LECTURE ON
LIFE IN THE UNIVERSE

By
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FOREWORD

The IMC Economic Research and Training Foundation completed 25 years in June 1984. The chosen objective of the Foundation is to disseminate to a larger audience basic information relating to economic situation and policy and to promote more informal participation by citizens in debates on public issues.

In its Silver Jubilee year, the Foundation extended its area of interest to another area by organising a series of lectures to spread the understanding amongst laymen of the role of 'Science and Technology' in national life. The first two lectures delivered in the series were on: (I) 'Science, Technology and Economic Development' by Prof. B. M. Udgaonkar, Senior Professor, Tata Institute of Fundamental Research, Bombay and (II) 'Science, Technology and Rural Development' by Dr. S. S. Kalbag, of Centre for Science Education and Research, Pune.

The Foundation organised on February 27, 1985, Pranlal Devkaran Nanjee Memorial Lecture on 'Life in the Universe' by Prof. Jayant V. Narlikar, an internationally renowned scientist and recipient of several awards, including Padma Bhushan, this being the third lecture in the Series of lectures on 'Science and Technology'. The lecture was widely appreciated by those who attended it.

The Foundation has the pleasure in publishing the lecture for a much wider circulation.

Bombay
April 15, 1985

H. T. PAREKH
Chairman

LIFE IN THE UNIVERSE

JAYANT V. NARLIKAR
TATA INSTITUTE OF FUNDAMENTAL RESEARCH
BOMBAY

Mr. Parekh, Professor Udgaonkar, and Friends,

The title of my talk is somewhat ambiguous and may be interpreted differently by different experts. Philosophers may have one approach to the subject, religious thinkers another, poets yet another, while the science fiction writers may have an altogether different angle to it. My point of view will be that of a scientist. As an astrophysicist I am normally concerned with the study of inanimate systems in the universe. Of these the universe has plenty and they occur on a scale whose immensity cannot be imagined from purely terrestrial considerations.

However, many astrophysicists today are also interested in the possibility that the universe may contain living systems. Judging from the fact that the Earth is a tiny planet in the Solar System which in turn is one amongst billions in the Galaxy which in turn is one amongst the many billions of galaxies dotting the observable universe, it seems hard to imagine that life exists uniquely on the Earth. Indeed, are we really alone in the universe? Or, are we one amongst many advanced civilizations that populate our Galaxy? Answers to these ques-

tions 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 talk I propose to review briefly this newly emerging interdisciplinary field, sometimes called 'exobiology'.

But before talking about the present, some remarks of historical nature are in order[1]. 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,

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[1] *For a historical account see F.J. Tipler in the Quarterly Journal of the Royal Astronomical Society, 22, 133 (1981).*

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.

THE LIFE ON OUR EARTH

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 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 one. It extends as a flat disc of diameter nearly 100,000 light years*, 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

**Light year is the distance travelled by light in one year and it is approximately ten thousand billion kilometres.*

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[2].

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 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).

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[2] *For a nontechnical account see J.V. Narlikar: From Black Clouds to Black Holes published by the World Scientific Publishing Company, Singapore (1985).*

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

$$N = R \times S \times P \times E \times O \times I \times C \times L,$$

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).

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.

The present understanding of this interdisciplinary equation is woefully inadequate. I have already commented on the paucity of information on biological the 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[3].

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 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

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[3] *For details see M.D. Papagiannis ed Strategies for the Search for Life in the Universe published by D. Reidel, Dodrecht (1981).*

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 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. 10 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[4]. This concept was proposed by J. Von Neumann in 1966 and it visualizes a

[4] *See F.J. Tipler in The Quarterly Journal of Royal Astronomical Society, 21, 267 (1980).*

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. 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 Barnard's star which

may have a planet[5]. 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 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 stock pile of weaponry on the Earth! Perhaps such a trip may be recommended if only to get rid of this stock pile.

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

[5] *See details in Ref. (3).*

ever... unless it is intercepted. If it is intercepted by an advanced supercivilization, 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 supercivilizations. 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 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.

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 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 technolo-

gical know-how. Its cost is estimated at a few percent of the U.S. Defence budget for one year. Will it ever be built? Perhaps a multi-national 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.

SEMINARS/ROUND TABLES/INFORMAL DISCUSSIONS/TALKS/LECTURES 1975-85

SEMINARS	YEAR
The Impact of Multinational Corporations	May 1975
Investment Policy of Financial Institutions	Sep 1976
Problems and Perspectives of Corporate Sector- The next two Decades	Oct 1977
Industrial Estate: Problems and Prospects	Aug 1978
Investment Market: Problems and Prospects	Dec 1978
Aspects of Gold Policy (Jointly with IFMR, Madras)	Jan 1979
Management-Labour Co-operation	Jul 1979
Money, Credit and Inflation	Sep 1979
Pricing of Industrial Products	Feb 1981
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Inflation and International Monetary Reforms (Jointly with IMC)	Oct 1981
Economic Potential of Gujarat State	Mar 1982
Exchange Control in India - The case for a more Relaxed System	Sep 1982
Investment Opportunities for Non-Residents in India	May 1983
Take-Over of Companies	Jul 1983

Gulf Oil Countries and India: Trade and Investments (Jointly with ICRIER)	Nov 1983
Industrial Sickness and Government Policy	Dec 1984

ROUND TABLE DISCUSSION

Seeds and Agricultural Development	Apr 1976
Financing of Agricultural Development	Jul 1976
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ONGC and Oil Exploration in India and Operations of Indian Petrochemical Corporation	Mar 1980

INFORMAL DISCUSSION/TALKS

Talk on Indian Economy (Prof. A.K. Das Gupta)	Jul 1978

Social, Cultural and Economic Co-operation among the Five Neighbouring Countries (H.T. Parekh)	Oct 1978
International Finance Corporation and India (Prof. M.A. Qureshi)	Mar 1979
Technology Transfer and U.S. Policies concerning Economic Aid to LDCs (Dr. Manoucher Parvin) (Jointly with Society for International Development)	Dec 1981
Economics of Oil Crops (Dr. P.F. Knowles)	Jan 1982
National Income of India (Dr. V.K.R.V. Rao)	Apr 1984
Health of the Indian Economy (Dr. Manmohan Singh)	Jun 1984
Adjustment in the Scope and Structure of Indian Planning in the light of Experience of Six Five Year Plans (Dr. I.G. Patel)	Jun 1984
International Economic Environment and its Impact on Indian Economic Development (Dr. Fredie A. Mehta)	Jun 1984

LECTURES ON SCIENCE AND TECHNOLOGY

Science, Technology and Economic Development (Prof. B.M. Udgaonkar)	Aug 1984
Science, Technology and Rural Development (Dr. S.S. Kalbag)	Jan 1985

Life in the Universe (Prof. Jayant V. Narlikar)	Feb 1985
Interaction Between Basic Research and Technology (Prof. Govind Swarup)	Mar 1985

IMC Economic Research & Training Foundation

Established in 1959, the Foundation is an autonomous service-oriented organisation dedicated to the cause of promoting economic research and training. The Foundation is also responsible for organising the B. F. Madon Memorial Lectures.

The Sir Purshotamdas Thakurdas Research Wing of the Foundation has published several research studies on topics of national importance. The Foundation, besides arranging training courses, has organised a number of seminars, round table discussions, informal talks on varied topics of great public interest and having a bearing on public policy.

In 1980-81, the Foundation added a new dimension to its activities with the launching of the Bulletin and a series of brochures on topics of current economic and business interest.

In this Silver Jubilee year, the Foundation has started a new activity by arranging a series of lectures to spread the understanding of the role of 'Science and Technology' in national life