

ARE WE ALONE IN THE UNIVERSE?*

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Let me at the outset thank the organizers of the IAC-BBV Programme of Colloquia for their warm hospitality to me and my wife. We have not been before to the places we are visiting this time and we are enjoying every moment of our stay in Spain.

Coming now to the topic of my lecture today let me confess that I am not an expert in the field, but I do retain a great deal of interest in the question as to whether there exists intelligent life beyond the confines of our Earth, somewhere in this vast universe. Of course, judging by the way the humans behave on some occasions, one may question whether intelligent life exists on the Earth!

Are we alone in the universe? Is the Earth the only habitat for intelligent life? Or is our universe full of advanced extraterrestrial civilizations? More than speculations, what scientific evidence can we look for in order to settle these questions? And, if such civilizations do exist, how can they be contacted?

In this lecture, I will discuss these issues which, in recent times, have brought together not only astrophysicists and biologists but also experts in computer science and artificial intelligence, communications technologists, social scientists and so on. What has happened in recent times to bring together experts in such diverse fields to discuss questions that only four decades ago were thought to belong to the subject of science fiction? I will answer this question in course of this lecture.

But, before talking about the present, some remarks of a historical nature are in order. Ancient civilizations in India and elsewhere had wondered about extraterrestrial life. Indian mythology contains references to Devas, Yakshas and Gandharvas, to say nothing about the Rakshasas, for example. These were superior to humans although not always benign! Mythologies of other cultures also contain such records. From mythology to recorded history, we find the doyens of Greek scholars, Plato and Aristotle, debating the plurality of life. To the Greeks, who regarded the Earth as the centre of the universe, the idea that life might exist elsewhere was unacceptable; for it would rob the Earth of its unique status and man, his paramount position in the universe.

The Christian cultures that succeeded the Greeks in Europe likewise regarded the Earth and Man as unique and special. The concept of a 'Saviour' being sent by God was inconsistent with other living beings elsewhere. For, if they existed, would they also not need a saviour? However, the Copernican revolution dethroned the Earth from its central position in the universe and a climate was created for thinking that man too did not enjoy a unique status so far as intelligent beings are concerned. In the more recent past, over the last 100 years or so, science fiction has freely brought in the extraterrestrials or taken the humans to extraterrestrial civilizations.

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From science fiction to hard science brings us first to examine the life that we know here on the Earth. The exciting developments in molecular biology, especially the discovery of the structure of the DNA molecule in the 1950s, have advanced our understanding of living systems in a big way.

The DNA molecule is found to be basic to living species on the Earth. It has a complicated structure resembling a spiral staircase. The 'double helix' of DNA has two strands of sugar and phosphate molecules interconnected with chemical bases, often labelled for short by A, C, T and G. The main components of DNA come from hydrogen, oxygen, carbon and nitrogen, and the precise arrangement of the various subunit molecules into the entire scheme is complicated enough to lead to the impression that 'life' is not simple. Would a random juxtaposition of jigsaw pieces make a coherent picture? Hardly! Likewise it may be an 'accident' of a very low probability that might have generated life on Earth.

This line of reasoning makes biologists as a rule very pessimistic about the accident repeating elsewhere. For, not only must DNA be somehow assembled but the next step (about which present-day biology has no information or clue to offer) towards the living system must also be somehow taken. It is hard to say on the basis of the present imperfect knowledge, what are the odds against life occurring spontaneously elsewhere. I mention this point since it is the first amongst the many imponderables that we will encounter in our quest for extraterrestrial life.

From the pessimistic view of biologists I now turn to the optimistic view of astronomers.

How Big Is The Universe?

Modern telescopes are a far cry from the pioneering instrument of Galileo. From 1609 to 1985, the span of nearly four centuries has seen a considerable enhancement in man's perception of the universe. Most of it has come in this century and a large fraction of it in the post-World War II era.

Galileo was the first to use a telescope for astronomical observations. That was in 1609. Although there were hostile reactions to the telescope at the beginning, this was largely due to the new and unusual discoveries made with it. Findings like craters on the Moon, dark spots on the Sun or the satellites of Jupiter did not fit into the prevalent concepts of the cosmos. Thus, to those who looked upon creation as perfect, the idea of pock-marks on the Moon and black spots on the Sun was unappealing. Likewise, with the belief that the whole cosmos revolves round the Earth, one found it hard to think of four moons going round Jupiter. Hence Galileo's contemporaries viewed the new device with suspicion.

However, within a few decades, the telescope became well established and an indispensable part of astronomy. As technology improved, the telescopes also became bigger and better. Likewise, there was improvement in instrumentation that went with the telescopes; for it became clear in due course that instruments can perform better than the human eye in collecting and analyzing the light collected through a telescope.

To contrast the Galilean telescope with the modern ones, by way of example, whereas Galileo had to hold the telescope to his eye, the modern telescope is so big that

a human observer can get into its eye! And the technologies of post-World War II era gave us new types of telescopes that catch cosmic radiation that is not visible to the human eye. Thus, huge radio telescopes began to be built. And with space technology astronomers could build an ultraviolet telescope which had to be carried in a satellite above the Earth's atmosphere. This is because the ultraviolet and many other forms of radiation are absorbed by the Earth's atmosphere and telescopes for these have to be out in space.

I have given these examples to illustrate how we are widening our horizons and improving our perceptions of the universe. So, with the high quality telescopes and instruments available today astronomers have before them a vast panorama of stars and galaxies. Let us briefly look at them, starting with the galaxy of stars of which our Sun is a member.

The Milky Way that appears as a white band across the sky is actually part of our own galaxy seen from inside. The galaxy contains some 200 billion stars of which our Sun is one. It has a spiral structure spread across a flat disc of diameter nearly 100,000 light years, with a central budge. Light year is the distance travelled by light in one year and it is approximately 10,000 billion kilometres. Our Solar system is nowhere near the centre—it is some 30,000 light years away from it. This is just as well; for the immense activity around the Galactic Centre would hardly be conducive to growth and support of life.

The Universe extends well beyond our galaxy. As far as our best telescopes can see, which is many billion light years, the universe is filled with galaxies. Thus, our galaxy is by no means unique and is in fact quite an ordinary member of this extragalactic world.

interstellar Dust Curtails Visibility

But let us concentrate next on the space within our galaxy, the vast interstellar space that appears to contain gas and dust. Although both are extremely rarefied, they can be detected in bright and dark nebulae. The interstellar dust (like the dust pollution on the Earth) curtails visibility and has led to the so-called dark nebulae in astronomical photographs. One such spectacular nebula is the Horsehead Nebula.

The early part of the decade of 1960s brought in millimetre-wave telescopes, which gave us the important information that interstellar space also contains complex chemicals, inorganic as well as organic. These could be detected because of millimetre-wave telescopes that can pick out waves coming from radiating molecules.

From the point of view of life in the universe this information is very interesting—for, these molecules are subunits of the life supporting the DNA molecule I mentioned earlier. So, the building blocks are out there in space and astronomers may be forgiven for being optimistic about life existing elsewhere in such a vast universe.

But let me now leave behind the prejudices and hunches of biologists and astrophysicists and come to the main part of my talk.

Just how does one go about estimating the number of extraterrestrial supercivilizations in our galaxy? The estimate may be made with the help of an equation attributed to Frank Drake, a radio astronomer who is one of the optimists

about extraterrestrial intelligence. Do not be frightened by the word equation: It is in fact quite simple to understand. The Drake equation helps us to calculate N , the number of extraterrestrial supercivilizations in the galaxy, as a product of several factors:

$$N = R \times f_s \times f_p \times n_e \times f_i \times f_y \times f_c \times L,$$

where the different factors have the following meanings:

- R = average rate of star formation in our galaxy. (Here we are primarily interested in stars which will resemble our Sun when they begin to shine).
- f_s = fraction of stars that have planetary systems. (We presume life to be based on a planet and living on the star's energy).
- f_p = average number of planets in a planetary system.
- n_e = fraction of the total number of planets in the eco-shell that may be suitable to house life. (Not all planets may be suitable; some may be too near the star and hence too hot, while some may be too far and too cold. Also the chemical composition has to be suitable. In our Solar system only the Earth seems suitable).
- f_i = fraction of planets on which life actually originates. (The biological factor between 'suitable' and 'actual' is involved here).
- f_y = fraction of planets on which intelligent life evolves. (We are interested in 'advanced' life not primitive ones).
- f_c = fraction of planets on which communications technology develops. (Only such civilizations will contact or could be contacted by others).
- L = lifetime of the supercivilization. If its 'advance' generates too many tensions and complexities for its survival, it will be hard to detect.

The present information on the various factors of this interdisciplinary equation is woefully inadequate. Let us begin with the first of them. In a giant molecular cloud we can see a typical location in the interstellar space where star formation is going on. This is the cloud called the Orion Nebula.

One Sun-like Star Born Every Year

Star formation takes place when clouds of gas contract into hot balls that begin to shine, eventually producing their radiation through nuclear fusion in their cores, as the Sun does. Before they get into this stage, however, the proto-stars begin to shine in infrared and it is this type of radiation coming from such a cloud that tells the astronomers that new stars are being born there. So the baby stars in this stellar nursery may be barely a few 100,000 years old! Based on such evidence the astronomers estimate that on an average one star like the Sun is being born in the galaxy every year.

What about planetary systems around stars? Planets are not self-luminous and so visual telescopes find it very hard, almost impossible to spot planets around other stars. Recently, however, evidence was found in the infrared, with the infrared astronomy satellite, which was launched in 1983. The IRAS, as it is commonly called, found proto-planetary rings around a few stars like Beta Pictoris. It is believed, that our own planetary system formed from such a disc around the Sun. Thus, even though planets

around other stars, like the Sun, have not so far been detected, the astronomers believe that the process of planet formation may be a fairly common one.

I have already commented that simply a planet around a star is not enough; as the example of the Earth shows, the planet must be in the eco-shell. The next question, of how life begins and evolves to an intelligent species, belongs to biology and here we still have large gaps to fill. Several questions arise concerning the remaining factors in Drake's equation.

How does intelligence develop in a biological system? How can we rate intelligence in an ascending ladder? What criteria can be set for judging the progress along the ladder of communications technology? And, how long can a supercivilization last? These are questions still to be answered.

It is clear, therefore, that the final answer N to Drake's equation cannot be given yet with any degree of confidence. This has of course not stopped scientists from speculating and the results, as can be guessed, lie in a wide range. For the pessimists $N = 1$ (the Earth is the only location of life), while for the optimists $N =$ several billion. The 'middle of the road' opinion sets N at about a million.

Because the determination of N in a precise manner is not possible, arguments for or against ETI, that is, extraterrestrial intelligence, are considerable in vogue amongst the optimists and the pessimists. Here we consider one of two examples of such arguments.

Questions Not Easy to Answer

It could be argued that if ETI becomes so advanced that its members can undertake interstellar travel, then a handful of such civilizations would eventually spread all over the galaxy in an urge to colonize. This is a very debatable issue: What sociological factors urge a culture to spread out to remote places? If the star with whose energy the culture is being supported on the planet, turns hostile to life on that planet (as for example the Sun will one day become for us), then the survival instinct may drive the members of the culture elsewhere. The spirit of 'greener' pastures, or 'adventure', or the problems of natural resources or overpopulation are other causes. But, whether these causes are relevant to advanced civilizations as they are to us or whether new causes will urge them to colonize or whether they will be so satisfied with their lot that they will not feel like colonizing, are questions which we cannot answer easily.

But if they do colonize then it is a relatively simple matter to set up a mathematical model of how the colony will develop and spread. The answer, that the spread and bifurcation into more groups that cover more and more stars will lead an interstellar civilization to spread all over the galaxy in a matter of 10 million years, suggests that if colonization does occur it will lead to a large value, say $N = 10$ billion.

F J Tipler has very cleverly turned this conclusion into a proof that we are indeed alone in the galaxy. Tipler argues that if N were really so large as 10 billion, then we on the Earth should by now have been colonized by the superior extraterrestrials. The fact that we are not, means that there are no ETIs at all!

When Tipler argued in this way the optimists countered by saying that perhaps colonization is not so common because of the problems of sending live members on journeys lasting thousands of years as interstellar travel must do. The vast amount of

energy may also deter them from undertaking interstellar travel. Thus $N = 10$ billion may be an overestimate but N might still be as high as 10 million, say. Ten million is not a large enough number to crowd the galaxy and the lack of invasion of the Earth can be explained by saying that the nearest ETIs are several light years away.

To this Tipler has countered by invoking the concept of self-replicating machines. This concept was proposed by John Von Neumann in 1966 and it visualizes high-level technology-producing machines that can reproduce their replicas if materials are available. Computers that can programme themselves are essentially like human brains, and it is estimated by some experts that such computers and even Von Neumann machines may be possible in a human technology of a hundred years from now. So, argues Tipler, that colonization may not require living explorers; Von Neumann machines can equally well spread their culture all over the galaxy. Since we have not been invaded by such machines, they do not exist.

A new issue into the argument was introduced by the optimists, under the so called 'Zoo Hypothesis'. This hypothesis admits that we are indeed watched and surrounded by the ETIs who have colonized the galaxy, but we have not been interfered with as a matter of policy. Just as animals in a zoo or birds in a sanctuary are kept protected so are we. The ETIs are studying our growth and progress up the technological ladder as a part of their experiment in social sciences!

Search For ETI

I leave the debate at this stage, having convinced you that the matter remains unsettled one way or the other. An alternative to pure discussion and speculation is of course experimentation. Science has always advocated this alternative without which no progress could have been made in it to date. In this spirit, G Cocconi and P Morrison advocated, in 1959, a search for ETI. Known as SETI we can visualize three different ways this search may proceed.

The obvious method that comes to anyone's mind is sending manned spaceships on exploratory trips—just as Columbus, Magellan and other explorers went on exploratory voyages. Indeed, Spain has played a pioneering role in such explorations of the Earth. A closer consideration will convince the enthusiast that so far as SETI is concerned, it is not a practical proposition at least at present. For, consider the farthest manned voyage to date, to the Moon. The trip to and fro took about a week; by contrast light takes about two and a half seconds for the return journey. Suppose, by improved technology the return journey time to the Moon is reduced to two and a half days, that is, 86,400 times the time taken by light.

To search for the extraterrestrials on planets (assuming that they exist) around the nearest star, Proxima Centauri, the same technology will take about 700,000 years! For, the return journey to this star takes light about 8.5 years. Clearly, technology of rocket propulsion has to improve tremendously to bring down the duration of the trip to less than the human life span.

The British Interplanetary Society made a feasibility study, known as Project Daedalus, of such a visit to the Barnard's Star which may have a planet. This star is located six light years away, so that at the speed of light the return trip will take 12

years. Project Daedalus envisages a trip over a period of 100 years, the spaceship being propelled by nuclear-powered rockets. For a payload (including ship's mass) of 4,000 tonnes, the fuel needed is of 50,000 tonnes. The study presumes that fusion technology can be employed for nuclear power generation. The nuclear fuel required for the trip is just about equalled by the nuclear stockpile of all weaponry on the Earth! Perhaps such a trip may be recommended if only to get rid of this stockpile.

Martian Experiments Inconclusive

A more practical proposition seems to be to rely on unmanned space explorations. For example, an experiment was conducted by the Viking spacecraft which landed on Mars in the mid-seventies. Some chemical and biological experiments were carried out by remote control to look for bacterial form of life in the Martian soil. The results were negative and so the conclusion was drawn that there is no life on Mars. But, I understand, that the experiments were not as conclusive as reported and the issue is still open. Explorations by future landers on Mars in the next century may give us more precise results.

Another possibility is of fly-bys as performed by the Voyager spacecrafts which went near outer planets like Jupiter, Saturn, Uranus and Neptune and took many spectacular pictures, especially of Saturn. Future technology may permit even closer views and these might indicate possible existence or otherwise of life on these planets or their satellites. However, a rather unusual attempt towards SETI was initiated in 1972, which is worth reporting.

Imagine that you are lost on the high seas on a raft and you throw a bottle into the sea with a message about yourself, in the hope that someone may pick up the bottle and come to help. Something like that was done in 1972 when a spacecraft called Pioneer 10 was launched on a voyage into space. The spacecraft contains a plaque with information about the Earth and its inhabitants, human beings. The hope is that as the spacecraft leaves the Solar system and continues its journey farther out, some advanced extraterrestrials might pick it up and reading the information supplied on the plaque come looking for us. Thus, instead of our finding them we leave it to them to find us.

As is clear from the plaque, the information is not in any of the established languages of the Earth, but uses only the basic mathematics, physics and astronomy in a clever way to identify our location, and to tell the extraterrestrial about the physical size and appearance of humans. Although the idea is novel, the chance of its success is extremely small, considering the vast cosmic distances involved.

Nevertheless, at the time of its launch the idea generated considerable argument. There were those who were seriously concerned that this was a breach of the Earth's security and by disclosing our whereabouts we were inviting outsiders to come and rule over us! There were those who took it as a big joke and the cartoon in the *Los Angeles Times* shows the plaque being picked up by inhabitants of Jupiter and they are wondering why the Earthmen (as depicted on the plaque) wear no clothes.

Having looked at various methods of searching for extraterrestrials I now come to perhaps the most practical one, the method proposed in 1959 by Cocconi and

Morrison. I end my talk by outlining this method which is currently being followed by the SETI enthusiasts.

From the astronomy of our galaxy it is clear that the best waves for transmission of signals over vast interstellar spaces are radio waves. They are not absorbed enroute and it requires less energy to send them than other forms of electromagnetic waves. But, in the wide range of wavelengths, what wavebands are likely to be used in interstellar communication by the ETIs?

The universal wavelength 'known' to all ETIs in the galaxy is likely to be that of 21 centimetres, of the waves emitted by free atoms of hydrogen. Such atoms are all over the galaxy and their signature lies in this particular wavelength. This wavelength is radiated when the electron in the atom switches its direction of spin spontaneously from being parallel to the spin of the nucleus to the opposite. Since basic physics is expected to be the same everywhere, our intelligent extraterrestrial would know about it. A typical ETI will, therefore, use it for communication, on the assumption that other ETIs will be aware of its significance.

Frank Drake did make an attempt to detect such 21 cm. signals through the giant radio telescope at Arecibo, Puerto Rico, which has a collecting dish of 300 metres in diameter. He did not succeed in getting any signals that could be construed as coming from intelligent beings. A coded message was also sent to a few likely sites around nearby stars but has not evoked any response.

A Huge Eye of a Monster Peering into Space

To make a systematic search of stars within a few light years from us, a dedicated instrument, much larger than the Arecibo telescope, is needed. Bernard Oliver has suggested how such an instrument could be designed. Known as the Project Cyclops, this 'telescope' is a collection of nearly 1000 radio dishes, each of 100 metres diameter. Computer controlled, these dishes would all be aligned in a specified direction, the whole collection looking like a huge eye of a monster peering into space. (Cyclops was a one-eyed monster in Greek mythology).

Cyclops can be built with the current technological know-how. Its cost is estimated at a few percent of the U S defence budget for one year. Will it even be built? Perhaps a multinational effort (like the accelerator at CERN) can someday be motivated to build it or some other instrument like it. More ambitious projects think of gigantic antennas in space.

Meanwhile, at a more modest level, SETI efforts are continuing. Multi-channel analysers, which receive radiation and analyse it in several wavelengths simultaneously, are being used with some of the existing telescopes. High speed computers, with sophisticated data analysis techniques that can look for a tiny but meaningful signal amid a jumble of noise, are also being employed.

All such efforts amount to listening in at a keyhole from outside a conference room, where important deliberations are taking place. Those participating in the programme of trying to catch signals being exchanged by two extraterrestrials, light years apart, are listening in on deliberations in a cosmic club to which they have no right to membership!

A new radio telescope known as the Giant Metrewave Radio Telescope is currently nearing completion in India. At metre wavelengths it will be world's biggest radio facility. It will have 30 dishes each of 45 metre diameter, distributed over distances of several kilometres. The main priorities of the telescope will be to study the large-scale structure of the universe and such radio sources as quasars and pulsars. However, I hope that the telescope will have some time available for the SETI effort. For it is admirably suited for this experiment.

To sum up then, we still do not know whether we are alone in the universe. The optimists amongst us would like to think that we are not and are trying to search and establish contact with the extraterrestrials. If the SETI programme succeeds, it will be the greatest discovery in the history of human civilization. I don't have to underscore this in a country that launched Christopher Columbus. As Columbus's discoveries opened new horizons, so would our contacts with advanced ETIs, especially if they are ahead of us in knowledge of science and the universe.

Suppose that the SETI experiment finally succeeds and we discover an advanced civilization, say at a distance of ten light years. It will then answer our question, 'Are we alone in the universe' in the affirmative. But talking to our neighbours will not be easy. Imagine making a phone call which you begin by saying 'Hello'. Your greeting will reach your neighbour ten years later and the extraterrestrial's reply will reach you twenty years after your first word! You will agree that enormous patience will be needed to carry on any conversation.

On that note I conclude, by thanking you for your patience in listening to me, even though I could not offer a definitive answer to the question: Are we alone in the universe?