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HOW DID OUR VIEW OF THE UNIVERSE CHANGE?

David Christian explains three major changes in the way people thought of the Universe. This two-part lecture focuses on how **Ptolemy**, **Newton**, and **Hubble** viewed the Universe and covers the last 2,000 years of thinking about **cosmology**. The lecture also looks at how scientists such as **Copernicus**, **Kepler**, **Galileo**, and **Leavitt**, as well as inventions like the **telescope**, contributed to changes in our understanding of the Universe. After reading the text below and watching the video, you should be able to explain the major views of the Universe and what new evidence led one view to replace another.

Key questions

1 As you read and view this lecture, pay attention to the differences between Ptolemy's, Newtons, Copernicus's, and Hubble's views of the Universe. What makes them different from one another?

2 Why were they sensible to people at the time?

3 What new evidence supported each new view?

Transcript: Part 1

0:11-1:24

THE BIGGEST QUESTION OF THEM ALL

What's the biggest question that you could possibly ask? Surely it's "How did everything begin?" All **origin stories** ask that question and each has its own answer: perhaps it was always there, because a multicolored serpent created the world, the trees, the mountains, the animals, and people as it traveled through an empty landscape; perhaps the gods created it because they were bored; perhaps the one God created it.

Each answer makes claims of various kinds. But the stories aren't fixed. They change over time. Did you ever wonder why? One reason is that stories are always explaining things, and sometimes those explanations need to change as new information is discovered.

In this unit, we'll see how the modern, scientific explanation of the origin of everything evolved as new evidence overthrew earlier claims.

1:24-2:03

PTOLEMY'S UNIVERSE

We'll begin 500 years ago in Europe because that's where modern science first flourished. In Europe, Christianity was the dominant form of religion, and, like all religions, Christianity had its own answer to the question "How did everything begin?"

Most Christians believed that God created the Universe several thousand years ago. Most Christian churches linked this idea to an accepted model of the Universe that had been constructed by Ptolemy, an astronomer who lived about 1,900 years ago in Alexandria, Egypt.

2:03-3:06

EARTH AT THE CENTER OF THE UNIVERSE

Ptolemy said that the Earth was at the center of the Universe. It was a realm of imperfection. And around it was a realm of perfection which consisted of several concentric transparent spheres that carried the Moon, the planets, the Sun and the stars in perfectly circular orbits. Beyond them lay the perfect realm of Heaven.

NAKED-EYE ASTRONOMY

Ptolemy's model of the Universe was pretty good at predicting the movements of heavenly bodies, so it was believed not just because Christian churches supported it but also because it seemed to fit with the evidence of astronomy, which at that point relied on careful measurements taken with the naked eye.

If you could only evaluate the Universe using your eyes, it might look as if the Sun and stars were rotating around it, wouldn't it?

3:06-4:29

FLAWS IN THE PTOLEMAIC MODEL OF THE UNIVERSE

Between 1550 and 1700 new evidence and new technology undermined Ptolemy's claims. Some astronomers pointed out that Ptolemy's model had a tough time explaining some things, such as the fact that periodically planets seem to move backwards.

COPERNICUS, KEPLER & GALILEO SUGGEST A DIFFERENT MODEL OF THE UNIVERSE

In the 16th century, the Polish astronomer **Copernicus** showed that if you imagine that the Sun is at the center, not the Earth, this problem is easily solved.

Soon afterward another astronomer, **Kepler**, showed that the planets did not orbit in perfect circles, but in ellipses, or ovals. Finally, an Italian, **Galileo**, dealt the killer blow when he became one of the first astronomers to use a telescope and showed that Jupiter had moons of its own, and that the Sun was not perfect because it had sunspots.

So, using logic and a new tool that allowed people to see more than the naked eye could, astronomers began to replace Ptolemy's picture of the Universe with a new one.

4:29-5:16

NEWTON'S UNIVERSE

Late in the 17th century, the great English scientist **Isaac Newton** argued that the bodies in the Universe were not fixed to perfect, transparent spheres. Instead, he claimed they were held together by a mysterious force called **gravity**, which pervaded the entire Universe.

By 1700 most astronomers had abandoned Ptolemy's model. They concluded that there were no spheres and no outer edges to the Universe. In fact, they came to believe the Universe was infinitely old and infinitely large.

5:16-5:44

Let's call this model "**Newton's universe**." It rested on the discovery of new evidence that didn't fit the Ptolemaic model. It was the first model of the Universe that based its claims mainly on evidence rather than on authority.

By now, you may also be getting some idea of the power of shared ideas, how the sharing of discoveries between scientists, sometimes in many different countries, can generate new ideas through a process we call "**collective learning**."

Transcript: Part 2

5:44-6:17

OVERTHROWING NEWTON'S UNIVERSE

For over 200 years, most scientists accepted this model of the Universe until it, too, was overthrown by the discovery of new evidence that didn't fit with it and new tools that allowed us to see new things.

So what was the new evidence and what were the new tools that encouraged people to change the story? I'll briefly sketch it out here but your main job in this unit is to try to understand that evidence in more detail and to understand why it encouraged people to change their minds.

6:14-7:56

MAPPING THE UNIVERSE

As scientific instruments improved, astronomers got better and better at figuring out the shape of the Universe. How far away were the stars? And how were they moving?

MEASURING THE DISTANCE TO THE STARS: PARALLAX

If you were asked how to figure out how far away the stars were, how would you begin? Actually, the Greeks already knew how to do it in principle, using the method of **parallax**. Hold a finger up in front of your nose, waggle your head from side to side, and watch how the finger seems to move against the background. Now move the finger further away, waggle again, and notice that the finger seems to move less.

The ancient Greeks excelled at making claims based on reason, logic, and math, and they argued that the same ideas applied to the stars. They argued that if you saw any stars moving against the background as the Earth moved through space, you could use those movements to tell how far away the star was. Modern astronomers agree with them, but the Greeks didn't have precise enough instruments to test this idea. The movements of stars are so tiny the first parallax measurements could not be made until the 19th century.

7:56-8:34

MEASURING DISTANCE IN THE UNIVERSE WITH BRIGHT STARS

Modern astronomers now have many other ways of measuring the distance to the stars. One uses a type of star, called a "**Cepheid**," whose light varies regularly. An American astronomer, **Henrietta Leavitt**, figured out that you could estimate the real brightness of these stars and from that you could figure out how far away they were.

8:34-10:06

HUBBLE'S NEW VIEW OF THE UNIVERSE

Astronomers also began to figure out how to determine if stars or galaxies were moving towards us or away from us.

Just as the pitch of a siren seems to fall when an ambulance moves away from you, a phenomenon called the **Doppler effect**, so the frequency of light from a distant galaxy that is moving away from us seems to fall, moving to the red end of the electromagnetic spectrum.

Astronomers say it is "**redshifted**."

In the 1920s, **Edwin Hubble**, an American astronomer put all these techniques together to make a remarkable discovery. He found that most remote galaxies were moving away from us. Even more important, the farther away they were, the faster they were moving away from us. There seemed to be only one way of interpreting what this meant. The newly found evidence suggested that Newton's model of the Universe was wrong. The Universe was not eternal and infinitely large.

10:06-10:53

AN EXPANDING UNIVERSE HAS A BEGINNING

Instead, the entire Universe seemed to be expanding. And if it was expanding now, then at some time in the distant past it must have been much, much smaller and at some time it must have begun as what the Belgian astronomer **Lemaitre** called a "primordial atom."

This meant that the Universe had a beginning. Like you and me, it had a history. This was an astonishing conclusion, but it would take half a century to work out the full implications of what Hubble found.

In this unit, we'll explore the series of discoveries that led to Hubble's simple but powerful idea. And in the next unit, we'll see how scientists slowly unpacked its many implications.