Origin (?) of the Universe

1. Historical Background

Jayant V Narlikar

The first part of this series covers the historical background to the subject of cosmology — the study of the structure and evolution of the whole universe. Ancient ideas, such as those of the Greeks, already show the beginnings of attempts to account for observations by natural laws, and to prove or disprove these by other observations. It needed the invention of the telescope and studies by scientists like Herschel and Hubble to reach the current understanding of our place in our galaxy, and its place as only one member of a far larger collection of galaxies which fill the observable universe.

Jayant Narlikar, Director, Inter-University Centre for Astronomy and Astrophysics, works on action at a distance in physics, new theories of gravitation and new models of the universe. He has made strong efforts to promote teaching and research in astronomy in the universities and also writes extensively in English and Marathi for a wider audience on science and other topics.

Primitive Notions of the Universe

An assessment of our present understanding of the cosmos is best carried out with a historical perspective. The written history available today covers a very tiny fraction of the time span of human existence on earth and an even smaller fraction of the age of our planet estimated at some 4.6 billion years. Based even on such limited documentation we find that our ancient forefathers were indeed as curious about nature and the cosmos as we are today.

It is against this background that we should view the attempts our ancient forefathers made to understand the universe around them. They added conjectures and speculations to what they could observe directly. They used fertile imagination to extrapolate from the known to the unknown. Naturally the differing cultural traditions led to different cosmic perspectives in different parts of the world.

This six-part series will cover: 1. Historical Background. 2. The Expanding Universe. 3. The Big Bang. 4. The First Three Minutes. 5. Observational Cosmology and 6. Present Challenges in Cosmology.

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They perceived the complexity of the cosmological problem. The following lines from the Nasadiya Sukta are quite eloquent:

"Then (in the beginning) there was neither existence nor non-existence. There was no space nor was there anything beyond. (In such a situation) what should encompass (what)? For whose benefit? Was there the dense and deep water?"

"Who will tell in detail how and from where came the expanse of the existing? Who knows for sure? Even Gods came after creation. So who would know wherefrom the creation came?"

These are fundamental questions which are being asked even by present day cosmologists. Humans however are not satisfied by only asking questions. One must have answers too — and if one cannot get them one tries to concoct some. So out of questions like these arose answers that were believed by many to be right. There were no scientific proofs for them but nevertheless they became part of the mythology and gained intellectual acceptance.

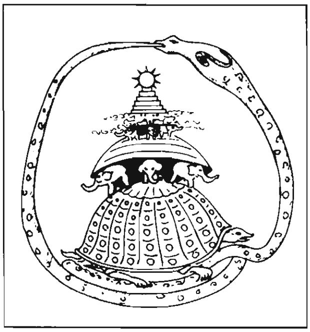

***Figure 1** A hierarchical cosmos: One of our many ancient speculations in India described the earth as resting on elephants, standing on a giant tortoise that was carried by a snake eating its own tail. We will come back to this picture in the final article in this series.*

It was during the Greek civilization a few centuries before Christ, that such speculations began to be viewed somewhat scientifically. The Pythagoreans — the followers of the Greek mathematician and philosopher Pythagoras — were worried about the sun-earth relationship. They refused to accept that the earth goes around the sun (or even vice versa!). Instead they believed that the earth goes around a central fire located elsewhere. The theory predictably ran into difficulty because of the obvious question: "Why don't we see this fire?" To answer this question, the Pythagoreans invented a 'counter-earth' that went around the central fire but in a smaller orbit. This orbit, they said, synchronized with the earth's orbit in such a way that it always managed to block the view of the central fire from anywhere on earth.

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Pythagorean theory was of this type. First there was the difficulty of the central fire not being seen. Next came the problem of why the counter-earth is not seen...and so on. However in spite of our criticism of the theory from hindsight it had the merit that it was a disprovable hypothesis.

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Karl Popper, the philosopher of science, has laid down this criterion for a scientific theory: it should be testable and in principle disprovable. In other words we should be able to think of a test whose outcome could rule out the theory. If the outcome does not disprove it the theory survives — until somebody can think of another more stringent test. Popper's criterion provides us with a way of distinguishing between philosophical speculation and a scientific theory.

Aristotle's Universe

Aristotle, another Greek philosopher, provided a series of principles that in today's parlance could be called a physical theory. He was a pupil of the famous philosopher Plato and the teacher of Alexander the Great. Today Aristotle's ideas are known to be wrong. Yet we should look upon them as man's first attempt at quantifying the laws that govern observed phenomena. The key to Aristotle's ideas lies in his classification of different types of motion.

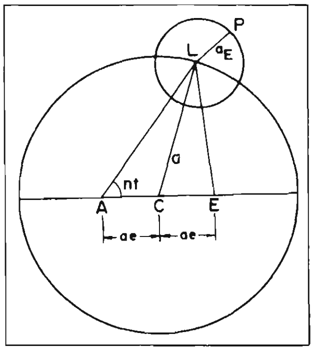

Figure 2 Epicycles: Example of how, following Aristotle, the Greek astronomer Ptolemy constructed epicycles to explain the motion of a planet P around a fixed earth E. The planet moves on a circle whose centre moves on another circle around the earth. In specific instances several epicycles were needed.

Aristotle distinguished two types of motion seen in the Universe: *natural motion* which he supposed always to be in circles and *violent motion* which was a departure from circular motion and implied the existence of a disturbing agency. Why circles? Because Aristotle was fascinated by a beautiful property of circles which no other curve seemed to possess. Take any portion of a circle (what we usually call a 'circular arc') and move it anywhere along the circumference: that portion will coincide exactly with the part of the circle underneath it. (The straight line also has this property but it can be considered a circle of infinite radius).

In the jargon of modern theoretical physics the above property

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is one of rotational symmetry. A one-dimensional creature moving along the circumference of a circle will find all locations on it exactly similar, there being no privileged position. As we shall find in the second part of this series, present-day cosmologists employ similar symmetry arguments about the large-scale structure of the universe.

Although the heavenly bodies, especially planets, did not appear to move (naturally) in circles the Aristotelians brought in more complicated geometrical constructions involving a series of circles called epicycles. Thus a planet may move on one epicycle whose centre moves on another epicycle whose centre moves on a third epicycle and so on leading ultimately to a fixed earth in the midst of all these moving real and imaginary points in space.

The epicycle theory was thus no different from the kind of parameter-fitting exercise that goes on in modern times when resolution of apparent conflicts between observations and a favoured theory is sought by introducing adjustable parameters into the theoretical framework. Such an exercise tells us more about the freshly introduced parameters than it does about the basic hypothesis of the original theory. In fact, as with the Greek epicyclic theory a theory, requiring too much patchwork of this sort eventually has to be abandoned.

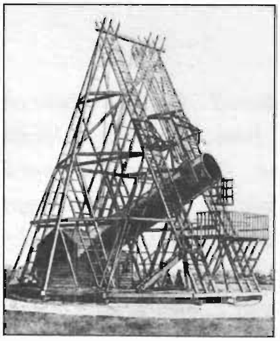

***Figure 3** Herschel's telescope: This major telescope had a tube length of 48 feet and an aperture of 48 inches.*

While it is easy to deride Aristotle and welcome Copernicus, Kepler, Galileo and Newton we must acknowledge that the Greek philosopher originated the notion that natural phenomena follow certain basic rules. Aristotle's perception of such rules turned out to be incorrect but the idea that they exist was carried over and has been the guiding light of theoretical physicists to this day.

The Advent of Telescopes

The major experimental input to astronomy as a science came in the seventeenth century with the discovery of the telescope. It was Galileo who first used the telescope for astronomical purposes and who first appreciated its value in observing remote heavenly bodies. Today we would not be discussing the subject of cosmology had there been no telescopes to give us a view of the universe.

No one appreciated the usefulness of the telescope more than William Herschel. A busy music master at Bath in England, Herschel was known for his organ recitals and his huge orchestras. At the age of thirty-five he decided to become an astronomer largely as a result of night-time reading of books on mathematics and astronomy. Herschel's interest was in observational astronomy and starting with a small telescope he eventually went on to build the great reflecting telescope of 48-inch diameter.

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The telescopic investigations of William Herschel and his son John led them to the first crude picture of our galaxy as a disc-like system of stars encompassed by the white band known as the Milky way. By examining the distribution of stars away from the Sun in all directions the Herschels concluded that the sun was at the centre of the galaxy. Thus although it was known in the nineteenth century that the sun is just a common star which appears to be the brightest object in the sky only because it is the nearest, it still retained the special status of being at the centre of the galaxy.

Our Galaxy

This picture of the galaxy so methodically built up by the Herschels still had two defects which were not corrected until much later at the beginning of the present century. But even in the eighteenth and nineteenth centuries there were those who suspected that something was wrong and whose perceptions came remarkably

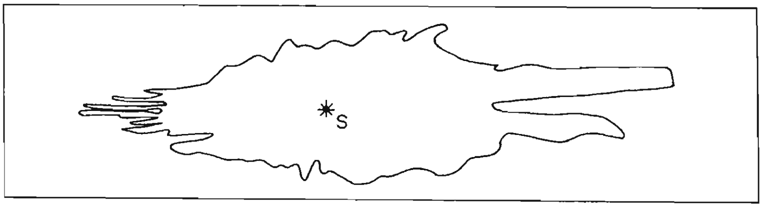

***Figure 4** This map of our galaxy as prepared by William Herschel had the sun S at its centre.*

Even as late as 1920, astronomers clung to the picture of our galaxy with the sun not too far removed from the centre.

close to the truth as we now know it. The mathematician J M Lambert suggested for example that the stars in the Milky Way are in motion around a common centre and that the sun along with the planets also moves around this galactic centre.

Lambert also suggested that not all visible objects are confined to our galaxy. In addition to stars and planets astronomers had also found diffuse nebulae whose nature was not clear. Were they far-away clusters of stars or were they nearby clouds of luminous gas? Lambert argued that the nebulae were indeed very distant objects far beyond the galaxy.

Even as late as 1910-20 astronomers clung to the picture of our galaxy as developed by Herschel. For instance J C Kapteyn used the new technique of photography which proved to be a boon to astronomy and arrived at a model of our galaxy as a flattened spheroidal system about five times larger along the galactic plane than in the direction perpendicular to it. In this model commonly known as the Kapteyn Universe the sun was located slightly out of the galactic plane at a distance of some 2000 light-years from the centre (one light-year is the distance travelled by light in one year and this is approximately 10^{13} kilometers). The Sun was thus not too far from the galactic centre just as Herschel had proposed.

When Kapteyn's work was published in 1920-22 it was already being challenged by Harlow Shapley. In a series of papers published during 1915-19, Shapley studied the distribution of large dense collections of stars called globular clusters. A globular cluster may contain upto a million stars and can be identified from a distance because of its brightness and distinctive appearance. Shapley found that the number of globular clusters falls of as one moves perpendicularly away from the galactic plane. Along the plane they seemed concentrated in the direction of the constellation of Sagittarius. Shapley therefore assumed that the galactic centre lay in that direction well away from the sun and estimated that the sun's distance from the centre was 50 000 light years. The modern estimate of this distance is only about 60 percent of this

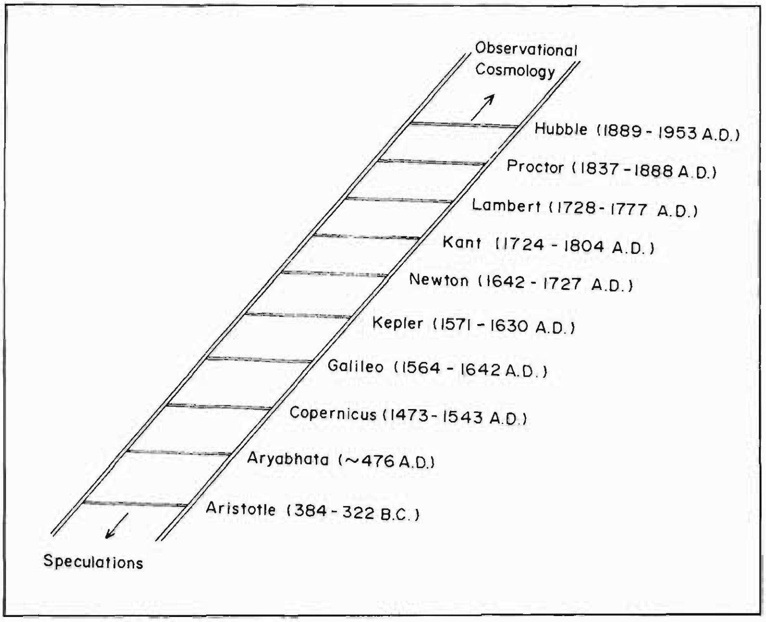

***Figure 5** Progress of cosmology: This ladder-like figure shows how ideas on the cosmos received major inputs. Some of them have been mentioned in the text. In addition, Aryabhata was aware of the earth's spin about its axis, which according to him explained why fixed stars appear to travel westward; Kant and Proctor had suggested that our galaxy is just one among many.*

value but the sun does go around the galactic centre as guessed correctly by Lambert. The total diameter of the galaxy is about 100 000 light years and it contains some 100-200 billion stars.

While Shapley was right in dethroning the sun from its presumed privileged position at the centre of the galaxy his distance estimates were too large because he ignored the effects of interstellar absorption. Nor did Shapley agree with Lambert's view that most of the diffuse nebulae lay outside the galaxy. But by the 1920s the obscuring role of the dust began to be under stood and the picture of our galaxy underwent a drastic change. Many stars which were earlier believed to be far away because they looked faint were discovered to be much nearer, their faintness being due to absorption by the interstellar dust. Even more important was the conclusion that many of the diffuse nebulae lay far away, well outside the galaxy. Indeed it soon became apparent, thanks largely to the work of Edwin Hubble, that these nebulae were galaxies in their own right as large as our own which are moving away from our galaxy at very large speeds. It was Hubble who found an empirical law governing their motion that was to become the foundation for modern cosmology.

Suggested reading

H Bondi. Cosmology. Cambridge University. 1960.
J V Narlikar. The Lighter Side of Gravity. W H Freeman and Co. 1982.
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Address for correspondence
Jayant V Narlikar
IUCAA, PB No. 4,
Ganeshkhind,
Pune 411 007, India