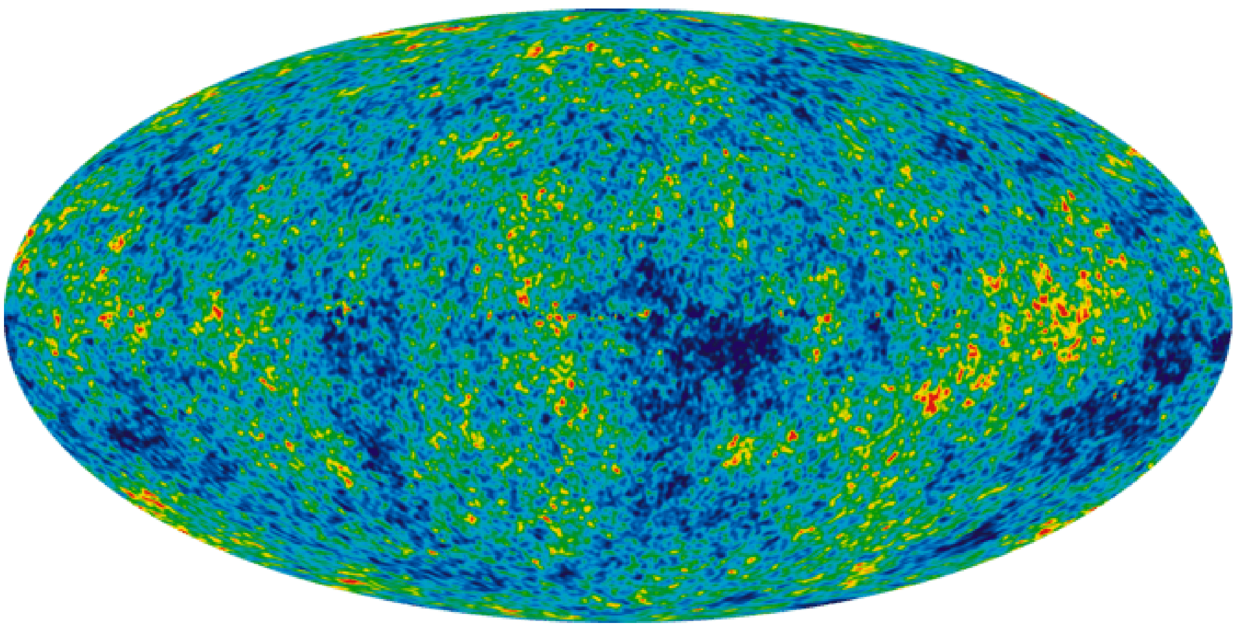
How an accidental discovery became the key to understanding the universe

July 24 2015, by Rhodri Evans



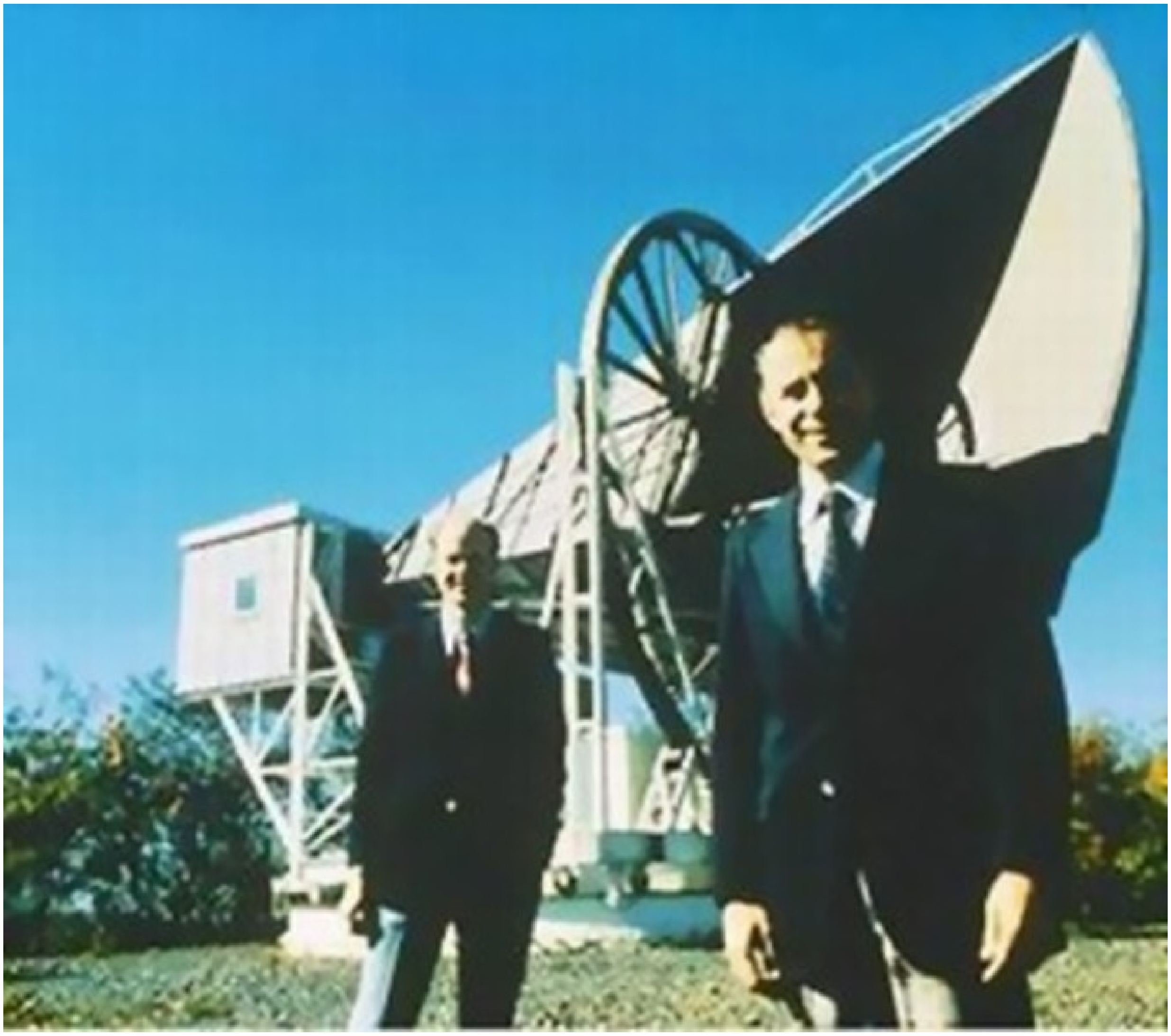
Lucky find. Credit: NASA/wikimedia

Fifty years ago, Bob Dylan had only just gone electric, mankind had yet to take its great leap and many people thought the Big Bang was something that happened when you burst a Big Balloon.

But in July 1965, Arno Penzias and Robert Wilson made a discovery that would cement our understanding of how the universe came into being. Their detection of the Cosmic Microwave Background (CMB), the radiation left over from the birth of the universe, provided the strongest possible evidence that the universe expanded from an initial violent explosion, known as The Big Bang. Today, the CMB is still one of the most important signals that helps us understand the cosmos.

The light from the Big Bang, which happened almost 14 billion years ago, has been travelling through the universe ever since, allowing us to detect this "afterglow" on Earth. At the time it was discovered, there were two competing theories for the origin of the universe. One was the Big Bang theory and the other was "the Steady State theory", which stated that the universe has existed forever.

Since its initial discovery, astronomers have used the CMB to learn a great deal about the universe, such as its origins, its age, its composition, its rate of expansion and even its future.



Wilson (foreground) with Penzias in front of the Bell Labs horn radio antenna. Credit: wikimedia

Serendipitous finding

Penzias and Wilson were working with a very sensitive radio telescope at Bell Labs in New Jersey, looking for something completely different – neutral hydrogen – when they happened to stumble upon a strange signal from their telescope.

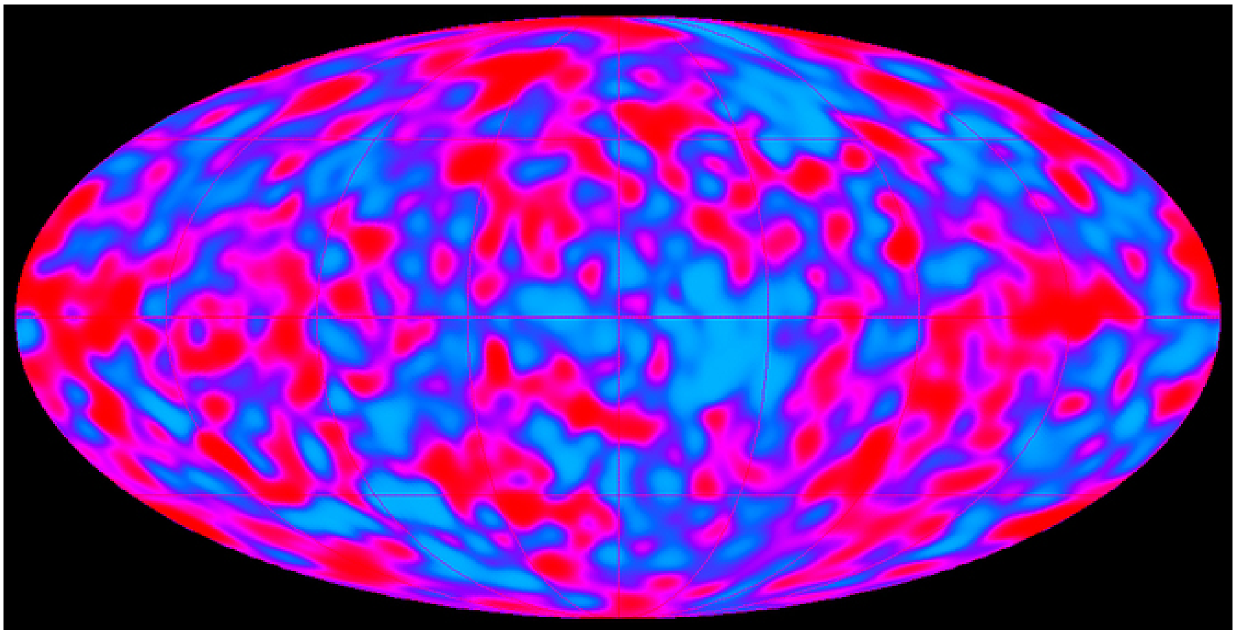
In order to detect such a faint signal, they needed to make sure they knew the source of every part of the signal their telescope was detecting. As such, they had to account for a number of peculiar things, such as badly insulated wires and even pigeon droppings in the horn of the antenna.

There was one part of the signal, however, that they could not eliminate. It was there day and night, throughout the year, and appeared wherever they were pointing their antenna. They were completely perplexed as to what it was, until Penzias ran into Bernard Burke, a radio astronomer working at the Department for Terrestrial Magnetism in Washington DC, on an aeroplane who urged him to phone Bob Dicke at Princeton University.

Dicke and his team were actually looking for the CMB, as their theoretical models suggested that a young, hot, dense universe would produce such radiation. They were months away from making their own measurements but Penzias and Wilson got there first. Dicke came off the phone to Penzias and said to his colleagues: "Boys, we've been scooped."

Their discovery was published in the July issue of the Astrophysical Journal with one of the most understated titles in the history of physics: *"A measurement of excess antenna temperature at 4080 Mc/s"*. But hidden behind these words was one of the most important discoveries in the history of science – the first direct evidence that the universe had begun with the Big Bang.

It turns out the CMB had already been predicted in 1948 by a team led by Russian theoretician George Gamow. Dicke was unaware of this work when he published in 1965, so when the paper appeared, Gamow wrote to Dicke pointing out his team's earlier work, and from that point on the two teams have been jointly credited with the prediction. In 1978, Penzias and Wilson were awarded the Nobel Prize for Physics for their joint discovery of the CMB; neither Dicke nor Gamow got anything.



CMB based on COBE data. NASA

Deciphering the CMB

Over the past 50 years, astronomers have gone on to examine the CMB in more and more detail. In the early 1970s theoreticians such as Jim Peebles at Princeton and Rashid Sunyaev and Yakov Zel'dovich in Russia realised that there should be structure in the CMB, called "anisotropies", and that these could be used to determine important parameters about the universe including its overall density, its age, and its future fate. However, the predicted structure would be manifested as tiny temperature variations, which were impossible to detect from ground-based telescopes.

In 1989 NASA launched the Cosmic Background Explorer (COBE), which confirmed previous measurements of the CMB to exquisite accuracy in 1990. In 1992, it saw the anisotropies for the first time – a result hailed by COBE scientist George Smoot as "like seeing the fingerprints of God". However, COBE was not sensitive enough to determine the geometry of the universe, which is related to its fate via Einstein's theory of gravity.

Just a decade later, the balloon-borne telescope BOOMERANG was the first to measure the universe's geometry from the CMB, followed by NASA's Wilkinson Microwave Anisotropies Probe (WMAP) satellite. In fact, WMAP confirmed BOOMERANG's findings with more accuracy and determined the universe's age, composition, and future. Europe's Planck satellite has confirmed WMAP's findings with even more accuracy, and has been measuring the polarisation of the CMB's light by matter in the more recent universe.

In March 2014 there was huge excitement when the BICEP2 team announced that their South Pole-based telescope had found the first ever evidence for "cosmic inflation", the idea that the universe expanded very rapidly in the first fraction of a second. However, by the autumn of 2014 this announcement had been found to have been flawed. The signal they had detected was more likely due to dust in our galaxy which they had failed to properly subtract from their signal.

Discoveries ahead

The quest is still on for the signs of cosmic inflation in the CMB, with researchers tackling extreme conditions at the South Pole and high in the Atacama Desert in Chile to search for the tell-tale signals. CMB research has reached maturity and we have entered an era of making precision measurements to find specific predictions of the Big Bang theory, with the evidence for gravitational waves, and hence for cosmic inflation, being one of the most important.

In the 50 years since its first discovery, it is no exaggeration to say that we have learnt more about the properties of the universe by studying the CMB than we have from any other single type of observation. Its first discovery in July 1965 is truly one of the landmarks of 20th century science.

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