IIB. The ΛCDM or Lambda-CDM Concordance Model of Cosmology

See Section XXII: Λ-CDM Model Theory and Parameters

The ΛCDM or Lambda-Cold Dark Matter Model is a **parameterization of the ΛCDM cosmological model** in which the universe contains three major components: first, a cosmological constant denoted by Lambda associated with dark energy; second, the postulated cold dark matter; and third, ordinary matter. **A Concordance cosmology is a model of the universe that assumes a minimum number of parameters**, especially the Lambda-CDM model, which has 6 parameters: physical baryon density parameter; physical dark matter density parameter; the age of the universe; scalar spectral index; curvature fluctuation amplitude; and reionization optical depth. Different sorts of measurements — each using different kinds of instruments to look at completely different kinds of objects, all involving different kinds of physical processes, give completely consistent results. It is frequently referred to as the Standard Model of ΛCDM Cosmology because it is

The Simplest Model that provides a reasonably good account of the following properties of the cosmos:

- the existence, structure, uniformity, and magnitudes of anisotropies of the cosmic microwave background
- the large-scale structure in the distribution of galaxies
- the observed abundances of hydrogen (including deuterium), helium, and lithium
- the accelerating expansion of the universe observed in the light from distant stars, galaxies and supernovae.

This model assumes that General Relativity (GR) is the correct theory of gravity on cosmological scales. It emerged in late the 1990s as a concordance cosmology, after a period of time when disparate observed properties of the universe appeared mutually inconsistent, and there was no consensus on the makeup of the energy density of the universe. The ΛCDM model can be extended by adding cosmological inflation, quintessence, and other elements that are current areas of speculation and research in cosmology. This model does not explain baryon asymmetry..
The model includes **a single originating event, the "ΛCDM", a singularity,** which was not an explosion, but the abrupt appearance of expanding spacetime containing **radiation at temperatures of around 10^{15}** K. This was immediately (within 10^{-29} seconds) followed by an **exponential expansion of space by a scale multiplier of 10^{27}** or more, known as cosmic inflation. The early universe remained hot (above **10,000 K) for several hundred thousand years**, a state that is **detectable** as a residual cosmic microwave background, or **CMB**, a very low energy radiation emanating uniformly from all parts of the sky.

IIC. Hypothesized Thermal History of the Universe

We will briefly summarize the hypothetical thermal history of the universe, from the Planck era to the present. As we go back in time, the universe becomes hotter and hotter and thus the amount of energy available for particle interactions increases. As a consequence, the nature of interactions goes from those described at low energy by long range gravitational and electromagnetic physics, to atomic physics, nuclear physics, all the way to high energy physics at the electroweak scale, grand unification (perhaps), and finally quantum gravity. The last two are still uncertain since we do not have any experimental evidence for those ultra high energy phenomena, and perhaps Nature has followed a different path.

In principle, one can theoretically trace the evolution of the universe from its origin till today. According to the best accepted view, the universe must have originated at the Planck era (10^{19} GeV, 10^{-43} s) from a quantum gravity fluctuation. Needless to say, we don't have any experimental evidence for such a statement: Quantum gravity phenomena are still in the realm of physical speculation. However, it is plausible that a primordial era of cosmological inflation originated then. Its consequences will be discussed below. Soon after, the universe may have reached the Grand Unified Theories (GUT) era (10^{16} GeV, 10^{-35} s). Quantum fluctuations of the inflaton field most probably left their imprint then as tiny perturbations in an otherwise very homogenous patch of the universe. At the end of inflation, the huge energy density of the inflaton field was converted into particles, which thermalized and became the origin of the hot ΛCDM as we know it. Such a process is called reheating of the universe.
Since then, the universe became radiation dominated. It is "probable" (although by no means certain) that the asymmetry between matter and antimatter originated at the same time as the rest of the energy of the universe, from the decay of the inflaton. This process is known under the name of baryogenesis since baryons (mostly quarks at that time) must have originated then, from the leftovers of their annihilation with antibaryons.