

THE FOG AT THE BEGINNING OF TIME

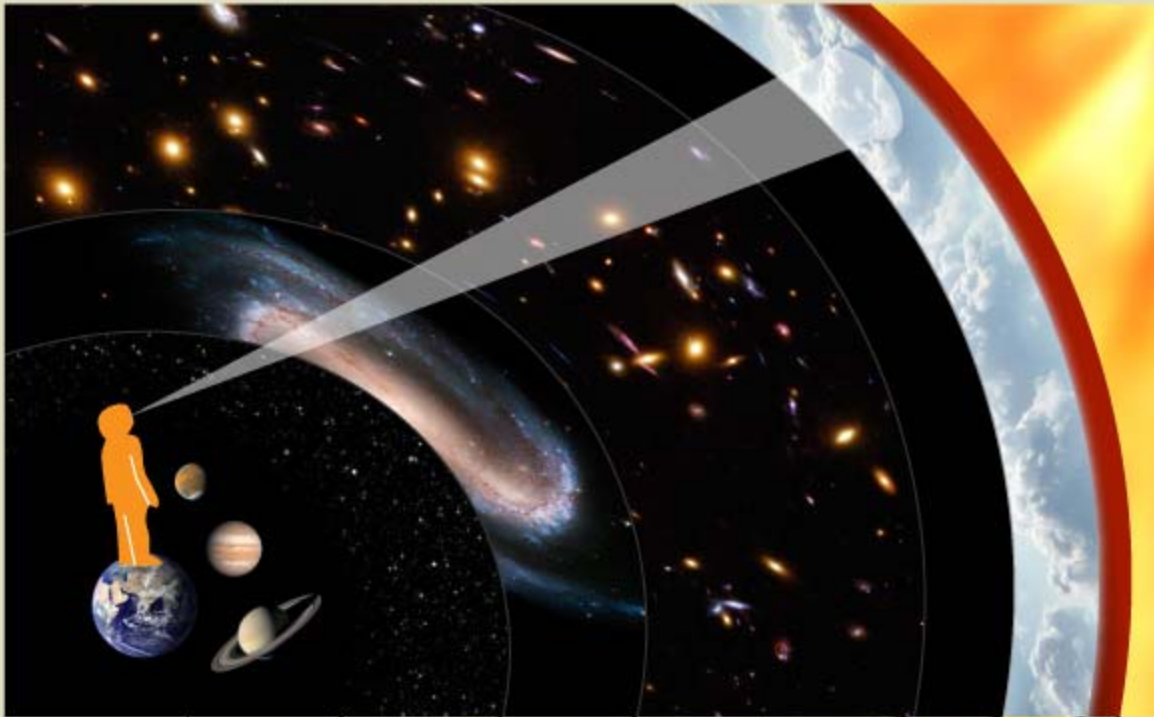
Cosmic Microwave Background

ABOVE: VISUALIZATION OF TEMPERATURE DIFFERENCES IN THE CMB RADIATION (CREDIT: PLANCK INSTITUTE)

The Cosmic Microwave Background, or **CMB**, is **radiation** that fills the universe and can be detected in every direction. Microwaves are invisible to the naked eye so they cannot be seen without instruments. Created shortly after the universe came into being in the Big Bang, the CMB represents the earliest radiation that can be detected. Astronomers have likened the CMB to seeing sunlight penetrating an overcast sky.

What is the CMB?

Looking out into deep space, and therefore back into deep time, astronomers see the CMB radiation saturating space beginning at about 378,000 years after the Big Bang. Before the creation of the CMB, the universe was a hot, dense and opaque plasma containing both matter and energy. Photons could not travel freely, so no light escaped from those earlier times.



	Earth	Solar System	Stars of our Galaxy	Local Group of Galaxies	Galaxies of the Universe	Dark Ages (few stars)	Recombination Era	Inflation (very brief)	Big Bang
Look-back time	none	up to 14 hours	up to tens of thousands of years	up to 5 million years	up to 13.37 billion years	13.37 to 13.82 billion years	13.82 billion years	13.82 billion years	13.82 billion years

The CMB was created at a time in cosmic history called the **Recombination Era**. The universe had cooled to a temperature of about 5,000 degrees Fahrenheit (2,700 degrees Celsius), cool enough for electrons and protons to “recombine” into hydrogen atoms. Photons were released, and today this radiation is called the CMB.

How Pigeons Discovered the CMB

In 1963, **Arno Penzias** and **Robert Wilson** were studying faint microwave signals from the Milky Way galaxy. They found a mysterious noise of unknown origin.

At first, the noise was thought to be interference caused by **pigeon droppings** on the antenna equipment. Pigeons were trapped and dung was cleaned from the antenna. Ultimately, Penzias and Wilson realized that the noise was an actual signal.

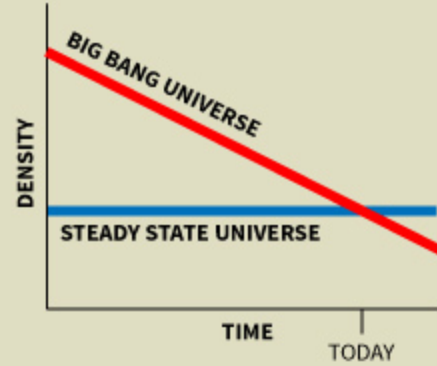


WILSON AND PENZIAS (CREDIT: BELL LABS)

Proof of the Big Bang

By the mid-20th century, there were two competing theories for the origin of the universe. The **Steady State theory** held that matter is continuously created as the universe expands, the overall density of the universe remains the same and the universe has existed forever. The **Big Bang theory** stated that the expanding universe must have been denser in the past, and therefore at the very beginning must have been a point of infinite density.

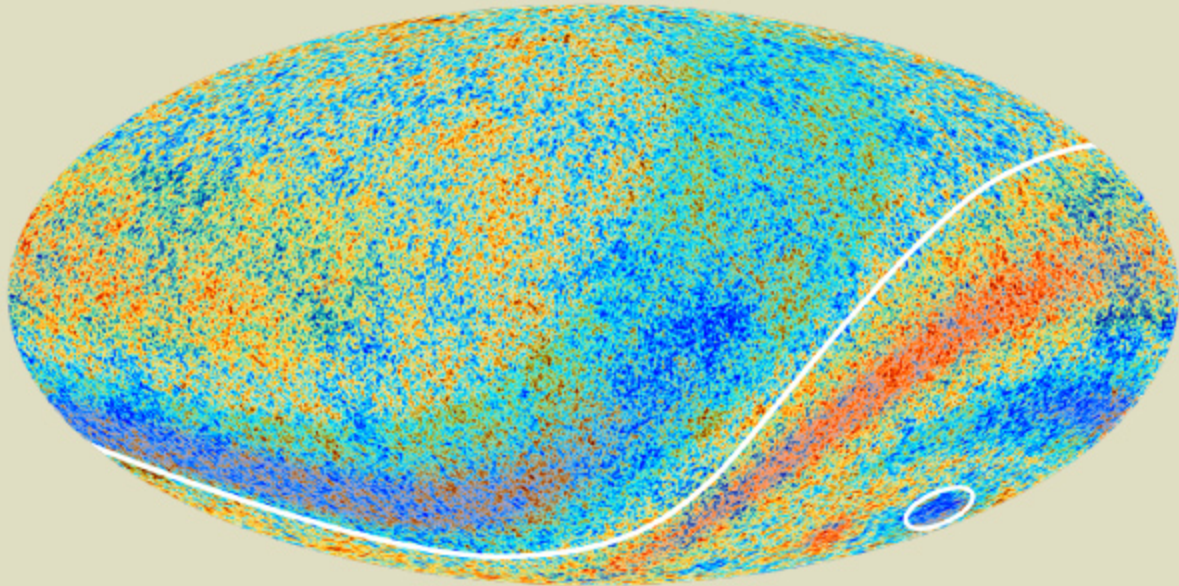
Penzias and Wilson theorized that if the Big Bang theory was correct, the universe would be filled with background radiation left over from the creation event.



What the CMB Tells Astronomers

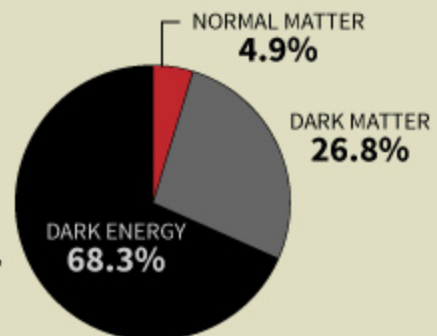
In this all-sky image of the CMB radiation (below), tiny differences in temperature are exaggerated. The curved line is the border between the northern and southern hemispheres of the sky. Overall, the data confirm that the standard Big Bang theory is correct, but there are still some anomalies.

The southern hemisphere appears redder, therefore slightly warmer, than the northern hemisphere. The circled area is a "cold spot" that appears larger than was expected. The standard model of the Big Bang theory predicts that the CMB radiation should look mostly the same in every direction.



The CMB also provides insight into the composition of the universe as a whole. Most of the universe is made up of **dark energy**, the mysterious force that drives the accelerating expansion of the universe. The next largest ingredient is **dark matter**, which only interacts with the rest of the universe through its gravity.

Normal matter, including all the visible **stars, planets and galaxies**, makes up less than 5 percent of the total mass of the universe.



SOURCES: NASA, BELL LABS, PLANCK CONSORTIUM, SHUTTERSTOCK (PIGEON)

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