Introduction & Table of Contents

Standing, from left: Taniya Qureshi, Ken Graun, Chris Sinkinson, Ramesh Smith, Michel Schwemmer and Suzanne Maly.

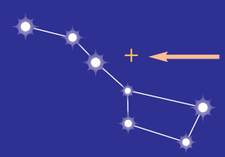
Sitting, from left: Isobela Georgiades, Azur Thompson, and Vanessa M. Padilla

The first book in this series explored our solar system and the planets. This book reaches beyond by taking you through our galaxy to the end of the Universe.

The Universe and all its galaxies are larger and more mysterious than anyone ever imagined. It has taken astronomers hundreds of years to piece together a basic understanding of the Universe and it will take many more to fully comprehend it.

The goal of astronomy and all sciences is to understand the workings of nature. We do this out of curiosity and we do it to help and better ourselves. Our scientific endeavors in the last century have lead to incredible insights that have provided us with modern medicines, computers, higher standards of living and a good sense of who we are in this Universe. However, we are still only at the beginning of a long scientific journey. May you join in and take us farther along the path.

When astronomers peer deep into the Universe, beyond the stars of our Milky Way Galaxy, all they see are galaxies. This picture was taken by the orbiting *Hubble Space Telescope*. Most of the specks and blobs in this picture are galaxies billions of light years from our Milky Way Galaxy. This picture represents an area in the sky about the size of this period (.) held at arms length.



Location near the "Big Dipper" where this picture was taken

Can You Find...

A few specs in this picture are stars that can be identified by their spikes. How many can you count? Remember, these stars are in our Milky Way Galaxy. They just happen to be in the direction that this picture was taken.

The Universe

The Universe is everything that there is. Astronomers define it as all of space and everything in it. It is very hard to imagine that the Universe came into being at the one instant of the "Big Bang" over 12 billion years ago. Everything, that is, all matter and energy came into existence at that moment. And, since matter and energy can neither be created nor destroyed, it is all with us today.

What's in it?

If you held the Universe in your hands and looked closely, you would see billions of fuzzy specs. Each of these specs would be a galaxy. A galaxy is a collection of billions of stars. Stars are only in galaxies and galaxies have various shapes and sizes. Astronomers estimate that there are about 125 billion of them in our Universe.

Do you know how big a billion and trillion are compare to a million?

Get this. If you started counting right now to a million, at the rate of one number a second, day and night, it would take you 11.5 days to complete the task. But if you wanted to count to 1 billion, it would take you about 31.7 years. A trillion would take 31,700 years. You better start right now. Wow!

1 million = 1,000,000
1 billion = 1,000,000,000
1 trillion = 1,000,000,000,000

How big is it?

Adults have trouble understanding the size of the Universe, so don't be surprised if you can't picture just how big it is!

Before we talk about its size, we need to start with a measurement "stick." Instead of using miles or kilometer, we are going to use the light year. A light year is the distance light travels in one year. In space, light moves at the rate of 186,282 miles per second. How fast is this? Snap your fingers and light has circled the world over 7 times. In one year, light travels nearly six trillion miles (6,000,000,000,000). It would take you nearly 9 million years to cover this same distance in a car going 75 miles per hour.

The nearest star to our Sun, Proxima Centauri is 4.3 light years away. Our galaxy is 100,000 light years in diameter. The Andromeda Galaxy, which is one of our nearest galactic neighbors is 2.3 million light years away. The Universe stretches for over 12 billion billion light years in every direction.

The most distant galaxies that astronomers can see are about 10 billion light years away. The starlight from these galaxies had to travel for 10 billion years before finally reaching Earth.

One inch scale

How big would the Universe be if the Earth were one inch across? In this case, the Sun would be 978 feet away. The nearest star over 50,000 miles. The diameter of our galaxy would be one billion miles. The Andromeda Galaxy would be 27 billion miles away while the Universe would stretch for 73 trillion miles in every direction.

Even this is too much to imagine for most of us, so lets really bring it down to size. If our Milky Way Galaxy were just one inch across, which is the size of a quarter, the Andromeda Galaxy would be a mere 23 inches away, and the Universe would stretch for 2 miles in every direction.

Universe Facts

Age: between 12 & 16 billion years old

Beginning: The Universe began from an "explosion" called the *Big Bang*.

Type: Expanding Universe? At this time, astronomers' best guess is that the Universe may exist and expand forever.

Chemical elements in the Universe: 75% hydrogen, 25% helium including traces of all other elements.

Number of galaxies in the Universe: Around 125 billion (125,000,000,000)

Observe this Yourself
SEE INSIDE BACK COVER

The Andromeda Galaxy, which is visible to the naked eye, is one of the closest spiral galaxies. It is located in the direction of the constellation Andromeda which is visible from September through February. This galaxy is 120,000 light years in diameter and just over 2,300,000 light years away.

A small elliptical galaxy that is gravitationally bound to the Andromeda Galaxy,

Another small elliptical galaxy that is gravitationally bound to the Andromeda Galaxy.

The Moon never gets this close to the Andromeda Galaxy in the sky! However, as you can see, the Andromeda Galaxy spans a greater area of the sky than the Moon. In fact, many celestial objects pictured in this book are "bigger" than the Moon in the sky, but can't be seen to their fullest extent with our eyes because they are very faint.

Galaxies

The debate over the true nature of galaxies was concluded at the end of 1924 after Edwin Hubble had photographed galaxies with the new 100-inch diameter telescope. He had conclusive proof that they were islands of star. This ushered in a new age of astronomy.

A Universe filled with different types of galaxies

There are about 125 billion galaxies and they contain all the stars in the Universe. There are no stars between galaxies. The stars in galaxies are gravitationally bound and revolve around a concentrations of stars at their centers. After taking thousands of photographs of galaxies, astronomers discovered that there are three basic shapes.

The most common type of galaxy is the **elliptical**. The smallest and largest galaxies are elliptical. These resemble balls or elongated balls. Overall, the stars in ellipticals are smaller and older than the stars in our sky. Inside these galaxies, there is little gas and dust to form new stars.

A second type of galaxy is the **spiral**, which resembles its name. The galaxy that we live in, the Milky Way Galaxy, is a spiral. Spirals are flatter looking, like a dish. They have round bulged centers out of which curved arms radiate. Spirals often have lots of gas and dust in their arms from which new stars are born. Although spiral galaxies only account for a small percentage of galaxies, their arms and centers are bright, so they stand out more than the others.

Finally, there are two kinds of **irregular** galaxies. One kind appears to be the result of the collision of galaxies. The other is usually a smaller galaxy being distorted or pulled on by the gravity of a nearby larger galaxy. In both cases, these galaxies have mixed up insides, often with no centers or nuclei and often containing large amounts of gas and dust, out of which new stars can form. The Large and Small Magellanic Clouds (see page 11), visible from the southern hemisphere, are two close irregular galaxies that are being distorted by the gravitational pull of our galaxy.

Moving fast

After Hubble determined the true nature of galaxies in 1924, he wanted to know their distances. In 1929, he made another important discovery. He found that the farther away a galaxy was, the faster it was moving away. He and other astronomers then confirmed that *all* distant galaxies were moving away, as if from an explosion. Eventually, this information helped provide evidence for the idea of the "Big Bang."

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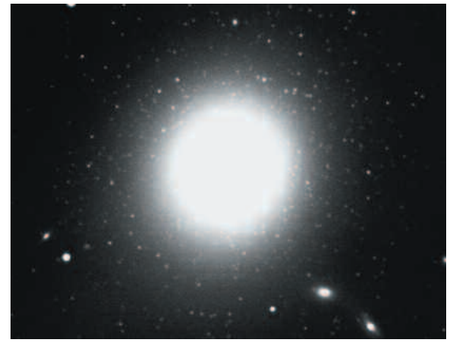
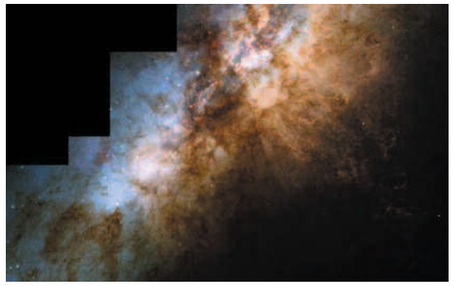


At least eighty percent (80%) of all galaxies are of the **elliptical** type. These galaxies are spherical in shape, that is, they resemble the shape of a ball or elongated ball similar to a short watermelon. They lack arms and are composed mostly of older stars, which revolve about their centers in "every which way," much like a swarm of bees. Pictured is a large elliptical (designated M87) found in the direction of the spring constellation Virgo. It is 55 million light years away and has a diameter of 133,000 light years. This galaxy is visible with a small telescope.

At most ten percent (10%) of all galaxies are classified as **spiral**. These galaxies are dish shaped. They have a central bulge, out of which curved arms radiate. In spirals, many stars are born in the arms where huge clouds of hydrogen clouds exist. Pictured is the Whirlpool Galaxy (designated M51), located in the direction of the constellation Ursa Major (the Big Dipper is part of this constellation). It is 15 million light years away and has a diameter of 35,000 light years. It can be seen in a small telescope but needs dark skies. Gravity from the larger Whirlpool is pulling on the smaller galaxy to the left.

Galaxies



The remaining ten percent (10%) of galaxies are classified as **irregular**. These look lumpy or irregular in shape. Astronomers believe that some irregulars represent two or more galaxies that have collided while others might result from being gravitationally distorted by nearby larger galaxies. Pictured is an irregular galaxy seen in the direction of the constellation Ursa Major (designated M82 and near the Big Dipper) which is visible with a small telescope, even in cities with lots of light polution. It is 17 million light year away, has a diameter of 55,000 light years and probably is the result of two galaxies that collided.

The above galaxy, known as the Sombrero galaxy (named for its resemblance to the sombrero hat), was once thought to be an elliptical galaxy. Today, it has been reclassified as a spiral galaxy. Astronomers, like other scientist reevaluate and update information and ideas as they learn more about the objects they study. The Sombrero galaxy (designated M104) is located in the constellation Virgo and is visible during summer with a small telescope. It is 65 million light years away and has a diameter of 165,000 light years.

Red Shift

Something happens to the light from distant receding galaxies. The lines in the spectrums of their light (see caption at bottom of page 28) shifts or moves towards the red part. The amount of the shift indicates how fast the galaxy is moving away and even provides a clue to its distance. Spectrums can also shift towards the blue part, which indicates movement towards us. Both of these phenomena are the same effect as the change in pitch heard when a train approaches and moves away. This shifting of the spectrum has proved immensely helpful in determining the movement or speed of most celestial objects.

Bumping into one another

For their size, galaxies are millions of times closer to one another than the stars they house. For example, our Milky Way Galaxy and the Andromeda Galaxy are only 20 diameters apart from one another. On the other hand, our Sun and the closest star, Proxima Centauri, which is in the constellation Centaurus are 29 million times farther away from one another. Proportionately, there is truly enormous amounts of space between stars, but not between galaxies

Galaxies cluster in groups. These groups are gravitationally bound and the galaxies within them revolve about one another, but not in the orderly fashion as the planets in our solar system. The closeness of galaxies in clusters, combined with their unorderly revolutions makes galactic collisions occur often. There is evidence to show that our Milky Way and Andromeda galaxies may collide some day.

Beginning to end

It appears that many elliptical and spiral galaxies have supermassive black holes at their very centers (You can read more about this on page 25). Astronomers are not sure if galaxies formed around black holes created at the beginning of the Universe or if the central black holes were later formed by the galaxies. In either case, this leads us to the evolution of galaxies. Galaxies are clumps of stars. Shortly after the Big Bang, billions of large clouds became the stars of galaxies. Astronomer think that elliptical galaxies may be the result of spiral galaxies colliding with one another. When they look deep into space, which is the same as looking back into time, they find that spiral galaxies were smaller and more numerous than they are now. Since galaxies frequently collide, it is a reasonable conclusion to say that the collision of 2 or 3 spirals produced an elliptical galaxy. Like anything that is not known for certain in science, this idea will be studied more.

Galaxy Facts

Number of galaxies in the Universe: around 125 billion

Types of galaxies: 80% are Elliptical, 10% are Spiral and 10% are Irregular

Diameter of galaxies: 400 to 500,000 light years.

Number of stars in a galaxy: averages in the billions but varies from 10 million to a trillion

Objects at very centers of galaxies: a supermassive black hole may reside at the center of almost every galaxy

Galaxies cluster: Galaxies cluster together in groups of a dozen to a few thousand. Clusters of galaxies form strands that stretch across the Universe.

Distance between galaxies: around 500,000 light years or less for those in a cluster

Stuff between galaxies: traces of hydrogen, helium, carbon, nitrogen and oxygen molecules

Objects inside galaxies: Stars, binary stars, nebulae, white dwarfs, neutron stars, black holes. Supernovae explosions occur in galaxies. Globular clusters surround galaxies.

Spiral galaxy in the constellation Ursa Major (designated M101) which can be found in the area of the Big Dipper. This galaxy is almost 18 million light years away and has a diameter of 147,000 light years.

Unfortunately, none of the objects shown in this book look as big, bright and colorful through a telescope as they do in the pictures. Through most telescopes, these objects appear smaller, fainter and whitish. Why? Simply because all of these object are faint and our eyes cannot detect colors at very low light levels. And, our eyes cannot accumulate light like photograph film or digital cameras. Don't let this dissuade you from looking at these objects through a telescope or binoculars. There is nothing like seeing them yourself and often, views through these instruments, especially those of star clusters are better than photographs!