

WAS THERE REALLY A BIG BANG?

By Jayant V. Narlikar

THE "universe", by definition, contains everything that has material existence. From the tiniest fragment of an atom to gigantic super-clusters of galaxies, everything is part of the universe we live in. Man's innate curiosity has always superseded his limitations of knowledge and the latter have never inhibited him from speculating about the nature, extent, origin and the future of the universe. Today scientists have largely replaced the philosophers and religious thinkers of the past in this game of speculation. The branch of science that deals with this field is called "cosmology".

Compared to the earlier speculations of our ancestors, modern cosmology starts with certain advantages. As a branch of science it is subject to scientific discipline. Its speculations must have roots in well-established laws of physics and they must be testable observationally. So the cosmologist today has a framework of science to help him formulate his ideas and he has at his disposal the latest astronomical equipment to check their detailed consequences. Were this not the case, cosmology would not have been admitted through the portals of science.

It was no less a person than Albert Einstein who in 1917 started cosmology on the scientific road. In that year Einstein published a classic paper in which he gave a *mathematical model* of the universe based on the equations of his newly formulated general theory of relativity.

What is a mathematical model? Just as a mechanical model describes the actual behaviour of a large system on a miniature scale (e.g. table-top models of a hydro-electric project, an electric railway, the operation of a coal mine, etc.), so does a mathematical model give a mathematical description of a simplified version of the real system. In the model proposed by Einstein, known as the "Einstein universe", the universe was taken as a uniform distribution of matter that was at rest. Galaxies like our own Milky Way were taken as points of matter in this vast system.

The actual size of our Milky Way is about a hundred thousand light years—that is, light would take 100,000 years to traverse a diameter of the galaxy. To what extent is it justified to take such a vast system as a point? Moreover, our galaxy is not uniform in structure and it has stars moving inside it.

Yet, Einstein's assumptions could be justified on the grounds that the size of the galaxy, large though it is by terrestrial standards, pales to nothingness compared to the present astronomical estimates of the size of the universe which are in the neighbourhood of ten thousand million (= 10 American billion) light

HOW and when was the universe created? There is the widely held "big bang" hypothesis of an explosion in the entire content of the universe which had been squeezed into a primordial point-like state, the fragments then moving away from one another to make up an expanding universe. But an alternative theory is that the universe, without beginning or end, has always been in a "steady state," its broad uniformity despite a balloon-like expansion being maintained by continuous creation of new matter.

years. Just as we regard water in a glass resting on a table as still and uniform even though on a microscopic scale it is composed of molecules dancing about at random, so can the theoretical cosmologist regard the universe as homogeneous and isotropic. Homogeneity means that all vantage points in the universe are alike and isotropy means that the universe looks the same in all directions.

While modern cosmologists would go along with these simpli-

fying notions of Einstein, they would differ from his assumption that the universe is static. The astronomical observations of galaxies shattered the concept of a static universe as early as 1929. Studies of the spectrum of light coming to us from a typical far-off galaxy tell us that the galaxy must be moving away from us at a substantial speed. Edwin Hubble who first discovered this systematic effect found that the speed of recession of the galaxy increases in proportion to its distance from us. The constant of proportiona-

lity is called Hubble's constant.

Although Hubble's discovery disproved Einstein's static universe, it did not disprove his general theory of relativity. In fact in 1922, Alexander Friedmann, a Russian physicist, had already obtained non-static models of the universe, models in which galaxies moved away from one another much as dots on a balloon do as it is blown up. Friedmann's models, together with Hubble's observations, led to the concept of the "expanding universe". As in the balloon analogy, imagine the space in which galaxies are embedded as points, expanding with time. In this picture any two galaxies move apart; a Hubble-type observer on any other galaxy will find exactly the same phenomenon of recession of the rest of the galaxies from him.

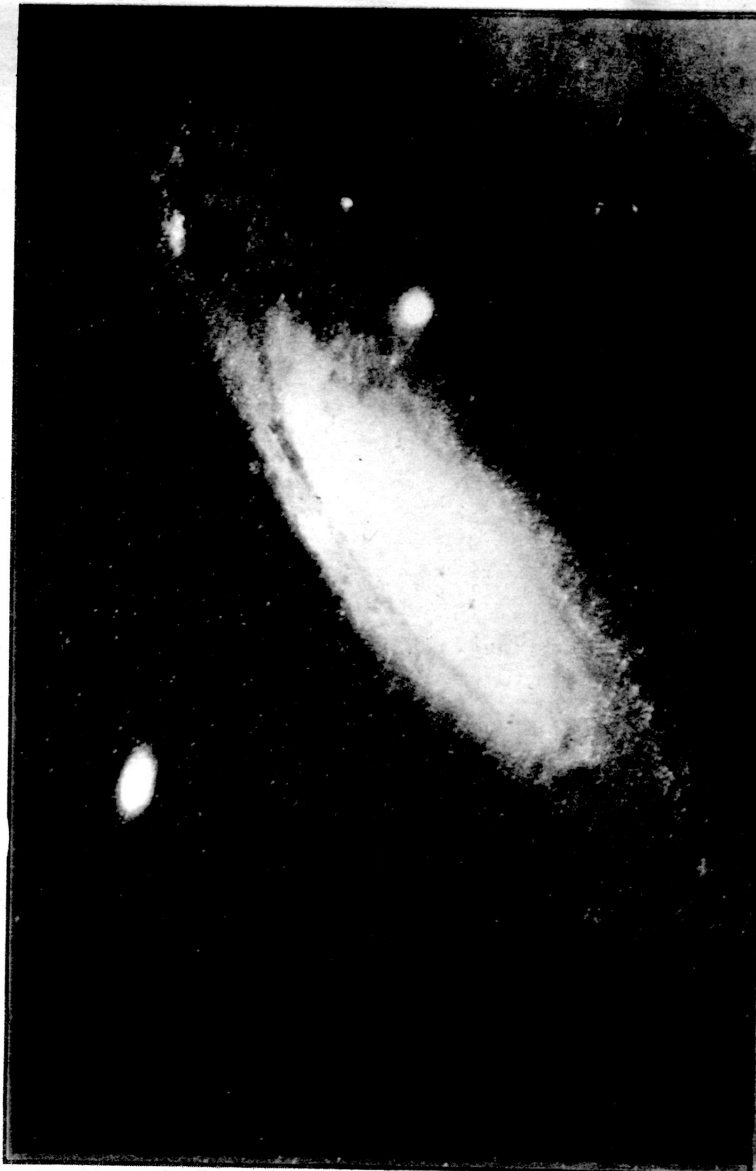
Friedmann's models, however, tell us a lot more about the universe than just what is happening in it at present. For example, they tell us that the universe has been expanding in the past from an initial state of zero volume and infinite density. Imagine all the contents of the vast universe squashed into a point-like state! Mathematicians call such a state "singular", since all their equations break down at this epoch. The physicists label the epoch as that of the "big bang", a gigantic explosion that created the universe.

The big bang model of the universe therefore envisages an epoch of beginning followed by expansion of the universe which has since slowed down, and will continue to do so. The slowing down occurs because of the gravitational pull of the matter contents of the universe. If the matter contents are sufficiently dense, the slowing down will bring the universe to a momentary halt followed by contraction back to the point-like singular state: an epoch of "big crunch". If the matter contents are not dense enough, the universe will keep on expanding until all its constituents are dispersed away from one another.

The big bang cosmology had a fairly uneventful passage through the 1930s and till the end of the 1940s. In those days astronomical observations of the universe in the large were few and far between. The physicists regarded cosmology as too speculative to be of real interest to them. Although brilliant minds like Abbé Lemaitre and Sir Arthur Eddington did a lot to popularize cosmology, the subject was really enlivened later, thanks to two important inputs in the late 1940s.

The first came from George Gamow who proposed the exciting idea that a big bang universe would have been very hot in the early moments; for example at

Continued on page 4



A galaxy like our own. If our Milky Way could be seen from outside, it would look like this galaxy (M31) in the constellation of Andromeda, containing about 100,000 million stars about two million light years away—which means that light, travelling at a speed of 186,000 miles per second, takes two million years to traverse the distance.

inside

INDIA IN FRANCE: C'EST MAGNIFIQUE Page 2

Sunil Kothari's recollections of the many-splendoured Festival in Paris.

SOME TV SERIALS ARE "SHOCKINGLY BAD" Page 3

Concluding part of the interview with Satyajit Ray.

WAGES FOR HOUSEWORK? Page 7

Ella Datta shows how this demand of Western feminists is not applicable in the Indian context.

LIFE WITHOUT LAWRENCE Page 11

A hundred years after D. H. Lawrence's birth, Supriya Chaudhuri discusses his relevance today.

IN DEFENCE OF WORLD CHAMPION STATUS Page 16

Kishore Bhimani's curtain-raiser on a busy season for Indian cricketers.

WAS THERE REALLY A BIG BANG?

Continued from page 1

the age of one second the temperature of the universe was estimated by him to be around ten billion degrees. Such a hot universe, according to Gamow, would act as a thermonuclear fusion reactor in which the chemical elements found in the universe would be cooked. Further, a relic of the hot epoch would today be a very cool radiation in microwaves. Gamow and his colleagues Ralph Alpher and Robert Hermann roughly estimated the temperature of today's radiation at around 268 degrees Celsius below zero. The work of Gamow, Alpher and Hermann thus brought nuclear and particle physics in contact with cosmology.

The second input came from three physicists, Hermann Bondi, Thomas Gold and Fred Hoyle, who proposed a rival model to the big bang hot universe. This model, known as the "steady state model", envisaged the universe as eternally expanding, yet maintaining an overall steady appearance. As galaxies get old and recede from one another new ones come in their place. This concept of continual creation of matter in a universe without a beginning and without an end was the opposite of the big bang notion in which all matter is supposed to have been created in one go. Since the steady state model did not have a hot dense era in the past, the origin of chemical elements in it had to come about another way. Astrophysicists Geoffrey & Margaret Burbidge, William Fowler and Fred Hoyle soon showed that chemical elements can be indeed are, created inside stars.

In the 1950s and till the mid-1960s the big bang versus steady state debate went on in different ways. Observational tests designed to probe the remote parts of the universe first claimed to have disproved the steady state theory by demonstrating that the universe in the past was different from what it is at present. Later appraisal,

however, made these claims inoperative. The observational uncertainties were too wide to categorically rule out the steady state model of the universe.

The blow to the steady state model came from another, unexpected quarter. In 1965 the measurement of the radiation in microwaves coming from outer space led two physicists from the Bell Telephone Laboratories, Arno Penzias and Robert Wilson, to a cool radiation background of temperature about 270 degrees Celsius below zero. If this was the relic radiation predicted by Gamow and his colleagues, surely it pointed to the big bang model as the correct one. Subsequent measurements indeed led to the strengthening of this point of view.

The spectrum of this radiation and its overall isotropy are strong arguments in favour of its relic character. A supporting argument also comes from the observed abundance of light atomic nuclei, mainly helium and deuterium. These are in such a measure that theoretically it is hard to see how they could be made in stars while they could easily be explained as the result of thermonuclear fusion in the hot universe.

While these arguments are considered overwhelming by the majority of astronomers, there are still some sceptics left to keep the debate going. For example, the age of the universe (that is, the time elapsed since big bang) according to the currently most popular big bang scenario is hardly long enough to accommodate the ages of galaxies, globular clusters and clusters of galaxies. How can the universe be younger than some of its own constituents?

The microwave background, once a strong point in the armoury of the big bang lobby, also poses problems for that model. The problem is that the background is far too smooth for com-



Crab Nebula, the expanding mass of luminous gases which resulted from a violent stellar explosion in the constellation of Taurus that was recorded by Chinese astronomers nine centuries ago.

fort. If a soldier claiming to have actively participated in fierce hand-to-hand battle returns absolutely unscathed, he will be disbelieved. Likewise it seems incredible that the microwave background should show no imprints of some of the important processes of the early universe, like, for example, the patchiness due to formation of galaxies.

Despite the application of enormous brain-power, the big bang cosmologists have yet to explain such important features of the universe as galaxies and clusters of galaxies, its composition (how much matter, how much antimatter, how much radiation), its apparent large-scale homogeneity and isotropy, etc. Recently Fred Hoyle has drawn attention to the likely inputs that questions of origin of life would make to our understanding of the universe. Hoyle argues that if life came about spontaneously then the overall lifetime of the big bang universe is far too short for the phenomenon to arise by chance processes. I have no doubt that biological issues will figure more and more prominently in the cosmological debates of the future.

On the theoretical side the singular origin of the universe which formed the basis of the big bang models becomes suspect within the framework of quantum theory. Just as the classical Newtonian mechanics has to be replaced by the new rules of quantum mechanics in the study of microscopic systems like atoms and molecules, so does classical general relativity have to give way to quantum gravity when the universe is of microscopic size. It is still too early to make a general statement about what quantum gravity will do to big bang cosmology; but preliminary work by this author and his colleague T. Padmanabhan indicates that the notion of "origin" in a big bang will turn out to be extremely unlikely within the quantum framework.

So the cosmic debate will go on. To me it seems hard to imagine that such a profound question as the origin of the universe will be solved so easily and so soon.