In this issue

Cosmology

It is sometimes suggested that Cosmology is the most ancient of all sciences, in the sense that (wo)men were curious about the skies and the structure of the universe from time immemorial. However, the hallmark of any good science is that observations must be ahead of theory but not far too ahead. From this criterion, Cosmology became a scientific discipline somewhere in mid-eighties and is possibly the youngest of all sciences.

Observational and theoretical advances which took place in the last two decades have led to a fascinating picture of our universe. To begin with, technological advances have made it possible to determine the composition of the universe – as well as several other parameters which govern its dynamics – with a high level of accuracy. Gone are the days when the cosmological parameters were uncertain by factors of two; if you learnt cosmology in those days it is time you took another course! Also gone are the days when cosmological models were mathematical structures dictated by aesthetic elegance. Today, model building in cosmology is a study of details with tremendous amount of attention paid to interpretation of data and to explanation of observational facts. The theoretical models are far from beautiful – in fact they are aesthetically quite ugly – but they seem to describe the universe we live in.

In the special section on Cosmology in this issue there are six articles which highlight different aspects of this exciting adventure. The article I have authored covers (**page 1057**) what has been widely accepted as the greatest challenge of theoretical cosmology – namely, providing a theoretical explanation for the *dark energy* which accounts for nearly 70 per cent of the energy density that is driving the expansion of the universe. Observations show that this component of matter is quite exotic and behaves like a fluid with negative pressure. Theoretical models can be devised with ad-hoc assumptions to reproduce the observed results but none of them even get to the first base of explaining the nature of this exotic matter from fundamental considerations.

One of the key observational probes which has allowed cosmologists to talk with such confidence about the composition of the universe is the study of temperature anisotropies in the cosmic microwave background radiation (CMBR). This radiation is a relic from the hotter phase of the universe and comes to us from an epoch when the universe was about thousand times smaller in size. Hence it has fossilized signatures of the nature of the universe at that time. The tiny wiggles in the temperature of CMBR at different angular scales carry important information about the cosmological parameters. K. Subramanian discusses (**page 1068**) the physics of CMBR anisotropies and how it is used to determine the parameters of the universe.

As mentioned above, the modelling of the observed structures in the universe is now a study of fine details. While the broad paradigm of structure formation (through the gravitational clustering of particles in an expanding universe) is well established, analytical techniques are not powerful enough for us to work out the details. To make detailed predictions that can be compared with observations, we need to simulate a large enough region of the universe in a computer with sufficient resolution. J. S. Bagla discusses (**page 1088**) the finer nuances of this task and how the theoretical ideas as well as observations are put to test by computer simulations of the universe.

A closely related issue of tremendous importance is quantifying the actual shapes of the large scale distribution of matter in the universe. Pictures of the spatial distribution of galaxies, clusters, etc. suggest to the human eye that matter is distributed in the form of sheets, filaments or occasional spherical lumps in the universe. However, given a collection of points in 3-dimensions, it is not easy to come up with quantitative measures by which one can classify the distribution as being filamentary or, say, sheet-like. This task requires developing very sophisticated tools (called shape-finders) and applying them carefully to data. Varun Sahni and Jatush Sheth describe (**page 1101**) how this is done and what results ensue. [It is a matter of profound sadness that Jatush Sheth was killed in an accident on 27 November 2004, in Italy.]

The direct observation of structures in the universe is limited to somewhat low redshifts, say, $0 \lesssim z \lesssim 7$. One of the key observations at these redshifts concerns the form of matter which is distributed between the galaxies, usually called the intergalactic medium. Observations show that the intergalactic medium is highly ionized on the whole, but contains islands of neutral gas, mostly hydrogen. It is not clear how exactly this ionization of the intergalactic medium occurred; the simplest models of structure formation do not seem to produce adequate amount of ionizing radiation. Several aspects of this problem are covered in the article by Shiv Sethi (**page 1117**). It is very likely that the intergalactic medium will be the next frontier from which our understanding of the universe will develop further.

Lastly, Sandip Trivedi describes (**page 1125**) how cosmology ties in with concepts from a leading contender for quantum gravity – the string theory. Few years ago, when the observations related to dark energy were established, there was some concern that string theory may not be able to account for it. This turns out to be a false alarm in the sense that it is quite possible to construct models with a positive cosmological constant within string theory. These models have attracted considerable amount of attention because they hope to connect the microscopic theories with the dynamics at the largest scales.

Among other things, the collection of articles shows that there is a vibrant group of cosmologists in the country working in virtually every leading area. Obviously only a small sample of these people could be invited to contribute to this special section. (Incidentally, the mean age of the contributors is about 40!). It is heartening to note that cosmology is one of the areas in which Indian contribution is making an international impact and is recognized globally.

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