The Early Universe and the Cosmic Microwave Background

It is easy to do an experiment in a laboratory on Earth and to check the results and calculations for correctness. If you doubt the results are correct, the experiment can be repeated. Our study of the early universe is different. We have to extrapolate the known laws of physics to find out what the early universe must have been like. We can use observations to find out if the results are correct. See series of lectures by Sean Caroll: http://preposterousuniverse.com/writings/cosmologyprimer/index.html

An invaluable instrument used to probe conditions in the early universe is the Cosmic Microwave Background Radiation (CMBR). The CMBR is the leftover radiation when the universe was about 370,000 years old. Before recombination the contents of the universe was hot plasma and it was opaque. The plasma emitted radiation like any hot object and it is this radiation which we observe as the CMBR. At time of recombination, the universe cooled enough for light to travel freely in what we observe as the CMBR. Light cooled as the universe expanded and we observe the light in the microwave part of the electromagnetic spectrum. The radiation cooled to 2.75 K. The CMBR tells us a remarkable story. It confirms most of our conclusions and calculations from observations as correct, well almost correct, with very slight variations from calculations as we shall see shortly. It gives us a picture of what the universe was like at time recombination when free electrons could join free atomic nuclei to form atoms for the first time in the evolution of the universe.

It tells us the universe was very smooth; fluctuations in density were about 1 in 100,000. But satellites like COBE, WMAP and Planck measured these fluctuations, called anisotropies, (where densities and temperature vary slightly) increasingly accurately. The term "anisotropies" translated means: the same wherever we look. The anisotropies grew into stars, galaxies and clusters of galaxies.

The CMBR tells us that our theory of the Big Bang is correct. It tells us the universe was very smooth with small fluctuations in temperature and slightly denser areas which grew under the influence of gravity into stars and galaxies as the universe cooled. There were problems with the smoothness of the universe. How could the universe be so smooth if the different regions were so far apart that they could have no contact with each other? Alan Guth's proposal that the early universe expanded exponentially explained not only why the universe appeared so smooth at large distances, but also explained why the universe appeared to be flat.1)

The CMBR is a valuable source of information. The perturbations arose from quantum fluctuations which became enlarged as the universe expands and which we can observe. The statistical properties of the fluctuations depend on two things. (See lectures referred to above). The first is the original perturbations from which they arose and secondly, and how did the ingredients of the universe evolve between time recombination and now? Imagine that the average strength of the perturbations is about the same. In his lectures (see above) Caroll pointed out that that we can conclude from this that there is more matter in the universe than we can see, i.e. dark matter. There is more energy than can be accounted for from matter; that is dark energy.

The CMBR also tells us that the universe was opaque before recombination and that we cannot see further back than 370,000 years after the Big Bang. We can conclude that electrons combined with free atomic nuclei to form such as deuterium, lithium and helium. It completed our picture that production of heavier metals took place in stars.2,3) The radiation at the time recombination was plasma composed of protons and neutrons in free nuclei, and free electrons and photons3).

So far the CMBR as confirmation of the events took place in the early universe has been considered. The very early universe can also be described as the Planck Era. The Planck time, denoted t_p is in order of 10^{-43}s after the Big Bang and is the time when quantum fluctuations occur at Planck length about 10^{-35} cm.

The information that follows was obtained from: http://sci.esa.int/science-e/www/object/index.cfm?fobjecdid=51551. The view of the Universe presented in the standard model may not be able to fully explain the richness of detail present in the CMB at the largest scales on the sky, as cosmologists revealed a number of 'anomalies' in the all-sky CMB map that do not fit very well with this model's predictions. While the observations on small and intermediate angular scales agree extremely well with the model predictions, the fluctuations detected on large angular scales on the sky – between 90 and six degrees – are about 10 per cent weaker than the best fit of the standard model to Planck data would like them to be. Another, perhaps related, anomalous signal appears as a substantial asymmetry in the CMB signal observed in the two opposite hemispheres of the sky: one of the two hemispheres appears to have a significantly stronger signal on average. An additional peculiar element in the data is the presence of a so-called 'cold spot': one of the low-temperature spots in the CMB extends over a patch of the sky that is much larger than expected.

The lack of power at large angular scale is convincingly revealed by Planck for the first time, but the hemispheric asymmetry and the cold spot had already been found in the data of Planck's predecessor, NASA's Wilkinson Microwave Anisotropy Probe (WMAP). However, there were lingering doubts about their cosmic origin. With WMAP, in fact, it was not possible to confirm that the anomalies were genuine features in the CMB, rather than the imprint of either data processing or foreground emissions. The fact that these anomalies are also present in the more precise Planck data clears up any doubt about their cosmic origin.

The latest information according to calculations made from observations by the Planck satellite showed that our previous calculations have to be amended as follows:

Dark matter up from 22.7 to 26.8%

Normal matter up from 4.5 to 4.9%

Dark energy down from 72.8 to 68.3%

Hubble constant down to 67.3 from WMAP's 69.3

Age of the Universe increased very slightly (13.8 billion years)

This latest information was supplied by Mr. Maciej Soltynski

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1) Guth, A. (1997) The Inflationary Universe. Jonathan Cape, London.

2) Gribbin J. ((2009). The Universe. A Biography. Penguin Books, U.K.

3) Coles P. *2008 Lucchin F. Cosmology. The Origin and Evolution of Cosmic Structure. John Wiley and Sons, Ltd. U.K. Dark matter up from 22.7 to 26.8%.