

Fifth Kumari L.A. Meera Memorial Lecture

Myths, Beliefs and Facts in Astronomy

by

Jayant V. Narlikar
Inter-University Centre for Astronomy and Astrophysics
Pune

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Kumari L. A. Meera Memorial Trust
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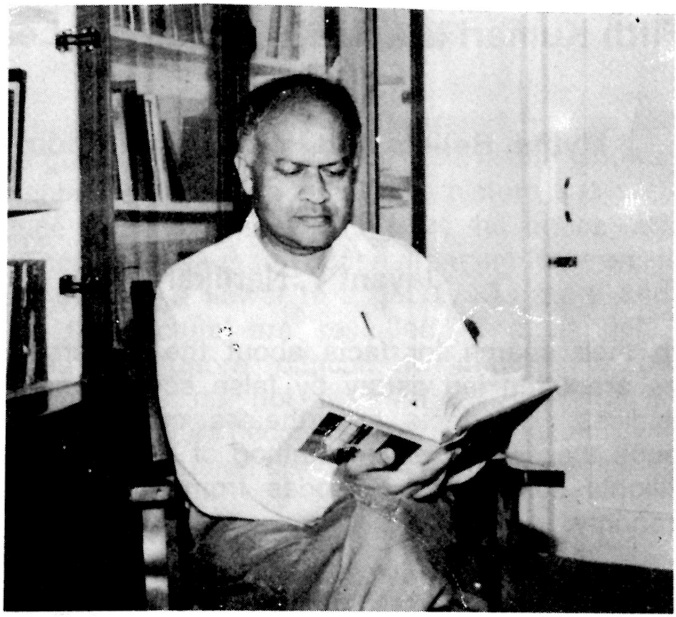
KUMARI L. A. MEERA
(1961–1985)

Kumari L.A. Meera, the youngest daughter of Mr. and Mrs. L.K. Ananthakrishnan, was born on June 1st, 1961, in New Delhi. Her academic career was uniformly brilliant with a distinction at the higher secondary level and a University rank in the B.Sc. (Honours) examination in Physics, from St. Stephens College, Delhi. After again obtaining a rank in her M.Sc., which was at the Indian Institute of Technology in Madras, she took up a Masters programme in Computer Science at the same institution with a view to preparing herself for the emerging applications of this area to physics. She was strongly oriented towards research, having attended summer schools at the Indian Institute of Science and the Tata Institute of Fundamental Research. Her teachers and colleagues recognised her promise and motivation and confidently expected an outstanding career in research. Her personality was warm and friendly with a strong streak of hard work, determination, and helping others. These characteristics endeared her to those who knew her.

She joined the University of Pennsylvania in Philadelphia in September 1985 for graduate studies in physics. But in November of the same year, her bright career was tragically cut short by her untimely death.



JAYANT VISHNU NARLIKAR

Jayant Narlikar was born in Kolhapur on July 19, 1938 and educated on the campus of the Banaras Hindu University, Varanasi, where his father was professor of Mathematics. After obtaining his B.Sc. degree, he went on to do his Mathematical Tripos at the University of Cambridge in England. He obtained the B.A. degree with distinction in 1960 and continued as a research student with Fred Hoyle, the renowned astrophysicist, obtaining his doctoral degree in 1963. After working at the Institute of Astronomy from 1966, he returned to India in 1972 to join the Tata Institute of Fundamental Research. He headed the Theoretical Astrophysics group at TIFR till 1988. In this year, he took up the task of establishing the Inter-University Centre for Astronomy and Astrophysics, Pune under the auspices of the University Grants Commission. This new institution has the goal of providing opportunities and facilities for staff and students of the universities in the areas of astronomy and astrophysics.

Prof. Narlikar's research has covered action-at-a-distance electrodynamics, conformal gravity, matter creation, the steady state cosmology, high energy astrophysics and other related areas. He has received many awards and honours, ranging from the Adams Prize in 1967 to his recent election to the Third World Academy of Sciences.

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In their search for facts about the universe, astronomers are often led astray by false scents and their own prejudices. The facts nevertheless come out eventually through the self-correcting method of science. This lecture highlights some such episodes from the long history of astronomy.

A Tribute

I feel honoured at being asked to speak in a lecture series in which very distinguished scientists have taken part. It is indeed laudable on the part of the Kumari L.A. Meera Memorial Trust to have launched activities beneficial to students seeking to achieve their full potential, an opportunity that was so tragically denied to Kumari Meera. I commend the Trustees for the programmes of the Trust aimed in this direction.

I should mention that throughout my career I have felt like a student first learning from my elders and now-a-days also from my juniors in age. And of course, in a scientific field one is constantly learning new facets of nature, and one has to be prepared to revise one's ideas from time to time.

In paying my tributes to the memory of Kumari Meera, I wish to keep this perspective in my talk.

A Picture Quiz

The essence of my talk is illustrated by the following picture quiz typically asked in television shows. The contestants are shown a tiny bit of a picture and are asked to deduce from what they see what the entire picture is about. There may be many options ranging from a cell to an elephant or from a flower to a galaxy. As more and more parts of the picture are revealed, it often gets more mysterious and more difficult to understand because the added parts do not fit into our first guesses. A cleverly hidden picture becomes very difficult to identify till most of it is revealed. We then discover how wrong our first guesses were.

Science as a subject has developed around such quizzes posed by nature. The scientists are shown a tiny fraction, a brief glimpse and challenged to find what it is all about. Nature often cloaks its mysteries so cleverly that it may take the scientists years, even centuries to understand just the basics, let alone the full details, of what is revealed. Till the full picture is clear, the scientist is often led to guess in the wrong directions. The history of science is full of such "wrong turnings" from the path towards the correct solution.

Till the correct solution is glimpsed, it often happens that a wrong alternative becomes a paradigm subscribed to by the majority of scientists. It may indeed be believed with such intensity that any search for the correct alternative is felt unnecessary and hence positively discouraged. Time and again history tells us of examples where the paradigm-shift has been delayed due to this phenomenon. As Sir Peter Medawar has warned: "*The intensity of the conviction that a hypothesis is true has no bearing on whether it is true or not...*".

The Geocentric Theory

Today a schoolboy knows that the Earth he stands on moves round the Sun, along with eight other planets. If he is more advanced in his knowledge he will tell you that the cause of this motion is the universal law of gravitation that operates between the Sun and the Earth just as it operates between any two particles of matter, howsoever far apart. In college he will learn how to compute the orbits of planets around the Sun.

These are steps in his understanding of the Solar system, but what takes him a few years took mankind millennia to grasp. There were several wrong turnings in the path towards the truth, as well as instances where hints of right turns were ignored and forgotten. Let us look at a few examples.

The followers of the Greek mathematician and philosopher Pythagoras, known as the Pythagoreans, believed that the Earth moves in space, not around the Sun but around a "Central Fire" of special significance. When sceptics asked, why don't we see the fire, these theorists replied that a "Counter-Earth" moved in just such a way that it always hid the fire from the Earth. So far, so good. But when further quizzed as to why this counter-planet itself is not seen, they replied that the part of the Earth on which Greece was located was always directed away from it!

Thus the myth was propagated not only with no observational support but also with attempts to explain why people did not see what they expected to see. While with hindsight we can see this as an example of a wrong scientific approach probably befitting an era when the modern scientific method was not known, the irony is that, as we shall see towards the end of this talk, even today theories with no observational support remain popular having been propped up with further theoretical conjectures as to why no observational evidence is to be expected!

This Pythagorean myth did not last for ever of course, but it was replaced by another. About three centuries B.C. the great philosopher Aristotle had set up a new set of rules about how nature operates. According to him motion is of two types, natural and violent. Natural motion which is normally subscribed to by matter in nature is in circles whereas interference into acts of nature by, say, a human agency would generate violent motions which need not be circular. Why such an emphasis on circles?

Aristotle was enchanted with circles because of their symmetry. Cut out any arc of a circle and place it anywhere on the remaining portion: it will lie exactly on it. This property is not to be found in any plane curve bar the straight line (which may be considered a circle of infinite radius). Moreover, look at the night sky and you will find that stars describe circular trajectories from the East to the West. Photographs of stars in the night sky obtained by exposing the film in the camera all night long brings this fact out very clearly. Instead of a pointlike image, we see circular paths along which the stars apparently move.

So Aristotle was led to the picture of the fixed Earth around which the whole celestial sphere revolves. The Earth itself therefore came to be recognized as the centre of the whole universe, a belief that lasted for more than eighteen centuries after Aristotle's death. Known as the "geocentric theory" this idea soon attained the status of a religious tenet.

The motions of planets which seemed too irregular to fit within the Aristotelian notion of natural motions along circles, were made to conform to that notion by the invention of epicycles. For example, a planet like Mars which shows forward and retrograde motions was believed to move along a circle whose centre moved along another circle that went

around a fixed Earth. To attain a higher degree of accuracy, the Greeks like Hipparchus and Ptolemy, following Aristotle, had to introduce several such "circles moving on circles". These moving circles became known as *epicycles*.

There were some who did raise alternative viewpoints from time to time. Aristarchus of Samos (*ca* 310-230 B.C.) had argued that the Earth moves round the Sun. As a test of this hypothesis he suggested looking for changes in the directions of stellar bodies in the course of the year as they are observed from different vantage points of the moving Earth. No such changes were seen and the idea was rejected.

This was, however, a case of rejecting the right theory for the wrong reasons. Aristarchus had grossly under-estimated the distances of the stars and over-estimated the relative changes of directions to be expected. Moreover, the accuracy of astronomical viewing in those days was not good enough to detect the correct changes of direction. It was only in the early nineteenth century that the observational capability needed to test Aristarchus's ideas was attained, when in 1838 Bessel used this method, now known as the *method of parallax*, to measure the distance of the star 61 Cygni.

The second episode of a right idea being ignored occurred in the fifth century in India. Aryabhata, the first in a long line of Indian astronomers extending over seven centuries, wrote a *shloka* in his astronomical treatise called *Aryabhatiya* stating that the Earth spins from west to east which is why the fixed stars appear to move from east to west. Aryabhata even gave an example of how fixed objects on the ground appear to move backwards when observed from a moving boat.

This statement was, however, contrary to the prevailing dogma that the Earth is fixed and the celestial sphere

revolves around it. It is said that Aryabhata was ridiculed for this statement and had to quit his native place in Bihar and go first to Gujarat and later to Kerala. His successors in the tradition, probably embarrassed by the statement, tried to give a different interpretation to his shloka so that it would not sound so outrageous!

I will not go through the historical episodes of Copernicus and Galileo, so well known anyway, to underscore the difficulties that stood in the way of the correct interpretation of facts relating to the geocentric theory. But let me narrate an instance of how Galileo himself defended a correct hypothesis through wrong evidence.

Much is said about Galileo's staunch defence of the Copernican theory which had the Sun at rest in the centre of the solar system and the Earth and other planets moving around it. Faced with the rigours of the Inquisition, Galileo publicly recanted and admitted that the geocentric theory was correct. However, his inner conviction and firm belief in the Copernican theory remained intact to the end. It is said that even after conceding in public that the Earth is fixed he muttered to himself "but it moves". However, what was the evidence on which Galileo based his conviction?

He was asked this question by the Inquisition. As a piece of evidence Galileo argued that the tides on the Earth indicate that it moves. (Water in a moving vessel gets tossed up and down.) This argument failed to convince the inquisitors and in retrospect is seen to be wrong. Today we know that the ocean tides occur because of lunar attraction and so far as that is concerned the Earth might as well be considered fixed in space with the Moon moving round it. But in Galileo's times the law of gravitation was still to be discovered and neither he nor his inquisitors were in a position to take this point into consideration!

What is the direct proof one can give today that the Earth is indeed moving? The experiment to demonstrate this involves the *aberration of light*, that is, the apparent change in the direction of a source of light observed from a moving frame of reference. If the same star is observed today and six months later, the Earth's velocity would have changed to the opposite direction between the two observations and this would result in the change in the apparent direction of the star. To ensure that it is not the star but the Earth that is in motion we carry out the same experiment for a large number of stars. Aberration experiments were done by Bradley in 1725. Certainly, these would not have been possible with the technology available to Galileo even if he had thought of them.

The Nature of our Galaxy

I now move on to another issue which took more than two decades to resolve. In the typical artist's impression of our Milky Way Galaxy, we see a spiral shape and our solar system is housed in it about two thirds of the way towards the periphery. A rough estimate of the diameter of the disc is 100,000 light years, a *light year* being the distance travelled by light in one year. (Approximately, one light year equals nine million million kilometres.) Thus our own distance from the Galactic Centre is about 30,000 light years. The entire visible structure of the Galaxy contains some 150 billion stars.

This "final answer" about the structure of our galaxy was not arrived at without difficulties, mistakes and controversies, however! We have to remember that we are ourselves part of the system and are trying to work out from within how the entire structure looks. This is not easy, certainly it would have been easier had we been looking at the Galaxy from outside. Observationally we see a whitish band of luminous material in the sky which gave the system its name "The Milky Way".

To begin with, the picture of our Galaxy prepared by William Herschel in 1785 had it shaped like an elongated disclike structure full of stars, with our Sun (and its planetary system) at the centre. The belief that we are at the centre of the Milky Way persisted for a long time, certainly till the first decade of this century. One of the difficulties in arriving at the correct perspective was as follows.

The vast space between stars in the Milky Way is not empty but has gas and particles of dust unevenly distributed across it. The dust may consist of frozen matter of different types made up in small units of varying sizes ranging upto around a micron (a millionth part of a metre). The dust absorbs light and thereby obscures the region lying beyond. Thus a relatively nearby star partially obscured by dust, may be seen very faint and be mistaken for a very distant star. In other words, it is possible to be mistaken about the size of the Galaxy if we do not take this effect into account.

By measuring the distances of stars known as Cepheid variables, Harlow Shapley had arrived at the conclusion that Herschel's picture of the Milky Way was wrong, both qualitatively and quantitatively. In particular, the apparent spherical symmetry of distribution of stars in the vicinity of the Sun was not indicative of the Sun being at the centre of the Galaxy. Rather, it showed that the more distant stars were obscured and hence the picture was very incomplete. (Recall my example of the incompletely revealed picture.)

Nevertheless there were many controversies, indicative of the strong feelings on both sides. The majority opinion was in favour of the Sun being close to the centre of the Galaxy, as projected by Herschel. But finally, the observational evidence of galactic structure became clear and strong in favour of Shapley's point of view.

However, there was another controversy concerning the status of our Galaxy in which Shapley was at the loser's end. We will look at it next.

The Extragalactic Universe

In the eighteenth century Immanuel Kant had put forward the so-called "island universe" hypothesis according to which our Galaxy is just one amongst many similar collections of stars, floating in otherwise dark empty space like islands in the ocean. The idea somehow did not catch on. I believe there is always an anthropic prejudice that tends to give undue importance to us humans in the overall scheme of things in the cosmos! This is why there was the geocentric theory and then the belief that the Sun occupies a privileged position in the Galaxy. Both paradigms were once popular but ultimately shot down. The Kantian hypothesis, on the other hand, made out our Galaxy as just one of numerous similar galaxies in the universe thus depriving it of any special unique status. Hence the hypothesis had few takers.

As early as in the last century, the photographs of the heavens taken after long exposures revealed the existence of faint smudgy objects. Called "nebulae", these objects were believed to be vast clouds of gas lit up by neighbouring stars. Thus all of them were believed to be part of our Galaxy.

By the beginning of the present century, however, there was emerging a minority view that not all of these nebulae belonged to the Galaxy. Rather they were of two kinds. One class of objects represents nebulae lying within the Galaxy but not the second. A nebula of the second kind was argued to be a galaxy in its own right lying outside ours and at a considerable distance from it.

Again there was a violent controversy about this point of view. The majority opinion is reflected in the following contemporary comment:

...The question whether nebulae are external galaxies hardly any longer needs discussion. It has been answered by the progress of research. No competent thinker, with the whole of the available evidence before him, can now, it is safe to say, maintain any single nebula to be a star system of co-ordinate rank with the Milky Way...

{*From: Clarke, The System of the Stars, (1905), page 349*}

One argument for believing that the nebulae were part of our Galaxy was that measurements of their proper motions by a distinguished astronomer van Maanen unmistakably showed that nebulae like M 33, M 81, M 101, etc., had transverse velocities. This argument may be made as follows. The astronomer may look at an object from time to time, say at intervals of a few months or a few years. If in this interval the object changes its direction in the sky, then the astronomer argues (rightly) that the object is moving perpendicular to the line of sight. If it moves through an angle of, say, one degree over a year, then it has an angular speed of one degree per year. If the distance of the object is known, then by multiplying it by the angular speed the astronomer can estimate its actual speed (in kilometres per second) perpendicular to the line of sight. The larger the distance, the larger is this speed.

In van Maanen's case, his claimed measurements of proper motions were such that if the nebulae were extragalactic, then their transverse velocities would have been unrealistically high, say, of the order of 15,000 km/s. Thus the majority view prevailed until independent methods of measuring distances to the nebulae could be found. This was done by Edwin Hubble by the mid-nineteen twenties. By

measuring their distances directly, Hubble was able to demonstrate that the nebulae were indeed extragalactic. Also, van Maanen's claims of proper motions could not be substantiated by others.

As mentioned earlier, Harlow Shapley who had been proved right in deciding the Sun's location in the Galaxy, believed that the Galaxy contains all the nebulae within it and was thus proved wrong in this debate. We quote his views in this matter:

...Observation and discussion of the radial velocities, internal motions, and distribution of spiral nebulae, of the real and apparent brightness of novae, of the maximum luminosity of galactic and cluster stars, and finally of the dimensions of our galactic system, all seem definitely to oppose the "island universe" hypothesis of the spiral nebulae...

{*H. Shapley, Publications of the Astronomical Society of the Pacific, 31, (1919), page 261*}

The Nature of Radio Sources

My next example takes me halfway through this century, to the emerging science of radio astronomy. The discovery of strong radio sources like Cygnus A in the late forties had set off conjectures as to what these sources were. Martin Ryle at Cambridge, who led one of the few pioneering groups in radioastronomy (others being Bernard Lovell's group at Jodrell Bank, U.K. and those of Bernard Mills and John Bolton at Sydney and Parkes in Australia), found that the radio sources were isotropically distributed and assumed that they were nearby. Recall Herschel's discovery that the stars were similarly distributed around the Sun and which turned out to be very local. So the prevalent belief was that these were radio stars.

At this stage a theoretician in the Cavendish Labs, Thomas Gold, threw a spanner into the set up. He argued that the isotropic distribution of these sources indicated the exact opposite, namely that they were very far away and thus were extragalactic. In the ensuing debates Gold, supported by a few radicals like Fred Hoyle, was outnumbered. The following comment made by Ryle at a discussion meeting, is indicative of the mood:

...As regards the possibility of accounting for radio stars by the emission from extragalactic nebulae, I think we already have a good deal of evidence against this and in favour of a "stellar" source within the Galaxy....The alternative possibility of accounting for all radio stars by extragalactic bodies presents very great difficulties...

In the end the situation turned around when Cygnus A was optically identified by Walter Baade who showed that the optical counterpart of the radio source was extragalactic. Baade's earlier interpretation that it was a pair of colliding galaxies later turned out to be wrong; but the extragalactic nature of the source was unambiguous. Subsequent identifications of other sources with galaxies confirmed Gold's conjecture.

Measurements of Hubble's Constant

From what has been said so far it is clear that the major issue of contention in astronomy has been the distance of a source. Exactly how does one measure the distance of a star? Of a galaxy? Or of a remote cluster of galaxies? Over the years astronomers have developed a series of methods that measure the distances of progressively more remote objects. There are a number of techniques at each step which, through mutual corroboration, lend credibility to the procedure. Nevertheless, there are a number of errors which lie beyond the observer's control and in a ladder-like

procedure where estimates at each new step depend on those of earlier steps, the errors mount.

One consequence of this is the continuing uncertainty that still surrounds the measurement of *Hubble's constant*, a quantity of fundamental importance to cosmology. Basically, Hubble's constant measures the rate of expansion of the universe. The original finding by Hubble in 1929 was that the radial velocity of recession of a galaxy is in direct proportion to its distance. This result forms the basis of most cosmological models.

The radial velocity of a galaxy is estimated observationally by measuring the shift in wavelength of the prominent lines in its spectrum. The lines are usually seen to have shifted towards the red colour of the spectrum, thereby indicating that their wavelengths have increased. The fractional increase in wavelength is called the *redshift* of the line. From the redshift one can estimate the radial velocity. The formula is particularly simple at low redshifts: multiply the redshift by the speed of light to get the radial velocity.

So if we know the radial velocity and distance of a galaxy their ratio gives us the Hubble constant. Hubble originally estimated the value of this constant at 530 km per second per Mpc. (Mpc is short for *Megaparsec*, a distance unit commonly used in extragalactic astronomy. 1 Mpc approximately equals 3 million light years). With today's more sophisticated observations astronomers have come to the conclusion that this constant lies somewhere between 60 to 80 km per second per Mpc.

The difference between Hubble's original value and the present value, as well as the present large uncertainty in its measurement today underscore the fact that it is a difficult constant to measure, if one takes account of all the errors and uncertainties of measurement. Yet, the progress of its

measurement by different groups from 1929 to the present day has been a story of misplaced confidence in measurements, an oversimplification of the complexity of the large scale structure of the universe, and subtle biases introduced by model building theoreticians. There have been two major groups, one opting for a high value of the Hubble constant and the other opting for a low value. It is interesting to note that when the group pressing for high value was quoting a value of 200 in the above units, the low value group was pressing for 100. Later these numbers changed to about 100 and 50 respectively, and today the gap has narrowed to between about 80 and 60. And at each stage either group would defend its value within narrow error bars!

On the theoretical side, let me add that the currently popular models of the universe assume that it started in a big explosive event (big bang) and has been expanding ever since. The value of Hubble's constant determines the age of a typical big bang cosmological model. A large value of the constant gives a low age and vice versa. Thus if we take the value of 80 we come to the conclusion that the most popular big bang model, known as the *inflationary big bang model*, has an age no more than about 8 billion years. This value may appear very large in human terms. However, for several years now, the stellar physicists have been quoting values for ages of stars far in excess of this value. This poses a major threat to the big bang model: how do you accommodate in such a universe certain stars whose ages are estimated at twice the age of the universe? Even taking the lower value of 60 for Hubble's constant does not remove this difficulty.

The approach taken by the majority of cosmological theoreticians is strikingly reminiscent of the epicyclic theory of the Greeks. They introduce additional parameters into their model in order to fit the observations without asking for the rationale for the chosen values. It will take me into too

many technicalities to describe the details. This approach, however,is in marked contrast to the philosophy behind the inflationary big bang model when it was first introduced in 1981. The big merit of this model was that it avoided the "fine tuning" of its parameters. Now, the theorists have to resort to fine tuning of all the available parameters in order to save the model.

The Nature of Dark Matter

Perhaps the best modern parallel to the Pythagorean view of the planetary system described in the early part of this talk is to be found in the current ideas of dark matter. Briefly, the scenario is as follows.

Astronomical evidence over the last two decades has shown that if one goes by the dynamical activity in the vicinity of a typical galaxy or in a cluster of galaxies, then one finds that there may be considerable amount of unseen matter present there. This conclusion is based on Newtonian dynamics and gravitation and thus poses the problem as to what this dark matter could be made of.

A first guess could be that the dark matter may be in the form of planetary masses or brown dwarfs, which are objects not massive enough to be able to shine as stars. The matter could also be in the form of dead stars which are no longer able to shine, or it could be made of black holes. However, none of these reasonable looking guesses meet the approval of the big bang cosmologists. The reason is as follows.

The most fashionable big bang model, the so called inflationary model, has the clearcut prediction of what the matter density of the universe should be. This value is some 30 to 100 times the matter density estimated to lie in galaxies, that is, in visible form. If this cosmological model is

correct, the rest of the matter must be dark. However, if it were in any of the forms mentioned just now, there would be trouble. For, this matter is "ordinary", being made of atoms containing protons and neutrons with which we are familiar on the Earth. This is generally called *baryonic matter.* Why would it spell trouble for big bang cosmology if all matter in the universe (dark as well as luminous) were baryonic?

Because, a consequence of this scenario is that it would be impossible to make the isotope of hydrogen, called deuterium, in such a universe. To explain the observed abundance of deuterium in the universe, one requires that the mean density of matter in the universe should not exceed ten percent or so of the value predicted by the inflationary model. This ten percent relates to baryonic matter. So to make up the balance, the rest of the matter has to be *non-baryonic.*

Another consequence of having all matter in baryonic form is that it would interact with radiation and make it lumpy rather than smooth. Just as we see matter in the universe distributed in lumpy form, like galaxies, their clusters and superclusters, so would we expect a significant inhomogeneity in the universal radiation. The lumpiness actually found in the background radiation is far too minute to be consistent with this prediction. So the solution to the difficulty is found by considering the bulk of the matter to be non-baryonic.

Exactly what do we mean by non-baryonic matter? To fill the bill required by the cosmologists the particle physicists have offered a host of possibilities. They are axions, photinos, gravitinos, massive neutrinos, etc. The only trouble is that they exist in the notebooks of particle theorists and have not been found in any experiments! What is more, most of them could be detected only if the present particle accelerators were enhanced in their energy producing capabilities a million million times. This goal is impossible to attain.

So in a bizarre combination of interests, the particle theorists say that their theories of high energy particles would be vindicated if we took the big bang model seriously and argue that such energies prevailed in the universe when it was a billion billion billion billionth part of a second old, while the big bang cosmologists insist that because particle theorists say so, such non-baryonic particles must exist.

That joining of two highly speculative conjectures should be interpreted as a confirmed certainty defies all scientific rationale. The trouble is that this subject is being taken very seriously and is now dignified by the name "astroparticle physics".

Judging by the history of astronomy over the last two millennia, I expect that only a major disagreement with observations would make the community think afresh the entire theoretical approach to cosmology.

Surprises for the Future

Perhaps the biggest myth that keeps reappearing in science time and again is that the end of the goal of a full scientific understanding of the universe is very close. This is again an anthropic prejudice which can be stated thus: *At any epoch the leading scientists wish to believe that the major problems in their subject have been solved during their lifetime and that only the mopping up work is left for posterity.*

Last century, with the quantification of thermodynamics and the formalisation of electromagnetic theory in Maxwell's equations, many leading physicists believed that the end of physics was near. They had not bargained for major revolutions like relativity and quantum theory. As late as 1980, Stephen Hawking felt that with the linkage between the very early universe studied by cosmologists and the very high energy physics studied by particle physicists, the end of physics was near. Today sixteen years later that goal still seems far off.

Scientists build major new facilities to confirm their theoretical convictions. Instead, successful facilities usually end up producing new puzzles to solve. Astronomy is no exception.

There are growing signs over the horizon that all is not well with the simple expanding universe picture which most cosmologists want to believe in. As our observational techniques improve at all wavelengths, e.g., through the usage of the Hubble Space Telescope, the Keck Telescope, the Very Long Baseline Array, etc., and of the more and more efficient detectors and spectrographs, discrepancies between theory and observation will grow. Some possible new discoveries, I can imagine, might be:

(i) the finding of inhomogeneity on a larger scale in the structure of the universe, say on the scale of 400-500 Mpc instead of the present scale of 50-100 Mpc,

(ii) the unequivocal confirmation that some objects in the universe have large redshifts that do not arise from the expansion of the universe,

(iii) the possibility of finding stars which are extremely old, say 40-50 billion years, which cannot be fitted into the present big bang models no matter how we tinker with their parameters,

(iv) the detection of blueshifts in some faint galaxies: a phenomenon that cannot be explained at all with the currently popular big bang models.

Or, what may be even more exciting, new observing facilities may throw up results that we cannot even imagine today. I can do no better than close with the words of J.B.S. Haldane:

The universe is not only queerer than we suppose, it is queerer than we can suppose.

KUMARI L.A.MEERA MEMORIAL TRUST

The Kumari L.A. Meera Memorial Trust was established on 28.8.1989 by Mr. L.K.Ananthakrishnan in Palghat, Kerala State in memory of his daughter, Kumari L.A.Meera. The Trust is dedicated to the service of mankind, with a wide range of activities in the fields of Physics, Mathematics and Computer Science besides Anthropology, and welfare and charitable activities. The Trust is managed by a Board of Trustees, the Managing Trustee being Mr. Ananthakrishnan.

The main focus of the Trust is to foster scientific interaction and activity in the fields of Physics, Mathematics and Computer Science in various scientific institutions, and encourage scientific education and advanced scientific research in these and interface areas by providing a few scholarships/stipends/awards for meritorious and deserving students. The Trust is committed to the development of excellence in Physics, Mathematics and Computer Science. It has instituted awards and scholarships in memory of Meera in several schools and colleges and has provided financial grants for upgradation of library, laboratory and computer facilities in a number of institutions in India. In addition it assists in the promotion of Sanskrit and traditional cultural values.

The Trust has instituted awards for the encouragement of excellence in Physics in the Indian Institute of Technology, Madras, St. Stephen's College, Delhi and other educational institutions.

The Trust also organises each year the Kumari L.A.Meera Memorial Meeting on Frontier areas in Physics. The first meeting in the series, on the topic 'Geometry and Topology in Physics', was held at Dhvanyaloka, Mysore from February 8 to 14, 1996.

The Kumari L. A. Meera Memorial Lectures

N. Mukunda	*'The Task of Picturing Reality'*	(1990)
V. Radhakrishnan	*'Flying Slowly'*	(1993)
G. Venkataraman	*'Parallel Computers'*	(1994)
V. S. Ramamurthy	*'Molecules to Materials – The novel transition domain of Clusters and Nano Structures'*	(1995)