cluster Pleiades.
Courtesy of Mironov/Shutterstock

Some nebulae do not emit light but do reflect it. They are called reflection nebula. Reflection nebulae are *scattered nebula clouds that reflect light from the nearby stars*. The reflected light typically appears as blue starlight.

Then we have *nebulae that do not emit or reflect light*; these are dark nebulae. Dark nebulae can be seen, as they are silhouetted against brighter backdrops.

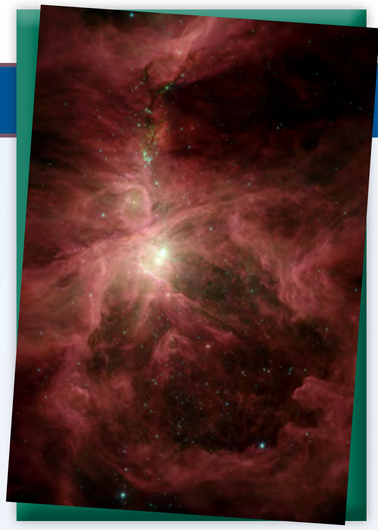
Another type of nebulae is a planetary nebula. A planetary nebula *occurs when a star reaches the end of its life*. The star will push its atmosphere into space and create a magnificent planetary nebula. The core of the star remains, lighting up the surrounding material.

When a massive star dies in a supernova explosion, remnants of the star remain. The explosion sends glowing material into space. As the material crashes into the surrounding gas, it expands over time. This type of nebula is called a supernova remnant. A supernova remnant is *the remains of a star that has expanded to create a nebula*.

The Right Stuff

Nebulae

Nebulae are fascinating features of the night sky, Using binoculars or a small telescope, you can easily observe some common nebulae. The Orion nebula is one of the easiest nebulae to observe and is located within the Orion constellation. It is an emission nebula that is 1,350 light years away.



Orion Nebula

Courtesy of NASA/ JPL-Caltech/Univ. of Toledo

Carina Nebula

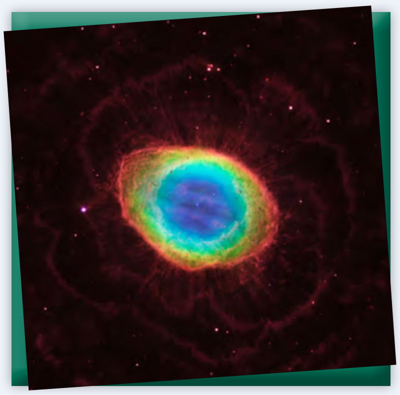
Courtesy of NASA Goddard

The Carina Nebula is 7,500 light years away in the Carina constellation. The Carina Nebular is a spectacular sight and produces many stars.

Crab Nebula is a supernova remnant. It is located in the Taurus (the Bull) constellation and is thought to have occurred in 1054. To locate this nebula, locate the Hyades star cluster at the head of Taurus. Follow the bull's horn to the Zeta star. The Crab Nebula is just a degree away from Zeta.

Crab Nebula

Courtesy of NASA/JPL



Ring Nebula

Courtesy of NASA Goddard

The Ring Nebula is a planetary nebula that is a must-see. It This small, glowing ring of light is the remnants of a star similar to the Sun. It is located in the constellation Lyra between the stars Gamma and Beta. Using a small telescope, you can easily view this wonder.

Pulsars and Neutron Stars

During a supernova explosion, the protons and electrons of a star are crushed together creating neutrons. This process creates *a ball of neutrons* called a neutron star. Think of an ice skater spinning on the ice. As they move faster, their arms and legs are tightly tucked against their body. A neutron star is similar to this concept; as the neutrons spin faster, they are pulled closer into a neutron star. A neutron star is about 20 miles in diameter, yet has approximately the same mass as the original star. If a neutron star the size of a sugar cube were on Earth, it would weigh over 100 million tons!

Neutron stars are very small, strange objects that have an extremely strong magnetic field. Neutron starts can become pulsars over time. A pulsar is *a rapidly spinning neutron star that emits radio waves in pulses*. The pulsar will emit a regular pulse at specific intervals. While some pulsars are extremely fast with a pulse period of 1.56 milliseconds, others are slow pulses at .715 seconds. As the pulsar emits a pulse, beams of radiation and light are pushed out.

Illustration of a pulsar.
Courtesy of Jurik Peter/Shutterstock

The Crab Nebula has a pulsar inside it. The pulsar pulses 33 times per second, lighting up the nebula as it pulses. The pulse of a pulsar is incredibly consistent. In fact, the timekeeping of a pulsar is more accurate than an atomic clock.

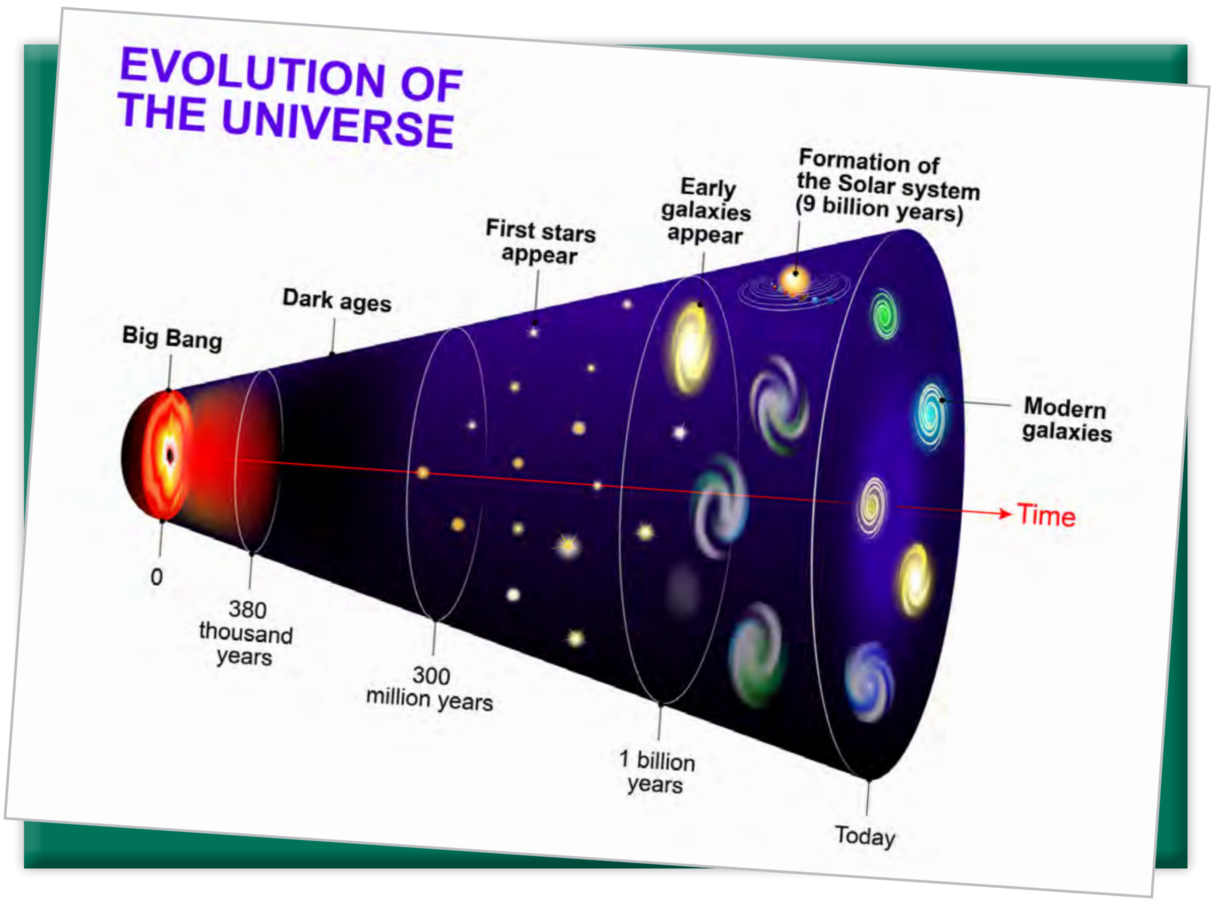
Did You Know?

Scientists use large radio telescopes to locate pulsars. The largest radio telescope in the world is located in Arecibo, Puerto Rico. It is used to search for pulsars.

Big Bang Theory

By this point, you have discovered that there is a lot of action happening in space! But how was the universe itself created? In 1927, astronomer Georges Lemaitre had an idea. He speculated that the universe began as a single point, and over time it expanded. His theory was that the universe would continue to stretch and expand over time. In 1929, the astronomer Edwin Hubble observed that other galaxies were moving farther away from Earth. And the galaxies that were the farthest away moved faster than those that were closer to us. Just as Lemaitre speculated, the universe is still expanding, and a long time ago everything was much closer together.

In the beginning, the universe was made of hot, tiny particles, light, and energy. The particles began to group together to form atoms. Then atoms began to group together to form stars and galaxies. Stars, galaxies, and molecules continued to group together. Asteroids, comets, black holes, and planets were forming. This entire process took 13.8 billion years. The theory of how the universe was created is called the Big Bang theory.



Evolution of the Universe. Cosmic Timeline and evolution of stars, galaxy and Universe after Big Bang.

Courtesy of Designua/Shutterstock

The Big Bang theory is still a controversial theory, as it is difficult to prove. Scientists rely on mathematical formulas and models to try to prove the theory. But astronomers are able to witness the universe expanding through "cosmic microwave background." The cosmic microwave background (CMB) is believed to be *the radiation leftover from the Big Bang*. This radiation is everywhere, but it is so cold (only 2.725^0 F above absolute zero) it is impossible to see with the human eye. CMB is visible in the microwave part of the electromagnetic spectrum.

Did You Know?

The term "Big Bang theory" has always been well known by astrophysicists, but it wasn't until the launch of the popular sitcom series in 2007 that the term became more mainstream.

CMB was first discovered by accident in 1965 by two researchers with Bell Telephone Laboratories. Arno Penzias and Robert Wilson were creating a radio receiver and confused by a signal they picked up coming from all over the sky. They had accidently found CMB.

Although the Big Bang theory is regarded as fact among the majority of scientists, some skeptics have alternative theories as to the creation of the universe. In addition, some scientists believe that while the Big Bang explains our universe, it is not the first time the universe expanded. Some believe that the universe has a regular cycle of inflation and deflation, and we just happen to be living in an inflation period.

✔ CHECKPOINTS

Lesson 4 Review

Using complete sentences, answer the following questions on a sheet of paper.

1. Who was the first to accurately determine the immense size of the galaxy and the location of our solar system?
2. How long is a galactic year?
3. What are the names of the four main spiral arms in the Milky Way galaxy?
4. What percentage of the Milky Way is composed of dark matter?
5. How was the Local Bubble created?
6. What are the four types of galaxies?
7. Which galaxy can be seen without a telescope?
8. What are the three ways galaxies are named?
9. How do scientists locate black holes?
10. How do nebulae form?
11. Which nebula is the easiest to observe?
12. How does a neutron star form?
13. What astronomer first suggested that the universe started with one single point?
14. How was cosmic microwave background (CMB) discovered?

APPLYING YOUR LEARNING

15. The Big Bang theory is still a controversial theory for the beginning of the universe in the scientific community. Based on what you have read and know, describe why you agree or disagree with this theory.