Introduction

Welcome to the Universe

How did the universe begin?

Since humans first evolved, people have wondered how the universe began. As science and technology became more precise, scientists and other thinkers have been able to put forth logical theories with supporting evidence—but there is still plenty we don't know!

Have you ever wondered where the universe came from? Did it have a beginning? Will it have an end? Where did all the stuff—the stars, galaxies, planets, people, and everything else—come from? These are the kinds of questions that cosmologists work to answer.

Cosmology is the study of the evolution of the universe—how it got its start, what it's like today, and what it will be like in the future. That's a pretty enormous topic!

Cosmologists use many different tools and branches of science to help them answer these big questions. Like astronomers, cosmologists use telescopes to view the most ancient and distant objects in the universe. Like physicists, they work with machines such as particle accelerators to unlock the secrets of the tiniest bits of matter and energy around us. And like theoreticians, they use mathematics to explore the parts of the universe that can't be observed or measured directly.

Despite modern tools, cosmology isn't a new science. In fact, as with astronomy, it's one of the oldest sciences in the world. For thousands of years, people have looked at the world around them and tried to explain what they saw. Most ancient cultures told creation myths—stories and legends to explain how and why the universe came to be. Many featured incredible tales of gods and goddesses who created the cosmos and everything in it.

Lots of these stories had the earth and people at the center of everything. But, as our understanding of math and science changed, so did our views of the universe.

Today, we know the universe is mind-bogglingly huge. The earth, our sun, and even our galaxy exist in just a tiny and unremarkable part of a cosmos filled with more galaxies than we can count. But humans haven't always accepted this as truth. For thousands of years, people thought the universe was much smaller and that the earth had a much more important position than we believe it does today.

THE GEOCENTRIC UNIVERSE

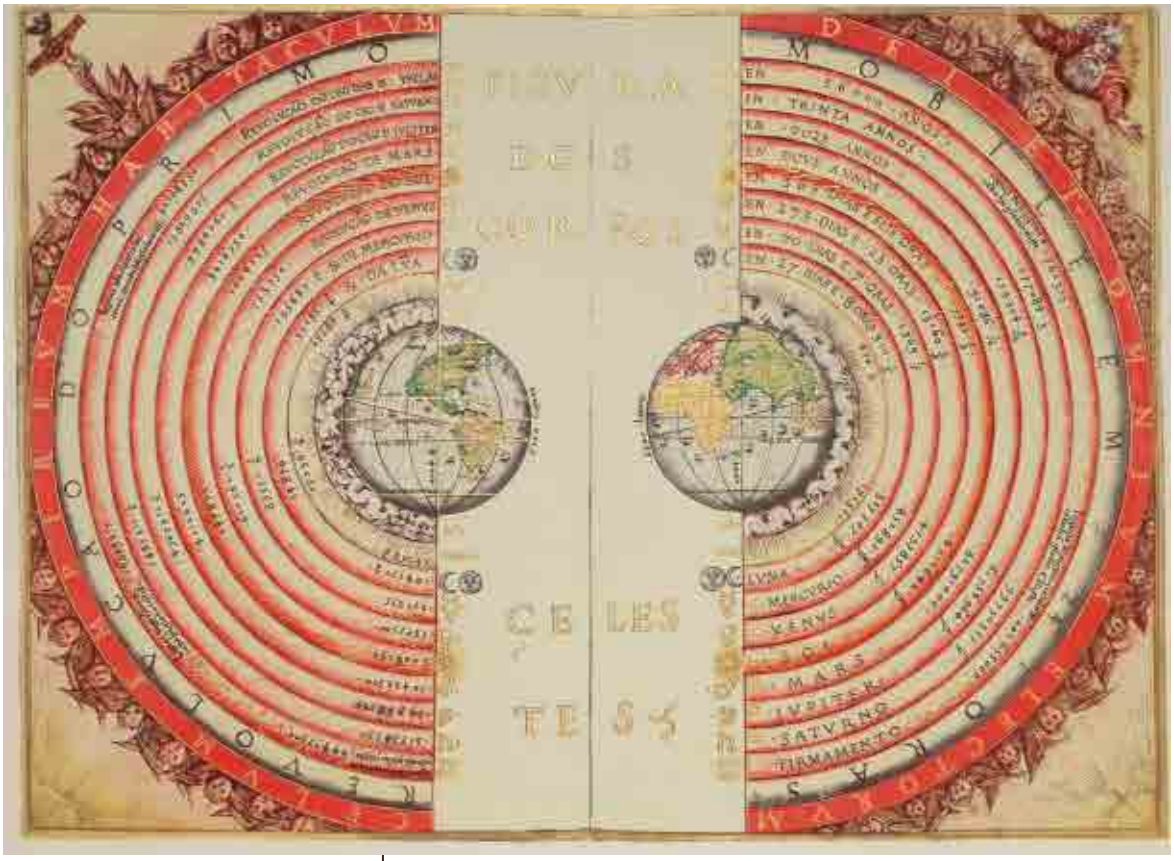
Do you know someone who thinks the whole universe revolves around them? It might seem a little selfish to us, but to the ancient Greeks, it made perfect sense to put themselves and the earth at the center of the universe. After all, they had no telescopes to examine the planets up close and no satellites with which to gaze at the earth from a distance. As far as they could tell, the earth under their feet was motionless while the rest of the cosmos circled overhead.

What is the universe? The universe is everything around us. It's everything we can sense, measure, or detect. That includes planets, stars, galaxies, matter and energy, time and space—even you!

COSMIC CONCEPT

Sir Isaac Newton (1642–1727) was an English physicist and mathematician and one of the most important scientists in history. His three laws of motion led to his discovery of the law of universal gravitation, which explained that the force that causes things to fall on Earth is the same force that keeps planets in their orbits around the sun.

The Ptolemaic geocentric model of the universe, drawn by Portuguese cosmographer and cartographer Bartolomeu Velho, 1568



COSMIC CONCEPT

One of the first people to make the geocentric model of the universe popular was Aristotle (384–322 BCE). Aristotle was a Greek mathematician and philosopher whose writings have influenced science, philosophy, and religion for more than 2,000 years.

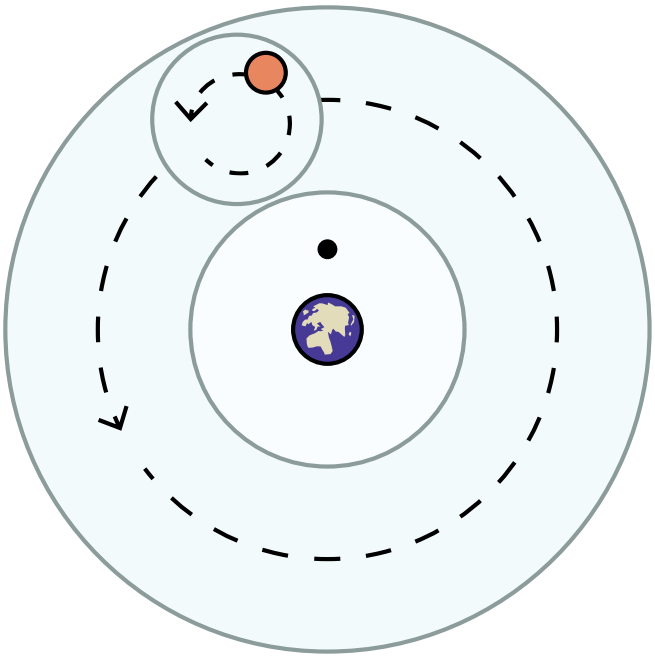
From these observations they created a geocentric model of the universe in which the sun, moon, planets, and stars all circled the earth on perfect and invisible cosmic spheres.

While this model was hugely popular, it had a few big problems. For one, people watching the skies noticed that the planets seemed to change in brightness over time, which didn't make sense if they always circled Earth at the same distance. Plus, the planets occasionally appeared to slow down and move backward in the sky before turning around.

This retrograde motion baffled astronomers for centuries.

An Egyptian astronomer named Claudius Ptolemy (85–165 CE) came along and offered a fix. After carefully observing and recording the motion of the planets, Ptolemy came up with a solution that neatly explained the strange motions.

In Ptolemy's system, as each planet circled the earth it also moved in a smaller circle called an epicycle.



By adding these epicycles, Ptolemy was able to predict planetary motions with an accuracy that nobody could beat. With this fix, the Ptolemaic model kept the universe centered on the earth for more than a thousand years. It became so popular that powerful religious authorities such as the Catholic Church adopted it and used it in their teachings. However, just because it worked didn't mean it was right.

Scientific Method

The scientific method is the process scientists use to ask questions and find answers. Keep a science journal to record your methods and observations during all the activities in this book. You can use a scientific method worksheet to keep your ideas and observations organized.

Question: What are we trying to find out? What problem are we trying to solve?

Research: What is already known about this topic?

Hypothesis: What do we think the answer will be?

Equipment: What supplies are we using?

Method: What procedure are we following?

Results: What happened and why?

Primary Sources

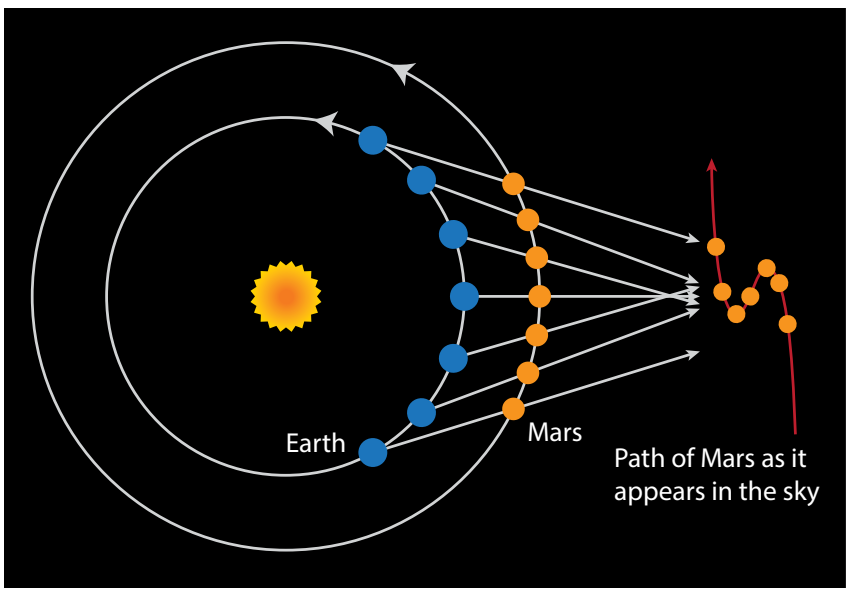
Primary sources come from people who were eyewitnesses to events. They might write about the event, take pictures, post short messages to social media or blogs, or record the event for radio or video. The photographs in this book are primary sources, taken at the time of the event. Paintings of events are usually not primary sources, since they were often painted long after the event took place. What other primary sources can you find? Why are primary sources important? Do you learn differently from primary sources than from secondary sources, which come from people who did not directly experience the event?

HERE COMES THE SUN: THE HELIOCENTRIC UNIVERSE

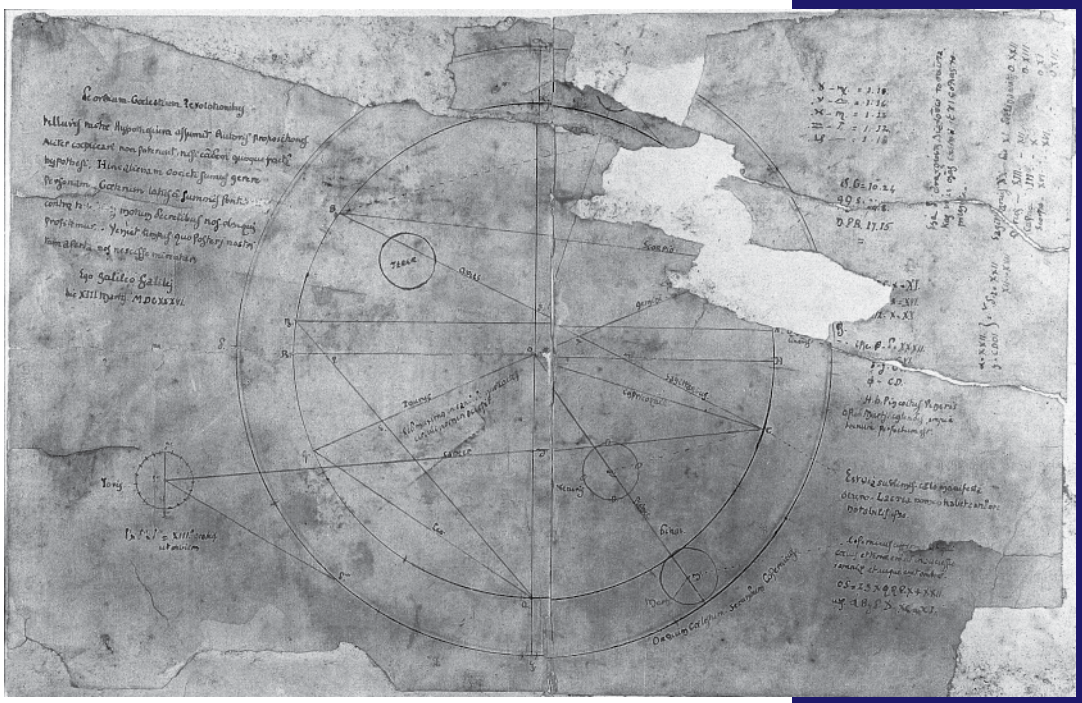
As the centuries went on and measurements became more precise, the Ptolemaic system started to show its age. By the sixteenth century, planets were in the wrong place, eclipses were off, and astronomers were getting frustrated.

In 1504, a Polish astronomer named Nicolaus Copernicus (1473–1543) thought he could do better. Feeling Ptolemy's system of epicycles was too complicated, Copernicus looked for a simpler solution to explain the backward motion of the planets.

His idea was to place the sun at the center, with the earth in motion around it as if it were just another planet. Copernicus's heliocentric system neatly explained the backward motion of planets as the effect of Earth passing another planet as both moved around the sun—not epicycles.



This diagram explains the apparent retrograde motion of Mars when viewed from Earth.



Credit: Wellcome Images, a website operated by Wellcome Trust (CC BY 4.0)

An astronomical drawing by Galileo, 1636

Once published, Copernicus's model didn't catch on right away.

There was a lot of resistance from the Catholic Church, which had a great influence on Western society at the time. But evidence that Copernicus was on to something began to pile up.

In 1610, the famous Italian astronomer Galileo Galilee (1564–1642) found the first direct proof that the earth was not the center of the universe. By pointing the newly invented telescope to the sky, he watched as Venus went through phases in the same way as the moon—something that could only happen if Venus circled the sun. He was also the first person to see the moons of Jupiter, proving that not everything in the cosmos circled the earth.

Copernicus, afraid of ridicule by his peers, waited until the end of his life to publish his heliocentric model in *De revolutionibus orbium coelestium* (*On the Revolutions of the Heavenly Spheres*). He didn't live to see how his ideas changed the world. Learn more about Copernicus and his life here.

PS

Biography
Copernicus video

SORRY!

While Galileo and many other astronomers were convinced of a heliocentric universe, the powerful Catholic Church was not. The church had taught that the earth was the center of the universe for centuries, and felt that a sun-centered universe challenged its power. Galileo was punished and forced to stay in his home under house arrest until he died in 1642. It took until 1822 for the church to officially accept heliocentrism, and it wasn't until 1992 that Galileo was officially forgiven! You can read a news article about it here. Why do you think it took so long for the church to admit Galileo was right?

PS

NYT Vatican Galileo

Around the same time Galileo was looking through his telescope, Johannes Kepler (1571–1630) discovered the laws of planetary motion, which described how the planets move in their orbits around the sun. This work let astronomers understand and predict the motions of the planets with more accuracy than ever before.

Among these astronomers was Isaac Newton, one of the greatest scientists of all time. He managed to unlock the laws of motion and gravity to show that the same forces keeping things on Earth also kept planets moving in their orbits around the sun.

In the face of all this evidence, most scholars agreed the sun had to be the center of the universe. It turned out, they were only half right.

A COSMIC SHIFT

By the end of the nineteenth century, the view of the universe had changed again. The sun was no longer the center of the cosmos but just one star in a sea of billions that make up the Milky Way. A great debate was raging about strange objects called spiral nebulae. Some astronomers believed they were "island universes," similar to our galaxy, while others argued they could exist outside our home galaxy.

In 1925, astronomer Edwin Hubble (1889–1953) solved the debate. He'd measured the distance to the Andromeda Nebula and found it to be more than 2.5 billion light years away—a distance that proved it was an island universe of its own: the Andromeda Galaxy. Suddenly, the Milky Way was just one galaxy out of many and the universe had grown tremendously in size.

The Andromeda Galaxy

Credit: NASA/JPL-Caltech

Hubble's most important discovery came a few years later, when he realized that, not only were almost all these galaxies moving away from us at a great speed, but also the greater their distance, the faster their speed. Astronomers around the world struggled to understand what this meant.

Until Hubble's discovery, the universe was considered a static, unchanging place. But now it was obvious that galaxies everywhere were racing away from us in all directions. What did it mean?

It turned out that a previously unknown physicist and priest named Georges Lemaître (1894–1966) had already figured out the answer. Lemaître had studied Albert Einstein's (1879–1955) famous work on general relativity, which describes how space itself can be bent and stretched. Lemaître found that Einstein's ideas predicted a universe that was growing and stretching, carrying galaxies away from each other as space itself expanded in all directions.

Fundamental Forces

The four fundamental forces of nature are like the universe's rulebook for matter and energy.

- Gravity is the familiar force that holds planets in their orbits and keeps us from flying off into space. Despite having a big influence on our lives, it's the weakest force.
- The electromagnetic force is related to electricity and magnetism. Without it, we wouldn't have electricity, refrigerator magnets or even light.
- The strong nuclear force holds together the particles that make up matter in the universe. Without the strong force, no atoms would exist, and without atoms, the universe would be a pretty boring place.
- The weak nuclear force helps break apart, or decay, particles, by emitting radiation. Without it, we wouldn't have nuclear fusion, the power source of stars.

Want to learn more about how these forces work? Check out this video.

PS

SciShow Fundamental Forces

Hubble discovered that, for galaxies, the greater the distance away they are, the greater their velocity away from us—and each other!

It took other scientists years to accept Lemaître's idea, but in the end, they all agreed he was right. However, there was more to Lemaître's view of the universe. He also reasoned that if things in the universe were moving farther away from each other, they must have been closer together in the past. And if you kept moving back in time, then everything in the universe must have been mashed together in an unimaginably small and dense space from which the universe began in a burst of time and space. He called this hot and dense state the "primeval atom" and its sudden growth and expansion a "big noise."

Like most things that change the world, Lemaître's vision of the universe was met with a lot of skepticism.

British astronomer Fred Hoyle (1915–2001), who didn't like the idea of a growing and changing universe, sarcastically called it the "Big Bang." And the name stuck.

The Big Bang didn't answer all the questions about the universe. In fact, it added new ones. How did the universe get started? How did stars, planets, and galaxies form? Where do we and our planet fit into everything? And if the universe had a beginning, will it have an end?

In *The Universe* you'll get to explore the latest scientific theories and discoveries concerning the universe, starting with the Big Bang. You'll learn about the life cycle of stars and the growth of galaxies, the formation of Earth and the rise of life. We'll even examine the possible fates of the solar system, our galaxy, and the universe itself.

The universe is a big place, so let's get started!

KEY QUESTIONS

- **Why are people sometimes resistant to new ideas?**
- **What are some other widely held theories that were debunked in your time? What was the process like?**
- **Is it important to know the origins of the universe?**

Inquire & Investigate

INVESTIGATE A CREATION MYTH

Nearly all civilizations had their own creation myths. Sometimes, these creation myths were weirdly similar, even if the cultures had no known contact. Let's take a look at some and see if there is any truth in the stories.

- **Research a creation myth.** If you already know one or more, try to find one you're not familiar with! Head to the library or search online to find them.
- **Think about the following questions.**
  - How does the culture represent the universe? Do they use people, animals, or supernatural beings such as gods and goddesses?
  - According to the myth, how was the world or universe created?
  - Where did people come from?
  - How old is the earth?
  - How does the myth describe the way people and nature relate to each other?

To investigate more, compare two or more creation myths. What are the similarities and differences? Do they seem connected in some way? Create a representation of a creation myth using any materials you choose. It can be a web page, a diagram, or a model—whichever method you think will best represent the myth.

VOCAB LAB

Write down what you think each word means. What root words can you find to help you? What does the context of the word tell you?

Big Bang, **cosmology**, **geocentric**, **heliocentric**, **solar system**, and **universe**.

Compare your definitions with those of your friends or classmates. Did you all come up with the same meanings? Turn to the text and glossary if you need help.