The Cosmic Microwave Background Radiation

Lecture 4 - October 22nd, 2011

The era of the Universe's history we'll be talking about today is a lot easier to understand than the periods we talked about in the past two lectures! The Cosmic Microwave Background Radiation, or CMB to its friends, was produced when the Universe was young (a spritely 400,000 years old) and hot -- around 3000 K -- but not unimaginably hot; the surface of the sun is hotter than that (around 6000 K). However, because the CMB is the oldest light in the Universe, we can use the patterns that are present in it to learn about what happened far before it was released.

The temperature pattern of the CMB comes from three contributing factors:

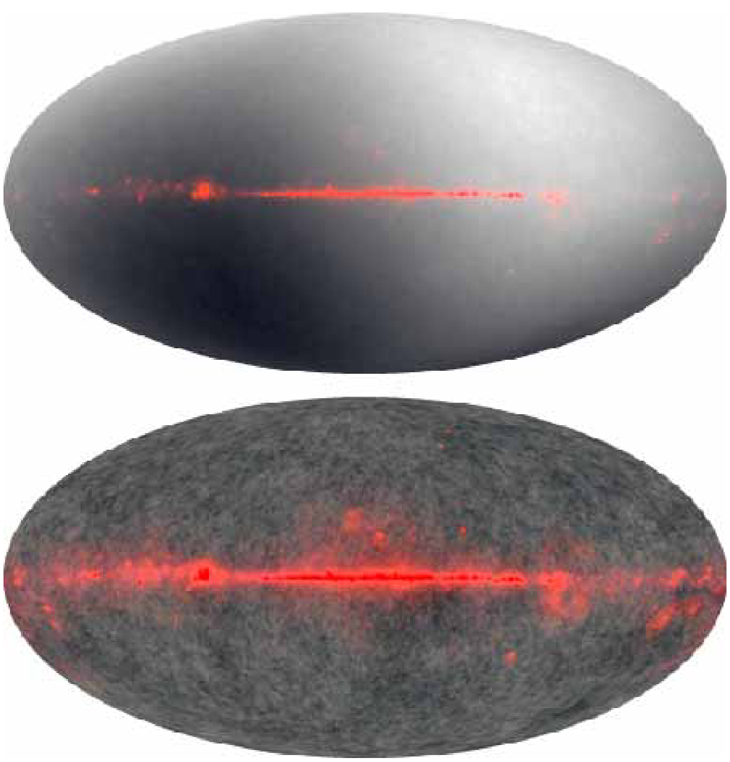
1. The even, overall background temperature, which is 2.7 K today
2. The "dipole", which is a modulation of around ±0.001 K, that comes from the Earth's motion relative to the CMB
3. Small ripples -- around ±0.00001 K -- that come from inflation and other effects.

The smallest ripples carry the most information! Some physical phenomena that affect the CMB are:

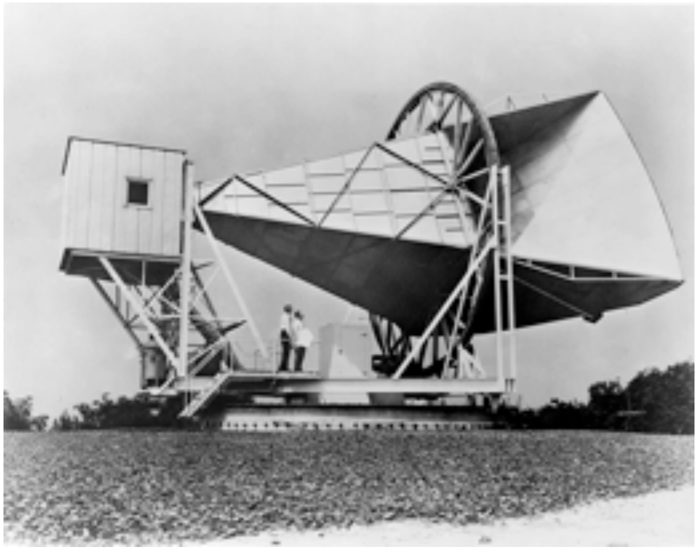
- **Acoustic oscillations:** essentially, the plasma's resonant response to the inflationary noise.
- **Silk damping:** named after physicist Joe Silk. Ripples in a plasma with small wavelengths decrease in their amplitude when the moment of the CMB's last scattering gets close. The photons can escape small wavelength fluctuations, taking energy with them; long wavelength fluctuations lose energy more slowly.
- **Sachs-Wolfe effect:** This happens to the CMB photons on their way to us. It is caused by gravitational effects the photons feel when they pass through clusters of galaxies on the way to us.
- **Sunyaev-Zeldovich effect:** This happens to the CMB photons on their way to us. It is caused by their interactions with gas in galaxies and clusters of galaxies.

I highly recommend these websites for more info:
http://map.gsfc.nasa.gov/

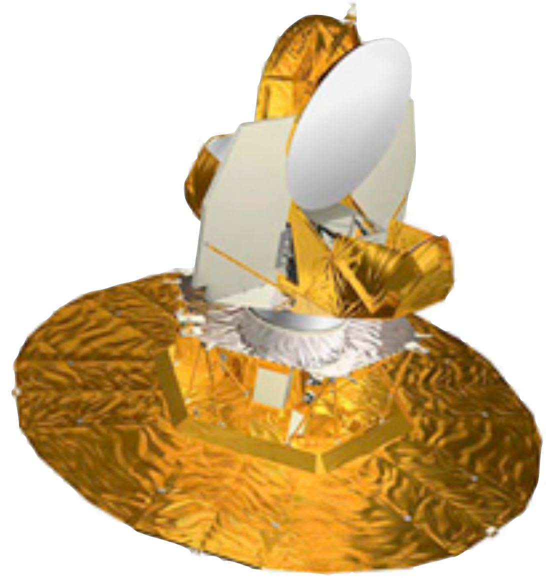
http://background.uchicago.edu/~whu/beginners/introduction.html



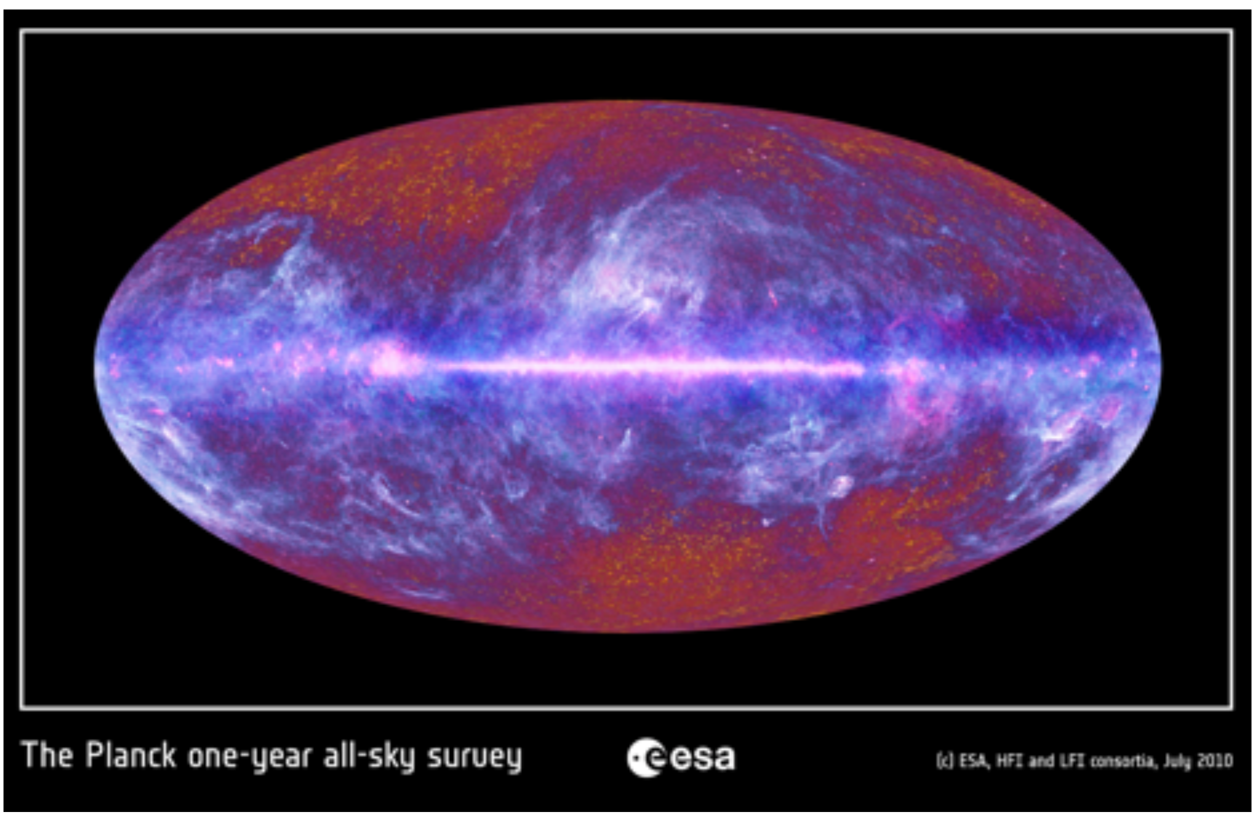
The microwave sky. Microwaves coming from our Galaxy are in red; the upper picture shows the motion-caused dipole, which is removed in the lower picture. We "subtract" the galaxy, too, to study the truly cosmic radiation. From WMAP.



The antenna Penzias and Wilson used to discover the CMB. Its shape made it a target for pigeon guano, which they originally thought was the culprit for the “noise” they were finding in their measurements!



NASA’s Wilkinson Microwave Anisotropy Probe (WMAP) satellite, which released its first data in 2003. Its discoveries have revolutionized our understanding of cosmology. It has been run by a famously small and tightly-knit team based at Princeton University



First image from the European Space Agency’s successor to WMAP, the Planck Satellite