WHAT IS THE UNIVERSE LIKE?

J.V. Narlikar

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Fig 1. Photograph of the 200 inch telescope at Mt. Palomer, southern California, operated by the Hale observatories. (Photograph : Hale observatories)

I have chosen the title "What is the universe like?"
I should have added a few more words to it and said "What is the universe like to an astronomer or to an astrophysicist?" because the universe by itself means everything and it would mean a different thing to different people. So it will not be possible for anyone to do justice with the title as it stands and, therefore, I would like to say right in the beginning that I want to give you an astronomer's view of the universe: which is the large scale structure of the universe.

Now, if you look at the night sky you see stars, the planets and the moon; but you should also be aware of the fact that there is a lot in the space which your eyes cannot see. It is because the human eyes have limitations imposed by their biological construction. Man is aware of these limitations and has invented the telescope and various other types of apparatus which help him to observe the universe.

In the first slide (Fig. 1) I will show you one such apparatus—the telescope. In this case this is the biggest optical telescope in working condition. If you are thinking of a telescope as something which you put to your eye and look through, that is not the case here. In fact, instead of attaching the telescope to the eyes of human beings, the human beings can in fact get inside the telescope and look through. Instruments of various sophisticated types such as photographic plates, image tubes and the like are used to collect information as it comes through the telescope. Now I would like to take you on a short trip round the universe. I will like to describe you what the universe looks like through some slides.

I have, by the way, dropped the moon because I will come to it later in a different context. This is the planet Mars (Plate I, Fig. 2)—if we are going away from the sun the first planet that we will encounter. Let me say something about its distance from here. We take distance from our sun as a unit, which is called in technical terms the astronomical units that is about 150 million kilometers. That is the distance and you can work it out (if you know the speed of light) that it takes about 8 minutes for light to come from the sun to us (earth). Now, compared to this astronomical unit, Mars is 1.6 astronomical units from the sun.

The Planet Jupiter (Plate I, Fig. 3) which is

further away. It is about 5.2 astronomical units, i.e., more than five times further away from the sun than the earth is. Then we go to a more remote planet which is about ten astronomical units away from the sun. Now one could go on in this fashion and I could tell you that the furthest well-established planet in our solar system at present is Pluto which is about 39.5 astronomical units or nearly 40 times further away from the sun than our earth is. So let us leave the solar system and go a bit further out, and see what we have in our OWN GALAXY which is a multitude of stars. But before that let me mention COMETS which come and go from close to the sun and disappear and can be very far away—almost well beyond the remotest planet and then come again. Their orbits are different from the orbits of planets. The Halley's Comet which comes every 75-76 years is expected again around 1986. As we leave the solar system we encounter vast collections of stars, gas and dust which form what is known as NEBULAE. A nebula is a bright object and there are many such nebulae in the MILKY WAY system in our galaxy.

In the next slide is shown a very interesting object. It is called the CRABNEBULA (Plate II, Fig. 4) and it contains a lot of information of different types for the astronomers; it was first seen, according to the ancient records available, by the Chinese and Japanese astronomers in the form of very bright stars even during the day time. You can imagine how bright it must have been. But it did not last like that for very long; it lasted probably a day or two and then it disappeared, which means, it became very faint and now you cannot see it with naked eyes. But when you take a picture you see something like this which appears to have a lot of filaments and there is an evidence of an explosion at the centre of this object. Now what does it mean? It means that there was an exploding star, a star which was seen to explode in the year 1054 on the 4th of July, according to the records. Now, this is known as a remnant of a SUPERNOVA. A supernova is an exploding star. A star explodes when its interior gets too hot and it becomes unstable and it blows off its envelope, that is, its outer region. This seems to have occurred 900 year ago. One can ask the question why it was not seen in India. Certainly we do not seem to have records available. One explanation given to me was that since it was in July, it might be that in the monsoon period the sky was cloudy and this is as good a reason as any.

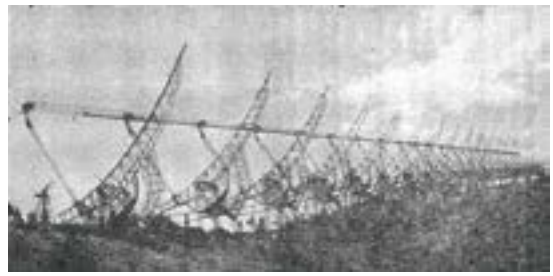
In the next slide is shown (Plate II, Fig. 5) the whole band of the Milky Way. It means if you look at the Milky Way which is the star system to which we belong, you will see that it is spread all round you and you may ask how many stars are there. The answer is that there are something like ten thousand crores of stars in the Milky Way system.

Let us see the next slide. It tells us what our galaxies would look like if we went on a space trip and looked at it from outside. This is our neighbouring galaxy, called ANDROMEDA (Plate III, Fig. 6).

This is another slide showing a galaxy further away than Andromeda and you can see that it has a spiral structure (Plate III, Fig.7). And this is why it is called a SPIRAL GALAXY. There are many galaxies of this type. Then there are galaxies which are elliptical in shape and they

are called ELLIPTICAL GALAXIES. There are also irregular galaxies which do not show any special type of structure. It is of interest because something
strange may be happening in it and the astronomer is always interested in extraordinary or strange phenomena which occur in our galaxy or elsewhere.

Now, so far I have been describing to you the Universe through pictures which have been taken with optical telescopes of the type which I showed to you right in the beginning; but this is not the only instrument available. After the Second World War, astronomers started looking at the Universe through a different window, as it were. They used the RADIO-TELESCOPE to measure and see what the Universe is like in the radio band of the electromagnetic spectrum and the interesting thing was that when they directed the radio-telescopes in different directions they got some very strong signals coming from certain regions of the space. So, just as you have galaxies all over the Universe of the type I showed you, there are things which are called the RADIO-SOURCES which emit the RADIO-WAVES which we can receive in the receivers of our telescope. Now, the radio-telescopes are always very big in size compared to an optical one. The reason is that the radio wave-length is considerably longer than the wave-length of visual light. And, therefore, to achieve the same degree of sensitivity in the technical term you have to have a much larger collecting area.



The radio-telescope at Ooty, operated by the Tata Institute of Fundamental Research

In the next slide (Fig. 8) is shown the radio-telescope at Ooty. You can see how big a radio-telescope can be. Indeed there are different types of radio-telescopes of different shapes and they do different jobs. The Ooty telescope is about km long and its axis is parallel to the axis of rotation of the earth. It is easier to build such a telescope closer to the equator than at high latitude. Now, one of the first radio-sources to be discovered was called CYGNUS A, as it was in the constellation of Cygnus. After its discovery, the optical astronomer wanted to see what was there in terms of visual light.

The optical photograph showed what at first looked like a pair of colliding galaxies. However, astronomers no longer believe in this hypothesis. They can now say definitely that there is no evidence of collision in the case of Cygnus A. In the next slide is shown the radio-source
C centaurus A, Plate IV, Fig.8) which is located near a big galaxy. The astronomers found that it has a central component which is showing signs of explosion and these explosions have posed an unsolved problem in the present-day astronomy. People want to know what these explosions are

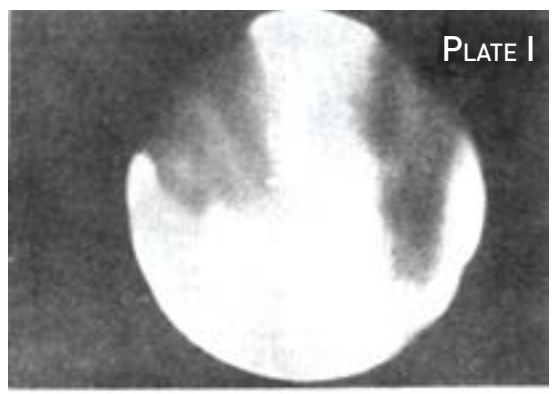
due to.

So far, I mentioned to you about optical (visual) astronomy and RADIO-ASTRONOMY. Let me now come to other branches of astronomy which became possible after space programmes materialised. The reasons are as follows:

So far as radio-waves and visual light are concerned, we can receive them on the surface of the earth without any absorption from the atmosphere in between. But these form part of a whole range of radiations which are collectively called the ELECTROMAGNETIC RADIATION and which have several different aspects. There are X-rays, γ rays, microwaves and so forth. Now all these other waves cannot be seen from the surface of the earth. So, after the space programme became possible, people could send up balloons, rockets, satellites well above the atmosphere and put in receiving instruments to get these types of radiation. In this way, in the last 10-15 years people began to look at the universe through the microwave, through γ rays, X-rays and so forth and this is yielding very interesting information.

One information that I can describe to you, which has become relatively popular in the recent days, is the so called discovery of a BLACK-HOLE. Let me first explain to you what a black-hole is and in what way one could claim that it has been discovered. Now you take any object, say, the earth. The surface of the earth has strong gravitational attraction for all the objects which are situated on it. If you throw any projectile or any ball in the sky it comes down because the earth's gravity pulls it. No, you can imagine the situation that the earth is made to shrink. What will happen is that on the surface of the shrinking earth the force attraction will go on increasing very rapidly. These days we have enough rocket power to send out a spacecraft from the earth's gravitational field. But this may not be possible with our present rocket-power if the earth was shrunk a little because it has now a stronger pull. So let us imagine this thought experiment and keep on compressing the earth and you can imagine that greater and greater rocket power will be needed
to push anything away from the surface of the earth.

Now the quickest thing which travels in the universe, so far as we know, is light and light has no difficulty to get away from the surface of the earth. But can we imagine a situation where the gravity has become so strong that even light cannot escape from the surface of the earth?



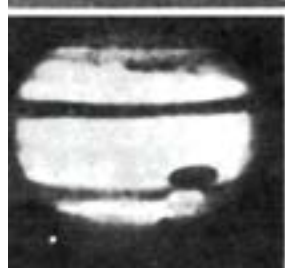


Fig. 2: The Planet Mars (Photograph : Hale observatories

Fig. 3: The Planet Jupiter (Photograph : Hale observatories)

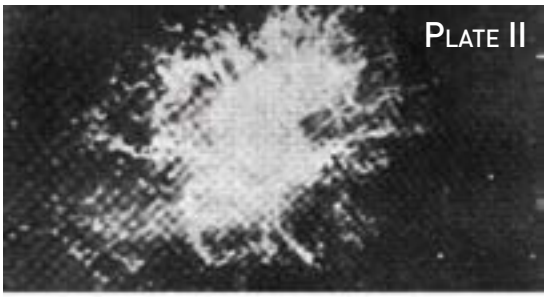


Fig. 4: The Crab Nebula (Photograph: Hale Observatories

Fig. 5: The Milky Way (Photograph: Hale observatories)

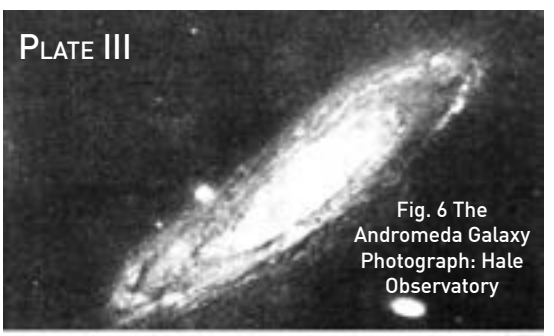


Fig. 6 The Andromeda Galaxy Photograph: Hale Observatory

Fig. 7: The Barred Spiral Galaxy (Photograph: Hale Observatories)

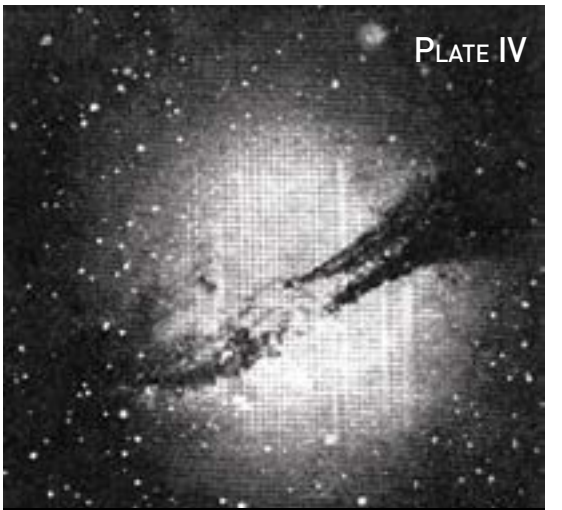


Fig. 8 Centaurus A, a Strong Radio Source (Photograph: Hale Observatories)

How much should the earth shrink in order that even light cannot escape from its surface? The answer is that it should shrink to a radius of about 0.8 cm. Imagine the whole earth shrunk to the size of a cherry. What happens then? So far as anybody outside is concerned, he cannot see this object (earth) because no light can come out of it. In order to see any object it should either be self luminescent or if you bounce light off it, (say, shine a torch light), it comes back to you. Either way, if light cannot escape from the surface of this object it won't be seen. So it is totally black and, therefore, it has been given the name of 'black hole'. The reason for calling it a hole is as follows— anything that approaches it, just falls in it and cannot come out. If there are black holes in the universe, how do we know of their existence when a black hole is not visible? It cannot emit anything that would reach you. And so if anyone comes and says that he has seen the black hole you can straightway say this is a

lie, because you cannot 'see' a black hole.

Then how do you find that there are black holes in the Universe? Let us imagine another experiment. Suppose we compress the sun and make it a black hole so that it becomes invisible. It will continue to attract us; that is the earth will continue to go round the sun but we won't see the latter. But we can deduce the existence of the sun from the fact that we are not moving in a straight line. This is the principle behind the detection of a black hole that it exerts gravitational pull but it is not seen directly. The scenario where a black hole has been seen or is claimed to have been seen is the following:

Supposing you have got two stars going round each other (planets go round a star; you can similarly have two stars each going round the other). It is called a DOUBLE STAR SYSTEM. Now suppose one of them is a black hole and the other is a bright star. If you look on such a system you will see the big star going in a circle but about apparently nothing! You can calculate how much should be the mass of this particular object which is invisible. People have deduced the following things.

They have seen a thing which is going round about something which is not seen. What is more, this 'something' which is not seen is claimed to be the black hole. Now this black hole attracts matter from the other companion star and this matter is forced into this hole because of its attraction and in the process of pouring into this hole it becomes very fast, develops high temperature and emits X-rays. It is these X-rays which have been detected by the astronomers. Then they saw X-rays coming from a source called Cygnus X-I (that is, X-ray source in the constellation of Cygnus).

This X-ray source has been identified with a star which is apparently going round another star which cannot be seen. So the astronomers argue that this other thing must be a black hole. There are various theoretical reasons for supporting this conjecture but there are also equally good theoretical reasons for doubting this conjecture. Because, after all, all the theories are based on certain assumptions and when you come right down to the brass tacks, you find that there is always some kind of uncertainty in the assumptions. So, currently there is not a universal agreement among the astronomers that a black hole has been detected. But this concept of black hole has generated a lot of excitement among theoreticians because they can work out various theories or phenomena which are associated with the very strong gravitational field which is in the vicinity of a black hole. A lot of research in the last ten years has gone into black hole physics.

Along with this black hole idea there is another type of hole that people talk about. This is the WHITE HOLE. A black hole, as I mentioned, is something which is shrinking, and as a result, is becoming highly compact. The phenomenon of white hole, on the contrary, is an indication of an explosion which is taking place somewhere. Now I describe to you the case of Centaurus A which is a radio source. This concept of white hole would be relevant to those places in the Universe where the astronomer is detecting explosions which are not accountable by any other means. Again, this is not a concept which is fully established. People are trying to see how

far it can be made to apply to what is actually seen. I would not like to say that this is a well-established fact. As in the case of black hole, here also is still some uncertainty. But both the black hole and the white hole form a very interesting aspect of modern physics which has been generated largely because of astronomical observations.

Now, so far I was talking about lifeless things in the Universe. And there is always a lot of speculation among the intellectuals on this earth as to whether there are intelligent human beings or intelligent beings elsewhere in the Universe.

Let us see what is meant by intelligent beings. The origin of life is broadly associated with those phenomena in nature where there is a generation of order starting from disorder. The reverse happens in the behaviour of inanimate systems. That is, if you take a cup and drop it on the ground it breaks. The original position of the cup was a well-ordered arrangement of molecules which finally became disordered.

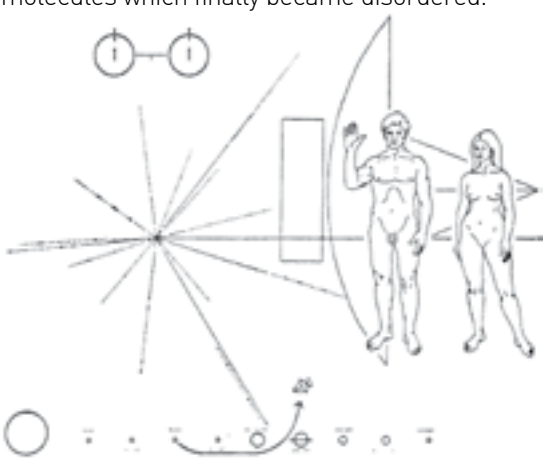


Fig. 9 : The Plaque in Pioneer 10 has information about the location of the earth and the human species.

In the physics of inanimate objects, the thermodynamic term ENTROPY has been used as a measure of disorder: the entropy always increases, or at most stays constant. Now where there is life, the reverse takes place. All kinds of chemical elements get together, form molecules and then they express 'life'. Wherever this happens one could say that there is a possibility of life. Now the nebulae which I mentioned earlier have been looked at by radio astronomers also and they find with their radio telescopes some very complex organic molecules in the space. This has led to increased interest in the last 2 or 3 years about whether these molecules indicate that life is actually possible and is being evolved in the outer space. Some scientists have conjectured what could be the conditions under which life could form in the Universe. For instance, one could go by the analogy of life on the earth and could say that there may be a star which has a planetary system and one of the planets has a suitable distance from the star, and it is hot enough or cold enough to generate life and then sustain it. You can make some very crude statistical calculations and estimate how many civilizations could exist in our Universe. The number of advanced super civilisations in our galaxy is estimated at a million. This has led to speculations as to how we can contact them or whether we should contact them or not, because it may not be to our advantage.

I will now discuss very briefly some of the procedures which have been advocated in trying to contact these extraterrestrial intelligent beings and we will see which is the best way to do it under the existing possibility, that is, our limited technology. The first thing that comes to our mind is now that we are entering

the space-age why not design spacecraft and take astronauts on trips to long distances and see whether life exists elsewhere. Now if you consider the elaborate things that went on the lunar trip, that is, .in the outer space, you will realise that this approach is not very efficient.

What one should remember in this case is the following: if you send light to the moon it hardly takes a second or two, whereas this rocket took about a week to go and come back. Now, if you want to examine whether there is life in some nearby stars, some 3 or 4 light years away, light will take 3 or 4 years to get there. How long would the spacecraft take to go to such a distant object and come back? It will certainly take much longer than the human life time! So even if you want to explore the nearby stars for intelligent life, the matter of sending an astronaut, at least at present, is not feasible. You might devise some means of freezing the people so that they don't age as they go. They can go and come back after a thousand years and you may not be here to see them but they may come back with some information. But that is not a very practical point of view. So, let us take up the next idea which is to send unmanned spacecrafts. The unmanned spacecraft means the following:

You set up the scientific instruments and let them work for you. This is what was done for the landing mission to Mars. Likewise, the Pioneer 10 spacecraft was sent to go beyond the solar system. If you are lost in the sea you throw a bottle with some information in it and somebody can pick it up and then look for you. In the same way, this spacecraft contained information about the earth, 'written in a cleverly designed code (Fig. 10).

Here is another method which is as follows: Suppose two people are talking to each other and you listen through the key-hole. The idea is that you are, of course, not good enough to be admitted to their conference but at least the best you can do is to hear something. So you design the key-hole, which, in this case, is a gigantic radio-telescope. Because these signals are travelling they are supposed to be travelling over vast distances. So the suggestion is made, that you should simply design huge telescopes and direct them to outer space and hope for some meaningful signals to come.

One such project is called Project Cyclops, which consists of something like a thousand dishes each of a diameter of 100 metres. You can imagine how big this will be. You put this in a desert-like place which has no interference from anything else and let it just survey. You can use it to see if there is any pattern in the signals — codes of dots and dashes. If you get regular signals then you can hope for some intelligent sender behind it.

I have tried to give you some description of what the Universe is like, in as simple terms as possible. I would just like to remind you that all this information I am giving you is incomplete.

The best comment on this found in literature was a statement made by the famous astronomer Eddington long back in the 1920's. He compared man's position in the Universe with that of a potato bug in a potato inside a sack

placed in the basement of a ship floating on the sea, trying to know what the sea is like. So, in the same way, we are in this planet of a solar system which is part of a galaxy and which is in turn a part of a system of galaxies in a small part of the Universe and we are trying to look, through all these limitations, what is beyond. What is encouraging in this is that such little science as we know can form a coherent picture. We should not delude ourselves that this is a correct picture or a complete picture but it is a coherent picture which is emerging. Maybe, it will form the first step towards a better picture that our successors will evolve. This is therefore a subject of enormous and growing interest and if you invite me to give another lecture on this topic ten years later, I may have something completely different to report on this subject.

STAR-GAZER HERSCHEL

One of astronomy's commanding figures was just an amateur when in 1781 he startled the professionals with his discovery of the planet Uranus (the seventh planet).

Since the days of Galileo, no telescopic find had created a greater sensation than Uranus. Before Herschel became world famous as the discoverer of the planet Uranus, he was almost completely unknown in professional circles... He was, in fact, a musician...who had only been engaging in astronomy as a hobby for a very short time...

He employed a completely new type of telescope, so unusually wide that a man could put his head into the tube. The metallic mirror at the lower end was twice the size of all known telescopes...His method of searching, what he called sweeping, was also an important factor in his great discovery. Every night he took a strip of sky of about two degrees. He went through it twice in order not to miss anything...

In all fields he outstripped his colleagues. If some German found a few dozen binary stars, Herschel discovered several hundred. If a Frenchman listed sixty nebulae, Herschel soon afterwards published a catalogue of a thousand.

At the age of thirty-six he became the music master at Bath...After his fourteen-hour working day as a musician, he sat up half the night reading enthralling books on the calculus of fluxions, theoretical optics and mathematical astronomy.

–Science, Science, Science, selection by Russell Hamilton, Frankon Watts 1960