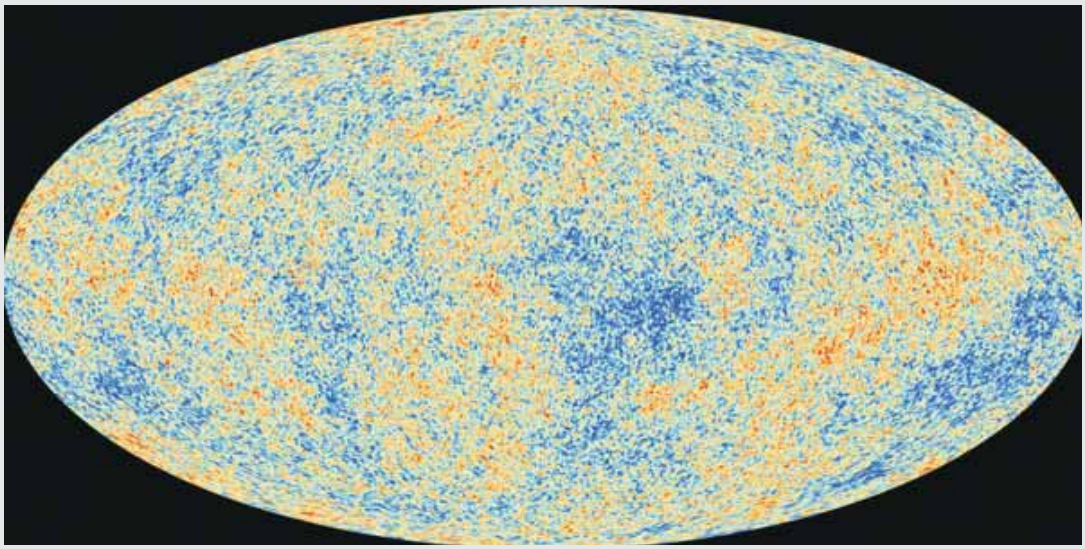
The earliest light

What the universe was like in its earliest stages

Jonathan Freundlich

When we look at the universe with our telescopes today, we can see stars, galaxies, clusters of galaxies and huge voids between them. As matter gathers around galaxies and leaves big empty regions, the universe is highly inhomogeneous. Have you ever wondered what the universe looked like in its earliest stages?



SHORTLY AFTER THE BIG BANG *The Cosmic Microwave Background as observed by the Planck satellite.* PHOTO: ESA AND THE PLANCK COLLABORATION

ASTROPHYSICAL SERIES

A homogeneous universe

What we call the Cosmic Microwave Background is the closest we can get to an image of the universe as it was right after the Big Bang, more than 14 billion years ago. It is a light which is not associated to any star or to any other astrophysical object, but rather bathes the entire universe in a background glow. It is the oldest light we can see, emitted when the universe was only 380,000 years old. At that time, the universe was much hotter and much more condensed than it is today.

In the same way that heated metals emit light and change colour with temperature, the Cosmic Microwave Background is a measure of the temperature of the universe. To each fluctuation of temperature corresponds a change in the matter distribution, so the Cosmic Microwave Background also traces the matter distribution of the Universe long before Earth and our Milky Way came into existence. And contrary to what we can observe today, it reveals an incredibly homogeneous universe!

The amount of matter is almost exactly the same everywhere in the universe at the epoch of the Cosmic Microwave Background: between the blue and red areas on the map, the difference in matter density is comparable to the difference a sand grain would make on your own weight. But although small, there are tiny fluctuations and they are the seeds of all future galaxies!

The formation of galaxies

Gravitation is an attractive force, so each excess of matter tends to attract more matter and to grow. This is how the tiny density fluctuations seen in the Cosmic Microwave Background lead to matter structures as large as galaxies and clusters of galaxies.

The temperature of the universe decreases with time, which helps forming stable structures. Lower temperatures indeed imply smaller velocities for the matter particles, and a particle with a small velocity is more likely to feel the gravitational attraction of the other particles and to aggregate with them, as it is less carried away by its own momentum. But while gravitation pulls particles together, the expansion of the universe tends to dilute and scatter them, as more space becomes progressively available to the same amount of matter. The formation of structures is a constant fight between the gravitational force and the expansion of the universe!

Nevertheless, a huge network of matter structures slowly starts to assemble. In the densest regions, gas cools and starts to form stars. Galaxies are born.

The Cosmic Microwave Background is a snapshot of the universe as it was shortly after the Big Bang, before the first galaxies were created.

But it is also much more than this. The detailed properties of its temperature fluctuations tell us about the very nature of our universe, and help us answer fundamental questions such as: What is the composition of our universe? How old is it? Is it going to expand forever? Is it finite? Is it infinite?

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- Planck is a mission of the European Space Agency (ESA) designed to make the most precise measurements of the Cosmic Microwave Background. It was launched in May 2009 and started releasing its scientific conclusions in 2013.
- Planck's predecessors include NASA missions COBE (launched in 1989) and WMAP (2001).
- Light emitted before the epoch of the Cosmic Microwave Background doesn't reach us because the Universe then was too dense and opaque.
- The glow of the Cosmic Microwave Background is strongest in the microwave region of the electromagnetic spectrum, hence its name.