Large Scale Structure of the Universe

The appreciation of the complexity of the large scale structure of the universe began to come with bigger telescopes and better observing techniques.

One important development was the measurement of redshifts of galaxies on a large scale, which gives an idea of the distribution of matter in depth. From the 1980s, the surveys of specific directions have led to a picture of the extragalactic universe which is inhomogeneous on the scale of ~ 100 megaparsecs. Thus there are superclusters of this size interspersed with voids, also of comparable sizes. The voids seem to have very few galaxies in them. The supercluster would typically contain upwards of 10^{15} solar masses, distributed in the form of clustered galaxies, often spread out in a filamentary fashion.

The so-called Great Wall is one such structure that has dimensions 60 Mpc x 170 Mpc. The larger the scope of the survey, the more of this inhomogeneity is being revealed, and the question at present is, whether we have reached the end of the hierarchy of scale or there is more to come. The Hubble law itself identifies a scale of the order of 3000 Mpc. So as the scale-hierarchy grows the question arises as to whether the assumption of a homogeneous universe on a large enough scale, made by most theoretical cosmological models is still on a sound basis.

The data in the 1990s is also beginning to reveal relatively large scale motions of the order of 1000 km/s over and above that of the Hubble flow. While in a cluster, one may expect peculiar motions (due to gravitational interaction) of the order of 250 km/s, the above motions are on a larger scale. This has led to the hypothesis of the Great Attractor, which is a massive system (as yet unseen) responsible for generating such a motion in its direction.

These measurements acquire great theoretical importance within the framework of the standard big bang model, which assumes that in the early universe radiation and matter were closely coupled and so any inhomogeneities of matter would be coupled to those of radiation. The fact that the cosmic microwave background is so much more homogeneous than the matter distribution has led to the belief, that the inhomogeneities in matter became pronounced only after matter and radiation got decoupled. Indeed, the smoothness of the CMB had become something of an embarrassment to the theoreticians till 1992, when the COBE satellite revealed the first such inhomogeneities on the scale of about 10 degrees, and of magnitude of $\Delta T/T$ of a few parts in a million.

The present challenge before big bang theoreticians is to have a viable structure formation theory which meets the above observational constraints. The existence of non-baryonic dark matter is considered essential for such theories to work, but so far no acceptable theory has emerged.