Dark Universe Transcript

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Way out here, ten million light years from planet Earth, every point of light is a galaxy containing billions of stars.

And yet we've managed to map the visible universe well enough to chart an accurate course all the way back home.

Just within the last hundred years, we humans, inhabitants of a small planet orbiting this unexceptional star, have learned where the galaxies are, what they're made of, and how they got to be that way.

We've discovered that the universe was born in fire—13.8 billion years ago—and that it's been expanding and evolving ever since.

But with new instruments on Earth and in space, we've begun to glimpse how much we still **don't** know about the cosmos.

This is Neil deGrasse Tyson, and I’m here to guide you through a century of discovery about the past, present, and future of our universe.

Our story begins in the nineteen twenties, when astronomers using what was then the world’s largest telescope—on Mount Wilson, near Los Angeles—began piecing together our place in the cosmos.

The astronomers knew that we live in a disk-shaped galaxy called the Milky Way, and that the band of light, arching across the sky, is our view of that galaxy from our location inside it.

But their observations hadn’t yet revealed whether any **other** galaxies existed.

That changed when the astronomers aimed their telescope at a fuzzy patch of light in the constellation Andromeda.

There, the astronomers identified pulsating stars like those in **our** galaxy. By measuring the stars’ distances, they found a galaxy in its own right, far outside the Milky Way.

The Andromeda Galaxy is more than two million light years from us—so we see it as it looked more than two million years ago, long before humans first walked the Earth.

As they probed deeper and located many **more** galaxies, the astronomers were startled to see that the light from distant galaxies was always stretched out to longer, redder wavelengths, signifying that they're all moving away from us.

They found that the more **distant** a galaxy, the **faster** it's moving. Cosmic space is constantly stretching, carrying the galaxies with it.

But there's no center to the universe: An observer in **this** galaxy would see the same evidence of cosmic expansion as we do.

So would observers in that one **there**.

Wherever you are, it looks as if you're at the center and everyone else is speeding away.

As the universe expands, it cools, its energy thinning out across a growing volume of space. The overall temperature of the cosmos today is only three degrees above the coldest possible temperature, absolute zero.

But if we ran time **backward**, all that energy would be compressed into a **shrinking** volume of space, and the universe would get **hotter**.

Realizing this, a few scientists calculated that the entire universe must once have been hotter than the Sun. Skeptics ridiculed the idea, naming it the “big bang” theory.

But then, in 1964, two astronomers at Bell Labs in New Jersey started testing a horn-shaped radio antenna. They wanted to detect the natural radio waves produced by gas clouds in space.

Instead, they encountered something they couldn’t explain—low-level energy, coming evenly from all directions in the sky.

Without realizing it, they had made one of the most profound discoveries in human history: Light from the big bang itself, released when the universe was only 380 thousand years old, less than one hundredth of one percent of its current age.

Evidence of the big bang was written all across the sky—in the glow of what is now called the **cosmic background radiation**.

Satellites have since mapped the cosmic background radiation in detail, revealing how matter and energy were distributed in the infant universe.

In **this** map, created by the Planck satellite in 2013, the slightly more massive regions are colored blue. Over billions of years, they went on to form clusters of galaxies. The less massive regions, colored red, became cosmic voids.

Because it takes time for the light from distant objects to reach Earth, everything we see in the sky belongs to the past.

These spheres mark distances from Earth in light years. When we observe galaxies billions of light years from Earth, we see them as they looked billions of years ago.

We're flying through a three-dimensional atlas of millions of galaxies. The gaps are regions we have yet to map. Beyond every galaxy we could ever observe, farthest away in space and furthest back in time, the cosmic background radiation marks the visible edge of our observable universe.

Yet evidence of what happened even earlier in cosmic history **can** be found--right in our own neighborhood.

In 1995, NASA’s Galileo spacecraft released a probe to study the upper atmosphere of Jupiter.

Scientists had calculated that the **simplest** atoms were forged during the first **minutes** of the big bang. One of them, heavy hydrogen, is destroyed inside stars— so it should have become ever rarer as the universe evolved.

Unlike Earth, Jupiter acts as a cold-storage locker, preserving samples of the materials from which the solar system formed—more than four billion years ago.

By analyzing the giant planet’s atmosphere, scientists could check how much heavy hydrogen existed back then.

Observations of the cosmic background radiation had established that the universe was once hotter than the surface of the sun.

Galileo's audacious exploration of Jupiter found enough heavy hydrogen to confirm that during the first minutes of the Big Bang, the entire universe was hotter than the **center** of the sun – hot enough to forge simple atoms.

But while scientists were piecing together the history of atoms, evidence emerged that most of the matter in the universe isn't made of atoms at all.

The universe contains clusters of galaxies, like this one. Each cluster, home to **trillions** of stars, generates enough gravity to warp the space around it into a giant lens that distorts our view of the galaxies beyond.

But when we calculate the strength of these gravitational lenses, we find that each cluster must contain **six times** more matter than we can see there.

So now it seems that all the glowing stars are just the glittering froth on a dark cosmic ocean of invisible stuff called **dark matter**.

The motions of galaxies **within** each cluster confirm the presence of dark matter. The galaxies orbit too fast to be held together by the gravity of normal matter alone.

Remove the dark matter… its lensing stops … and the cluster flies apart.

Scientists find that dark matter —shown here in black --was essential to forming the large-scale structure of today's universe.

This computer simulation traces how cosmic structure evolved over time.

The bright knots contain thousands of galaxies, drawn together by the vast sheets and tendrils of dark matter. These knots grew from the densest regions seen in the cosmic background radiation.

The less dense regions of the background became cosmic voids—big, empty bubbles, hundreds of millions of light years wide.

The gravity generated by **normal** matter is much too weak to create this cosmic web. Dark matter must be doing the job.

What **is** dark matter? Scientists are conducting experiments to find out. Some of their detectors are buried deep beneath Earth's surface, to minimize interference.

One detector, mounted on the International Space Station, looks for signs of dark-matter particles interacting far across the Galaxy.

While scientists expect that dark matter particles may soon be found, another mystery has emerged that's changing how we think about the future of our universe.

Astronomers had thought that the gravity exerted by all the matter in the universe would slow down the rate of cosmic expansion.

To check this prediction, teams of observers charted the distances and speeds of extremely remote galaxies by studying exploding stars called supernovas.

As this time-lapse view of the Milky Way shows, stars explode fairly often—at a rate of about two per century in a galaxy like ours. So if you observe enough galaxies, you can spot a new supernova every few nights.

The observers were especially interested in a particular type of supernova, like this one, where the corpses of two dead stars orbit each other so closely that they eventually collide…and **detonate**.

Such supernovas are very bright and **consistent** in brightness, providing scientists with an extraordinary tool for measuring cosmic distances across the universe and back through time.

By measuring the distances and speeds of hundreds of supernovas, the astronomers learned how **fast** the universe was expanding billions of years ago.

By 1998, to their astonishment, they found that the universe hadn't expanded faster in the past, as expected. Just the opposite: It used to expand more slowly than it does today.

The expansion rate isn't slowing down, it's speeding up, **accelerating**. And it's been accelerating for the past five billion years.

The pressure causing the acceleration is called "dark energy," but that's just a label. Nobody yet understands dark energy, though it appears to be powerful enough to shape the course of cosmic destiny.

Matter and energy are two sides of the same coin—as Einstein revealed in his famous equation E equals mc squared.

In those terms, dark energy weighs in at nearly 70 percent of the total stuff of the universe.

Dark **matter** accounts for almost all the rest.

Normal matter—all that we are, all that we've ever seen or touched—amounts to less than five percent of the known universe.

So we know precisely when the universe began, and we’re beginning to understand what it’s made of. But how big is it?

Our observable universe is limited to the part of the cosmos from which light has reached us here on Earth.

But **every** galaxy occupies the center of its own observable universe.

Observers in this distant galaxy can see light from regions we cannot yet see.

And **we** can see regions **they** cannot see.

So no matter who or where you are, you’ll reach the same conclusion—that the universe as a whole must be bigger than the part of it you can perceive.

How much bigger? Some scientists speculate that if the observable universe were the size of a planetarium dome, the entire universe would be larger than planet Earth—others suggest it may be **infinitely** large.

Clearly there’s more to the universe than meets the eye.

The Big Bang happened long ago but not far away. It happened here, there, and everywhere.

Peering into the dark, we stand on the threshold of great discoveries—and we always will, as long as we keep exploring.