COSMOLOGY: In Ancient and Modern Times

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COSMOLOGY is that branch of astronomy which deals with the origin, evolution and large-scale structure of the universe. Ever since man first gazed at the skies dominated by the brilliant sun during the day and studded with countless stars during the night, he has been wondering about the nature of the heavenly bodies. Even today, astronomers have only partially succeeded in finding answers to many age-old questions. Such success, as the modern astronomer may claim today, rests on the application of the techniques of science both in theory and in observation. Although the question—what is the nature of the universe—has not changed over the ages, the answer to it has changed. And, it is the purpose of this article to review briefly the evolution of ideas in cosmology.

Ancient mythologies contain numerous highly imaginative concepts on the structure of the universe. Even the Hindu mythology, to take just one example, contains so many ideas that it is not possible to do justice to them here. Unfortunately, the descriptions are rather poetic and are not in the matter of fact language of the modern scientist. Therefore, it is difficult to assess them. Nevertheless, I am always intrigued by an extract from the Vishnu Purana which calculates one day of the Creator, the Brahma, as equal to 4,320,000,000 years. This is remarkably close to the time-scales that today's astronomer associates with the evolution of the universe.

The Greeks had a simple picture in which the earth was at rest and the heavenly bodies were fixed on a celestial sphere which revolved round it. While this picture fitted reasonably well with the motion of the majority of objects in the sky (which we now know as stars), there were a few objects which had retrograde motions. That is, their trajectories were more complicated with apparently irregular motions back and forth. It goes to the credit of the Greek astronomers of the day that they could discover a pattern in this irregularity. The positions of these objects had been well documented over centuries because man had learned to relate the changes in seasons with the changes in the pattern of the heavenly bodies in the sky. So, out of some information primarily collected for agriculture, there emerged the first scientific description. The Greeks, Hipparchus and Ptolemy, constructed a theory of epicycles in which these objects, which we now identify as planets, moved on circles whose centres moved on other circles, and so on. The crux of the epicyclic theory was that the Earth must be at rest and all other objects would move in circles, in circles moving on circles... around it.

Greek cosmology

The Greek cosmology prevailed for many centuries and even became a part of the religious dogma. The interchange of ideas which accompanied trade between different civilisations led to the spread of these concepts to Arabia and India. In the 4th century A.D., Aryabhata was the leading Indian astronomer. His volume Aryabhatiya contains many results in astronomy including the distances of planets from the sun, the method of predicting eclipses, and a general description of objects in the night sky.

Some people want to credit Aryabhata, also with the heliocentric theory—the theory in which the sun is thought to be fixed at the centre of the revolving planetary system including the earth. However, at present, there are no convincing records available of detailed calculations supporting this claim. It should also be remembered that the Greek astronomer Aristarchus (before Christ) had also suggested placing the sun in the central position. But, he did not go into detailed calculations to substantiate this statement.

A complete theory in this respect was given in the 16th century by Nicolaus Copernicus. The Copernican theory met with a lot of opposition at first because it was considered as contrary to the teachings of the Church which supported the old Greek school of thought. However, because of its simplicity and elegance, the Copernican picture gradually gained acceptance. The astronomers learnt the unpalatable (?) truth that the earth does not occupy any special position in the universe and that it is just one of the planets revolving round the sun. After painstaking work of many years, Johann Kepler was able to give empirical laws governing the motion of the planets.

From Kepler's Laws to Newton's Laws of Motion and Gravitation was the next step aided no doubt by the work of Galileo whose approach to the mysteries of nature would have done credit to any modern scientist. Around the same time, in the 17th century, astronomers were beginning to use the telescope to probe the universe more than the naked eye could ever manage. As the technology of optics improved, so did the range over which an astronomer could probe. By the end of the last century, the astronomers were looking out to the edges of the Milky Way and beyond, though they did not realise it then.

The Milky Way is a flattened poori-shaped system containing some 100,000,000,000 (a hundred billion) stars of which the sun is one. Alas, man cannot even claim that his sun is in any special position! It is tucked away at a distance of 30,000 light years from the centre of the Milky Way system—nearly two-thirds of the way to its outer edge. A light year is the distance covered by light in one year and is equal to about 10,000,000,000,000 (ten million million) kilometres!

Astronomers in the early 20th century believed that the entire universe was contained in the Milky Way system which is also called the galaxy. The powerful telescopes of the present century soon demolished that view. By the 1920's it was realized that many bright nebulae which were believed to be part of the galaxy, in fact lie well beyond it. Moreover, they were like our own galaxy in that they contained similar systems of stars. They looked small because they were far away.

By the late 1920's the American astronomer, Edwin Hubble, arrived at a dramatic picture of the universe which forms the basis of modern cosmology. This is the picture of the "expanding universe" which implies that the vast structure of the universe consisting of galaxies is expanding so that the galaxies are all moving away from one another.

Big-bang universe

This immediately raises issues about the past and the future of the universe. If it was expanding in the past as it is doing now, was it more concentrated in the past? Will it expand for ever, or, will it eventually contract? To answer such questions, the theoretician is called in. He tells us that if we use Einstein's general theory of relativity, we shall arrive at the concept of the big-bang universe. According to this concept, the universe exploded into existence as a super-dense (ideally a point) object and has been expanding ever since. The rate of expansion is slowing down and whether the universe will expand for ever or contract will be determined by the total amount of matter in the universe. A powerful evidence often cited in favour of the 'big-bang' is the observed microwave radiation background of temperature—270°C, first discovered in 1965. The is believed to be the relic of the hot era immediately after the big-bang.

Since World War II, astronomy has made very rapid progress. A powerful tool which became available to the astronomer in the 1940's was the radio telescope. Astronomy, using the radio waves, has provided tremendous inputs into our knowledge of the universe. Big radio telescopes of various types have come up in many countries. In India, the Tata Institute of Fundamental Research has a radio telescope at Ooty. This impressive array of parabolic reflectors, some half a kilometre long, has recently obtained important data on the angular sizes of very faint radio sources, located well beyond our galaxy.

Many astronomers today would like to think that the simple model of the big-bang universe represents the core of the truth about the actual universe. There are a few dissenters who are not happy with the idea of its mysterious creation out of nothing; they feel that the picture is over-simplified and may even be grossly wrong. Already, there are odd bits of evidence which tend to suggest that not everything is right with this simple model. I tend to side with the dissenters in the current controversy; for, if the history of cosmology is anything to go by, people holding the dogmatic view—"we know what the universe is like"—have invariably been proved wrong. While man's scientific attempts to grapple with the mysteries of the universe must continue, he must keep an open mind and be prepared for many more surprises from the universe.