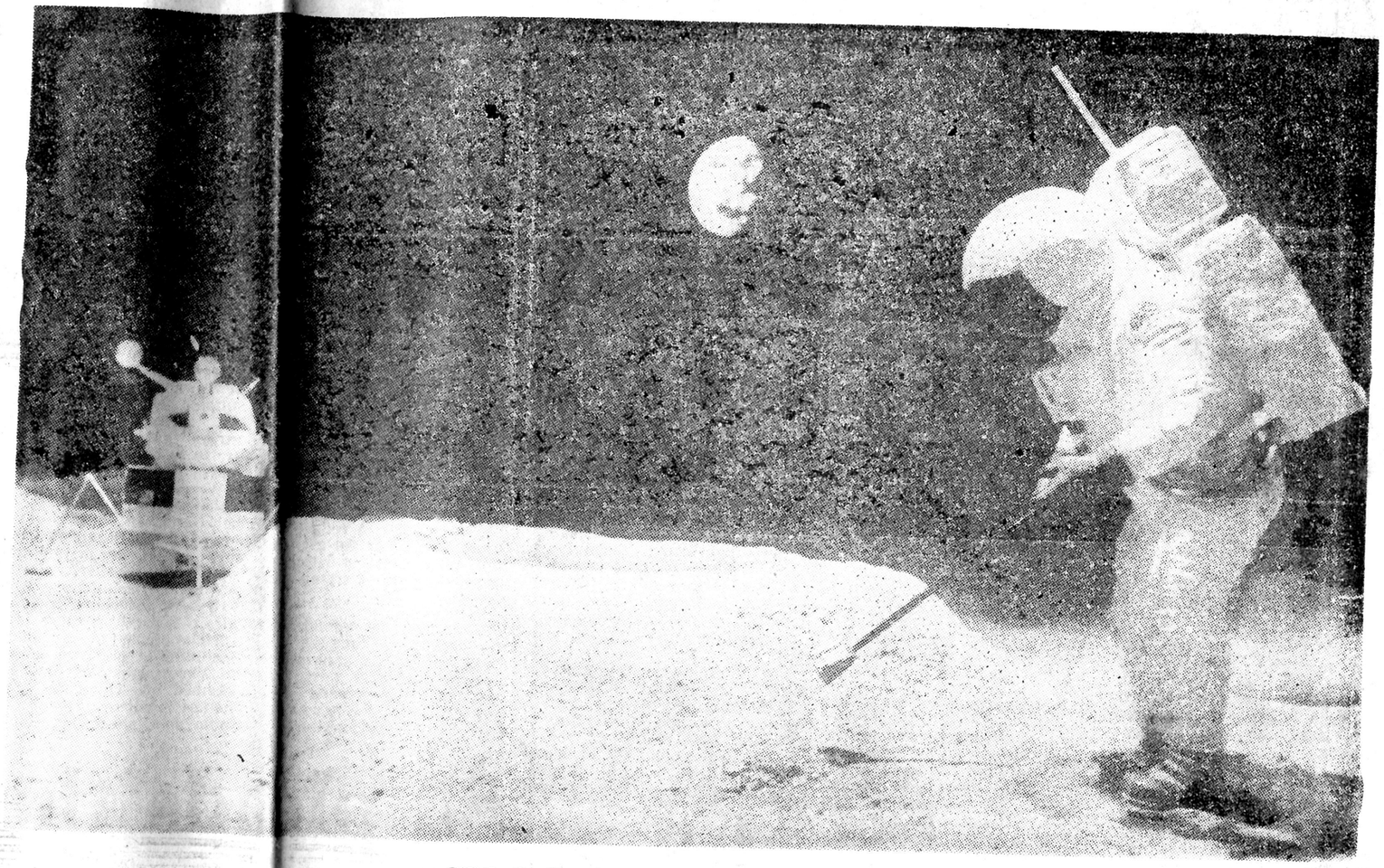


With the Earth in the background, an American astronaut collects samples of moon soil.

ARE WE ALONE IN THE UNIVERSE?

To search for 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 about 8.5 years. Clearly technology of rocket propulsion has to improve tremendously to make a trip of duration comparable to the human life span.

By PROF JAYANT NARLIKAR

MAN considers himself the master of this planet Earth, having achieved control over all other living species. He also considers himself intellectually the most advanced form of living specimen on the Earth. In a comparatively short time span, he has made considerable progress since his caveman ancestors and if the present trend is anything to go by, science and technology will take him even higher up the ladder of progress.

But a village champion may not necessarily be the national champion let alone an Olympic gold medalist. How does man compare with advanced life systems outside the Earth? For, judging from the fact that the Earth is a tiny planet in the solar system which in turn is one amongst several billion stellar systems in the Galaxy, which in turn is one amongst the billions of galaxies spread all over the observable universe, it seems hard to imagine that life exists uniquely on the Earth.

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 special 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

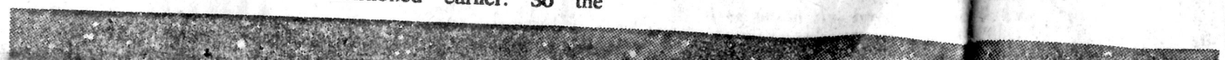
one. It extends as a flat disc of diameter nearly 100,000 light years, light year is the distance travelled by light in 1 year and it is approximately ten thousand billion kilometres with a central bulge. Our solar system is nowhere near the centre—it is some 30,000 light years away from it. This is 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 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.

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.

The early part of the 1960s-decade brought in the important information that the 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. To give examples, the molecules H_2,OH, H_2S, CH, HCO, H_2CO, H_2CS, HCOOH, $HCONH_2$, H_2CCHCN, C_2H_5OH, HC_9N, have been found in interstellar space.

From the point of view of life in the universe this information is very interesting—for, these molecules are subunits of the life supporting DNA molecule mentioned earlier. So the



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all over the observable universe, it seems hard to imagine that life exists uniquely on the Earth.

Indeed, are we re... in the universe? Or, are we one amongst many advanced civilizations that populate our Galaxy? Answers to these questions are now being sought by science and they bring together experts from different branches; astronomy, biology, computers and artificial intelligence, communications, technology, social sciences and so on. In this article I propose to review briefly this newly emerging inter-disciplinary field, sometimes called 'exobiology'.

But before talking about the present, some remarks of historical nature are in order. Ancient civilizations in India and elsewhere had wondered about extraterrestrial life. Our mythology contains references to Devas, Yakshas and Gandharvas to say nothing about the Rakshasas, for example.

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 also 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 Earthmen to extraterrestrial civilizations.

From science fiction to hard science brings no 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 only must DNA be somehow



Astronomers are hard put to explain some of the strange events that are occuring in the nuclei of some galaxies similar to this centre region of the Great Galaxy of Andromeda.

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 occuring 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.

The Milky way that we see as a white band across the sky is the view we get of our own Galaxy from inside. The Galaxy contains some 200 billion stars of which our Sun is

building blocks are out there in space and the astronomers may be forgiven for being optimistic about life existing elsewhere in such a vast universe.

Drake's Equation

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 (often shortened to ETI, as we will do here).

The Drake equation is supposed to calculate N, the number of extraterrestrial supercivilizations in the Galaxy, as a product of several factors:

N = R x S x P x E x O x I x C x 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).

S = fraction of stars that have planetary systems. (We presume life to be based on a planet and living on the star's energy.)

P = average number of planets in a planetary system.

E = fraction of the total number of planets 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).

O = fraction of planets on which life actually originates. (The biological factor between 'suitable' and 'actual' is involved here.)

I = fraction of planets on which **intelligent** life evolves. (We are interested in 'advanced' life not primitive ones.)

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 for its survival, it will be hard to detect owing to its short span of existence.

The present understanding of this interdisciplinary equation is woefully inadequate. I have already commented on the paucity of information on the biological side. The astronomical side is somewhat better understood. The present rate of star formation is reasonably well known (about 1 star like the Sun per year being born at present). The knowledge about other planetary systems is beginning to improve with progress in infrared astronomy.

The IRAS satellite based telescope has turned up several cases of stars with planets in the process of formation around them. the analysis of data collected during 1983 continues to yield new information even today. The Space Telescope to be launched during 1986-87 will make special searches for planets around nearby stars. Thus by the end of this decade we may get a fairly good idea as to how common are planetary systems around stars.

How does intelligence develop in a biological system? How can we rate intelligences 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. 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 (ETI is very common in the Galaxy). The 'middle of the road' opinion sets N at about a million.

Arguments for and against ETI

Because the determination of N in a precise manner is not possible, arguments for or against ETI being very common in the Galaxy are considerably in vogue amongst the optimists and the pessimists. Here we consider one or two examples of such arguments.

It could be argued that if ETI becomes so advanced that its members can undertake interstellar travel, then a handful of such civilizations will eventually spread all over the Galaxy

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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 on whose energy the culture is being supported on the planet, turns hostile for 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 ten million years, suggests that if colonization does occur it will lead to a large value, say N = 10 billion.

Tipler has 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 the interstellar travel must do. The vast expenditure 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 millions 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 J. Von Neumann in the 1950s and it visualizes a 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 this 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. A closer consideration will convince the enthusiast that 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, 86400 times the time taken by light.

To search for 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 make a trip of duration comparable to the human life span.

The British Interplanetary Society made a feasibility study of such a visit to the Bernard'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 twelve years. The Project Daedalus envisages a trip over a period of 100 years, the spaceship being propelled, by nuclear powered rockets. For a

(Continued on page FIVE)

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payload (including ship's mass) of four thousand tons, the fuel needed is of fifty thousand tons. 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 weaponry on the Earth! Perhaps such a trip may be recommended if only to get rid of this stockpile.

A more practical proposition might seem therefore to send unmanned probes like the Viking and Voyager missions. Suitable detectors can bring or rather transmit information about life systems in fly-bye missions. However, unless the rocket technology catches up to the level envisaged in the Daedalus project, we do not expect to gain information from such trips within human life spans.

In 1972 the Pioneer 10 spacecraft was sent out on an orbit that would take it beyond the Solar System. It has by now entered the vast interstellar space beyond the limits of the Solar System and may keep travelling for ever...unless it is intercepted. If it is intercepted by an advanced supercivilisation, the spacecraft contains a plaque within, that would inform the interceptor as to where it came from. The information on the plaque is written in the code language of mathematics, physics and astronomy.

The Pioneer 10 approach is guided by the motive "let them find us if we can't find them." If 'they' do find us and come here, it would mean that they are considerably more advanced than us. Perhaps, if the experiment succeeds, we will have lost our freedom to these visitors!

However, the chance of interception is indeed remote judging by the vastness of the universe. It may be easier to look for the proverbial needle in the haystack. No, the real chance for SETI to succeed is through our interception of signals being exchanged by two advanced supercivilisations. This is what Cocconi and Morrison advocated.

From the astronomy of our Galaxy it is clear that the best waves for transmission of signals over vast interstellar spaces are the radio waves. They are not absorbed enroute and it requires less

Life and universe

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 centimetre, of the waves emitted by free atoms of hydrogen. Such atoms are all over the Galaxy and their signature lies in this particular wavelength. 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. He did not succeed in getting any signals that could be construed as coming from intelligent beings. But the search was not a systematic one, nor was it comprehensive.

To make a systematic search of stars within a few light years from us, a dedicated instrument much larger than the Arecibo telescope (which has a dish of 1000 feet diameter to collect radio signals) is needed. Bernard Oliver has suggested how such an instrument could be designed. Known as **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 per cent of the U.S. defence budget for one year. Will it ever be built? Perhaps a multinational effort (like the accelerator at CERN) can someday be motivated to build it or some other instrument like it. Until then the question "Are we alone in the universe?", will remain within the domain of speculations. And while it continues to be so we may at least try to preserve the only living system that we know—here on the Earth.

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