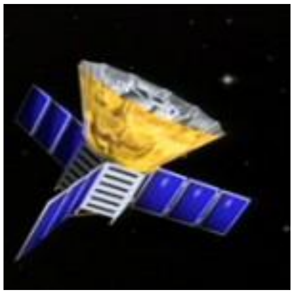
Flash Photo of the Earliest Universe

October 5, 2012



Let's take a closer look at the cosmic background radiation (CMB), the relic light from the early universe we examined in an earlier article. Just 20 years ago, astronomers made a discovery in the CMB that transformed cosmology from near-speculation to a precision science. It was a discovery of such profound importance that nearly every astronomer and physicist remembers where they were when they first heard the news.

A quick review of the CMB… For 380,000 years after the Big Bang, the universe was packed with protons, electrons, and a huge number of light particles called photons. The light got knocked around by electrons before it got very far, so the early universe was as opaque as an Irish fog. But as the universe expanded and cooled enough for protons and electrons to assemble into hydrogen atoms, light finally burst forth freely through the universe. This first light is the cosmic microwave background. It appears to come from all over the sky, but it's been stretched into microwaves by the expansion of space itself over billions of years.

The CMB, which has the signature of being emitted by a surface just 2.7 degrees above absolute zero, was first detected in 1965. Better measurements in the '60s and '70's revealed the CMB was amazingly uniform to less than one part in a thousand. This was expected by cosmologists. But theory showed the CMB should not be completely uniform: there should be tiny, random fluctuations in the temperature of the CMB. This stands to reason: since the CMB is an early snapshot of the universe, and if today's universe is clearly "lumpy" with galaxy clusters and superclusters, then surely the early universe itself was not completely smooth.

The fluctuations in the CMB were too small to detect with ground-based radio telescopes. So NASA launched a satellite in 1989 to make more discerning measurements. Called COBE (Cosmic Background Explorer, see image at top of page), this satellite spent two years slowly measuring microwave radiation over the entire sky to an amazing degree of precision, and a crack scientific team examined the data for tiny differences in the temperature of the CMB.

They succeeded. COBE revealed tiny, random fluctuations in temperature over the sky of just one part in 100,000. It was an amazing discovery. The announcement was made on April 23, 1992 and made the front page of the New York Times.

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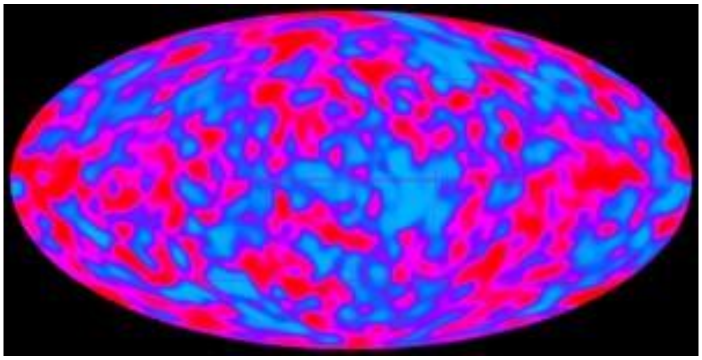
Here's a false-color image of the CMB as seen by the COBE satellite. In this image, red (lighter gray) means slightly hotter than average and blue (darker gray) means slightly cooler relative to the average temperature of the CMB of 2.712 K.

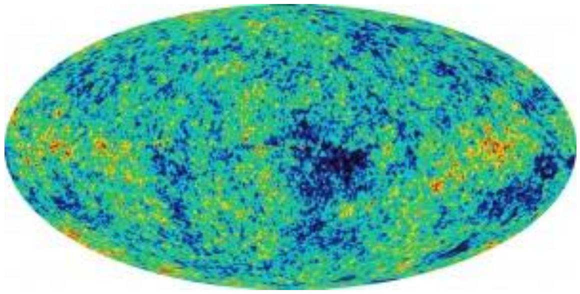


Map of the cosmic microwave background made by the COBE satellite.

What do these temperature fluctuations mean? The slightly warmer regions show where matter was more dense in the young universe and cooler regions show where it was less dense. Over time, the gravity of the denser regions pulled in more matter and grew larger, eventually forming the first stars and galaxies, which themselves congealed to form the massive galaxy clusters and superclusters we see today. The ripples in the

CMB originated in the tiny quantum fluctuations embedded in the Big Bang when the universe was smaller than the head of a pin.

These results from COBE were astonishing, but just hinted at the amazingly rich information embedded in these ancient microwaves from the early universe. In 2001, NASA launched a more advanced mission designed to measure the CMB with higher sensitivity and angular resolution. Eventually called WMAP (the Wilkinson Microwave Anisotropy Probe), this satellite produced a detailed full-sky map of the CMB at a resolution of 0.2 degrees (see below).



High-resolution map of the cosmic microwave background made by the WMAP satellite. Click to enlarge.

By comparing the measured results from the WMAP satellite with predictions from the Big Bang Theory, cosmologists have made an astonishing range of hard conclusions about the universe, including:

- The universe is 13.75 billion years old (to within 1%)
- Space is “flat” in the Euclidean sense, finally settling the argument about the geometry of the universe, and confirming a major prediction of inflation theory
- Ordinary matter, made of atoms, make up only 4.6% of the universe
- “Dark matter”, which experienced gravity but otherwise weakly interacts with “normal” matter, makes up 22.7% of the mass of the universe
- An even more mysterious “dark energy”, which causes the expansion of space to accelerate, makes up 72.8% of the universe

WMAP also mapped statistical properties of the CMB fluctuations. There are several hints of unexpected non-randomness that would be a very important signature of new physics in the early universe.

All these profound insights have been made in just the last 10 years. It’s a wonderful time to be a cosmologist, and a wonderful time for those of us who take a little time to set aside the day-to-day concerns of life to ponder the structure and history of the universe.

Global Science
Unit 2: Astronomy

Name ___________________________
Date ________________ Per. ________

Reading Questions for **Flash Photo of the Earliest Universe**

1. The light got knocked around by electrons before it got very far, so the early universe was as ___________________ as an Irish fog.

2. What does the word opaque mean? ____

3. "first light" is the ____

4. Cosmic microwave background appears to come from all over the sky, but it's been stretched into microwaves by ____

5. The fluctuations in the CMB were too small to detect with ground-based radio telescopes. So in 1989 NASA launched a satellite called ____

6. COBE revealed a tiny, random fluctuations in ______________________ over the sky of just one part in 100,000.

7. The slightly warmer regions show where matter was more _________________ in the young universe and cooler regions show where it was less ___________.

8. In 2001, NASA launched a more advanced mission designed to measure the CMB with higher sensitivity and angular resolution. Eventually called ____________________ this satellite produced a detailed full-sky map of the CMB.

9. The universe is _________________billion years old

10. Ordinary matter, made of atoms, make up only ___________% of the universe.

11. "Dark matter", which experienced gravity but otherwise weakly interacts with "normal" matter, makes up ___________% of the mass of the universe.

12. "Dark energy", which causes the expansion of space to accelerate, makes up ___________% of the universe.

13. In your best writing describe one thing you learned about the Universe from this reading.