The Afterglow of the Big Bang

June 12, 2012

When you look into the night sky, you look back in time. Moonlight bounced off the lunar surface nearly two seconds ago. Light from the bright star Vega left about 26 years ago. And the light from the Andromeda galaxy began its journey to our telescopes about 2 million years ago.

But how far back in time can you see? Could you see, with a big enough telescope, the first stars and galaxies? And could you see the light from the great flash of the Big Bang itself? The answer to the second question is… almost. With radio telescopes, astronomers have detected faint light that fills the universe, and which has all the telltale signs of the first light to emerge from the hot universe just 380,000 years after the Big Bang.

Right after the Big Bang, the universe was hot… millions of degrees Kelvin. As the universe expanded, it cooled. But for hundreds of thousands of years it was still too hot for protons and electrons to combine into hydrogen. So the early universe was a hot glowing fog of charged subatomic particles that scrambled photons in all directions.

Then some 380,000 years after the Big Bang the temperature of the universe dropped to about 3,000 Kelvin, cool enough for protons and electrons to settle down as hydrogen atoms. With the meddlesome electrons safely locked up, photons were free to spray forth through the cosmos, and the young universe was filled with dull red and infrared light. We can still detect the vestiges of this light today. This “first light” was a major prediction of the Big Bang Theory. In the 1940’s, physicists Ralph Alpher and Robert Herman reasoned this light is now stretched to longer wavelengths by the expansion of space itself. A simple calculation showed the light waves are stretched by a factor of 1000, which means the infrared light were now microwaves corresponding to a glowing body of temperature about 3 K (three degrees above absolute zero). And, reasoned Alpher and Herman, such light should appear to come from everywhere at almost exactly the same intensity.

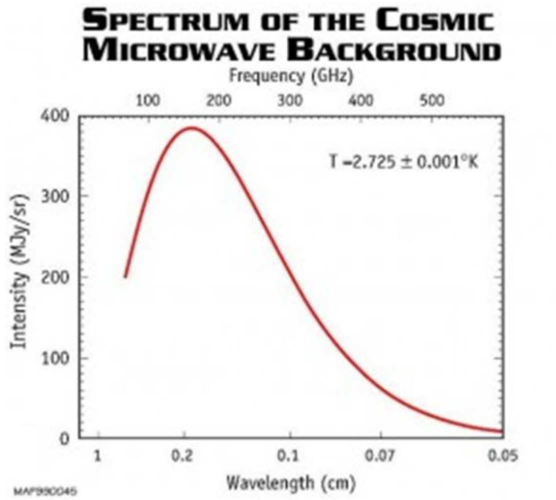
At first this bold prediction of this relic radiation was ignored, if only because no radio telescopes existed in the early 1940′s to detect it. But in the 1950’s and 1960’s, as radio telescopes matured, astronomers began to look for this relic radiation from the Big Bang. In 1964 a group of very astute astronomers at Princeton University, including Jim Peebles and Robert Dicke, began their search for the cosmic microwave background (CMB).

They were beaten to the punch. In 1965, Dicke got an unexpected call from two scientists at Bell Labs in Crawford Hill, New Jersey, Arno Penzias and Robert Wilson, who were testing a new antenna for commercial satellite communications. Penzias and Wilson were puzzled by a faint microwave signal that appeared to come from everywhere in the sky and which corresponded to a temperature of 3 K. The two had tried everything to get rid of this strange signal, including sweeping pigeon droppings from the antenna horn. Yet the signal remained. Penzias and Wilson asked Dicke if he had any idea what the signal could be. Dicke knew right away he had been scooped by the Bell Labs team. Although they came across the cosmic microwave background (CMB) by accident, Penzias and Wilson won the Nobel Prize for Physics in 1978. Dicke and Peebles did not.

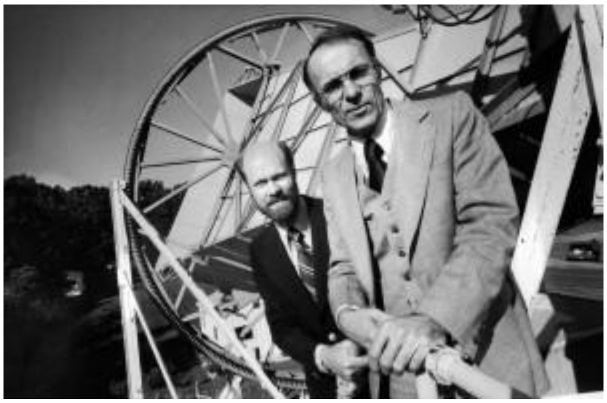
The spectrum of the cosmic microwave background

Big Bang skeptics insisted on alternate explanations for this cosmic background glow. But two features of the CMB are most accurately explained by the Big Bang Theory. For one, the CMB appears like a perfect glowing black body with a temperature of 2.725 K. For another, the temperature of the CMB is amazingly uniform across the sky, which means the early universe was amazingly smooth.

But there are small variations of about 2 parts in 10,000 in the CMB, variations which are also predicted by detailed calculations of the Big Bang. These slight variations have huge implications for the evolution of the universe from a hot soup of smooth gas to the lumpier stars and galaxies we see today. But that's a story for another day…



By the way, you can see the cosmic microwave background for yourself on a TV screen (no, I'm not kidding). Disconnect the cable and draw your signal from the antenna (even if it's not connected). Tune to a TV channel with no signal. You will see black and white "snow" on your TV screen. Most of this snow is just noise, but about 5-10% is caused by the CMB.



Robert Wilson (left) and Arno Penzias pose with the antenna they used to find the cosmic microwave background

Global Science
Unit 2: Astronomy

Name ______________________
Date __________ Per. ________

The Afterglow of the Big Bang

1. When you look into the night sky, you look back in ________________

2. With _______________ telescopes, astronomers have detected faint light that fills the universe.

3. What is "first light" ____
____

4. The light waves are stretched by a factor of 1000, which means the infrared light waves are now ____________________.

5. In 1964 a group of very ________________ astronomers at Princeton University, including Jim Peebles and Robert Dicke, began their search for the cosmic microwave background (CMB).

6. What does the word astute mean? ____
____

7. What does the abbreviation CMB stand for? ____

8. Who won the Nobel Prize for this discovery? ____
____

From the graph:

9. What units is frequency measured in? _________________

10. When the wavelength is 0.1cm what is the intensity in MJy/sr ? ________________

11. What was the most important thing that you learned from this reading?