The Great Photon Escape
transcript

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Our Sun is a star — one of hundreds of billions of stars in our galaxy, the Milky Way.

The Milky Way is one of billions of galaxies in the universe.

Where did all these stars and galaxies come from?

Astronomers think that soon after the universe was born, it was plunged into total darkness.

If anything had been around to witness this period — well, there wouldn't have been much to see. Everywhere you looked would have been complete blackness.

But the seeds of what would one day become stars and galaxies were planted during these "Dark Ages."

Eventually, the first stars and galaxies emerged to illuminate the darkness.

We call this time "reionization."

But we don't know when that happened… or what the first sources of light were, because we've never seen them.

What was the universe like when the darkness lifted?

The James Webb Space Telescope could show us.

Telescopes are like time machines. They see the past.

It takes time for light to travel from the distant corners of the universe. When light from faraway stars and galaxies finally reaches our telescopes, it shows us those stars and galaxies as they were when the universe was young.

The oldest pictures we have today are of our universe's "teen years" — except for one photo, one "baby picture" of the universe… the Cosmic Microwave Background.

It shows us the cosmos just before darkness fell upon it.

Today the universe is more than 13.7 billion years old. But the Cosmic Microwave Background is a map of the universe when it was just 378,000 years old.

The image is similar to a temperature map of the United States. But instead of showing a wide range of temperatures, the Cosmic Microwave Background shows tiny, almost unperceivable temperature differences in the newborn universe.

In fact, the temperature variations from place to place are less than one-ten-thousandth of a degree. If you wanted to change the temperature in your living room by that amount, you would need to run your heater for less than a hundredth of a second!

sound effect: Huh?

Amazingly, these little temperature fluctuations grew into all the structures in the universe: galaxies, stars, and planets. Over time, the slightly hotter areas pulled in more and more material, and the slightly colder areas grew colder and emptier. Today, hot, dense stars and galaxies are surrounded by cold, mostly empty space.

Maps of the Cosmic Microwave Background tell us about the early history of the universe, when it was hotter and denser.

The universe is made up of energy and matter. The light that we see by is a type of energy, and comes in the form of individual particles called “photons.”

The universe’s matter includes atoms, made up of particles like electrons, protons, and neutrons.

Temperature is a measure of how fast particles of matter move around. When things are hot, particles zip around quickly. When it’s cold, they wander slowly. Taking the universe’s temperature shows us the density and energy of the universe at that time and place.

And when the universe was first born, it was dense and hot.

In these cramped and heated conditions, particles of light and matter were rushing around, continuously running into each other. No atoms could form, because matter particles were traveling too fast to stay together.

But as the universe expanded, it became less dense and it cooled. The particles slowed down.

Soon, it was cool enough for protons and neutrons to glue themselves together and combine into these small units called nuclei. But electrons couldn’t gather onto these nuclei, because they were relentlessly smashed aside by powerful photons.

This made the nuclei “ionized” — they had protons, which are positively charged, but no negatively charged electrons to balance out their charge and make them “neutral.”

Meanwhile, the photons couldn’t go very far without crashing into electrons and newly formed nuclei. The photons bounced around like sunlight does in a dense fog.

Because all the light was scattered around, the entire universe was foggy.

But as time passed, the universe continued to expand and cool, and it became much less dense. With more space between them, photons and electrons collided less often. Electrons began joining with nuclei to form neutral atoms. And now, with the electrons out of the photons’ way, the path was clear for light’s “Great Escape.”

378,000 years after the Big Bang, the fog finally lifted. The photons stopped scattering and sped off into the distance. That fugitive light is the Cosmic Microwave Background.

No matter how big or powerful our telescopes become, the Cosmic Microwave Background is the oldest light we will ever be able to see. Because before that moment, not a single photon could escape to be seen.

After these photons made their Great Escape, however, the universe was plunged into the Dark Ages. That's because no other sources of light existed yet to illuminate the expanding universe.

But slowly, atoms accumulated into larger structures — molecules, then clouds of gas, then stars, and eventually galaxies. Light from these new stars and galaxies burst forth into their surroundings, and these photons began stripping electrons off atoms, "*re*ionizing" them. This is the dawn of "reionization."

At this time, the universe was much larger than it was in the early, foggy universe. Matter was more spread out, and while some photons were busy ionizing atoms, most other photons easily escaped without ricocheting off particles of matter. These freely moving photons brought an end to the Dark Ages, lighting up the universe and heralding in the age of reionization, which continued for about a billion years.

Yet, it's still a mystery how long the Dark Ages lasted and exactly when reionization began. What were the first stars and galaxies like? And when did they shed light on the universe?

The James Webb Space Telescope will find the answers, peering back to the time when the light from the first stars burst forth into the cosmos.

The Hubble Space Telescope is currently pushing the limits of detection as far back in time as it can.

But the Webb Telescope is designed specifically to find this special time in the early history of the universe. Equipped with the latest technology, Webb will allow us to see the objects that brought light to the cosmos and unravel the mysteries of reionization.

Only then will we have a better idea of how the universe grew from those miniscule fluctuations in the Cosmic Microwave Background into what we see around us today.