Lecture 4. Content and history of the Universe

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4.1. The visible versus the invisible in the Universe

WMAP data (see the next lecture) reveals that the contents of the Unverse include 4% atoms, the building blocks of stars and planets. Dark matter comprises 22% of the universe. This matter, different from atoms, does not emit or absorb light. It has only been detected indirectly by its gravity. 74% of the Universe, is composed of ”dark energy” [see Part V of this course], that acts as a sort of an anti-gravity. This energy, distinct from dark matter, is responsible for the present-day acceleration of the universal expansion(see Fig.4.1).

The total density of the Universe correspond to $\Omega = 1$ [See Part II of this course].

Luminous baryonic matter provides less than 1% of the total density.

4.2. Dark matter

Dark matter in contrast to visible matter (stars, galaxies and so on) does not radiate electromagnetic radiation and for this reason can be detected only due to gravitational effects on visible matter. Dark matter can be baryonic or non-baryonic (i.e. exotic, hypothetical).

Dark baryonic matter provides another 3% of the total density ($4\% - 1\%$). Thus the bulk of dark matter is non baryonic.
What is the nature of the ”dark matter”?

There are a number of candidates for the dark matter:

An example of ordinary dark matter is MACHOs (MAssive Compact Halo Objects). Halos surround galaxies as it shown on Fig.4.2.

MACHOs can be detected by gravitational lensing experiments (see Fig.4.3). MACHOs could be brown dwarfs, objects whose mass is not large enough and temperatures in their cores are not high enough to ignite nuclear reactions in their cores, so that these objects are practically invisible.

The role of MACHOs could be played by hypothetical primordial black holes.

An example of exotic dark matter is WIMPs (Weakly Interacting Massive Particles). These hypothetical particles interact so weakly with ordinary matter that the only way to detect them in astronomy is to search their gravitational effects on visible matter. There is also some chance to produce these particles in the laboratory (this one of the scientific objectives of ”supercolliders”).

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4.3. Brief history of the Universe

The cosmological principle allows the evolution of the universe. In other words, according to cosmological principle the Universe is not the same at different moments of time. The universe has its history (see Fig 4.4).

The expansion of the universe over most of its history has been relatively gradual, however a rapid period, "inflation", preceded the Big Bang expansion.

The CMB radiation [see the next lecture] was emitted only a few hundred thousand years after the Big Bang, long before stars or galaxies ever existed. Since the universe was very hot through most of its early history, there were no atoms in the early Universe, only free electrons and nuclei. The cosmic microwave background photons easily scatter off of electrons. Eventually, the universe cooled sufficiently that protons and electrons could combine to form neutral hydrogen. This was thought to occur roughly 400,000 years after the Big Bang. After that the Universe is absolutely transparent for CMB photons which practically don't interact with neutral hydrogen. Thus we can look through the universe back in time, what we actually see is called "the surface of last scattering" (see Fig.4.5).

4.4. Olber's paradox and expansion of the Universe

Expansion of the Universe can help to resolve what is termed Olber's paradox. This concerns the question of why the sky is dark at night. In an infinite static Universe with a uniform density of sources, the sources would cover the whole sky when R got too large, so one could expect that the surface brightness of the sky be the same as brightness of the Sun. This paradox is resolved in the Big Bang picture, partly because the Universe has a finite age (so that one never sees sources much more distant than the Hubble scale) and partly because the flux from remote sources is reduced by redshift due to expansion of the Universe (seeFig. 4.6.