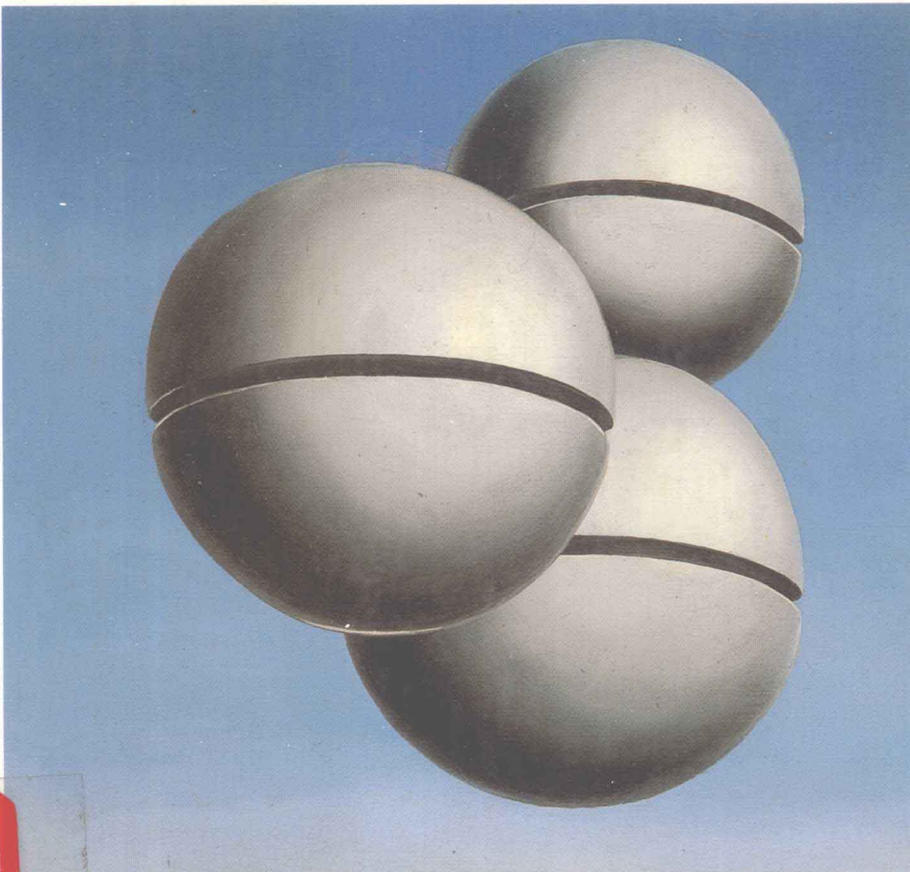
EXTRATERRESTRIAL INTELLIGENCE

JEAN HEIDMANN



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Translated by Storm Dunlop

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Once again, my dear Marie, I dedicate a book to you. After the Scylla and Charybdis of the Cosmic Odyssey we now set sail for distant New Worlds.

Preface

As we come to the end of the second millennium, our view of the universe has been radically altered, and our perception of the cosmos has expanded. In future, we will see life as a natural phenomenon that has arisen as part of the evolution of the universe as a whole. If this is really true, the wondrous adventure that led to the appearance and subsequent evolution of life could well have occurred elsewhere, not just on Earth. We have thus ceased to see life as an exclusively terrestrial phenomenon, but instead as one that possesses potential on a cosmic scale, and one that we must consider in terms of the universe as a whole. We have moved from the concept of a physical universe to one of a biological universe.

Our study of the origin of life, our exploration of space, and astronomy itself all prompt us to give serious consideration nowadays to the idea of extraterrestrial life, which until now has been the preserve of science fiction. Straightaway, we need to be more precise: the word 'extraterrestrial' naturally evokes images such as those in *The War of the Worlds*, *Alien*, *ET*, or *Close Encounters of the Third Kind*. We tend to think either of gentle beings or of horrible monsters endowed with amazing powers. Above all, we tend to confer on them a degree of intelligence at least equal to our own. In contemporary literature or films, extraterrestrials are generally either an idealization of what humanity would like to be, or else a caricature of what we fear it might become. In particular, when we envisage forms of extraterrestrial life, we tend to ignore the fact that they might not have attained the level of intelligence and civilization that we have reached. Yet, on a cosmic scale, the evolutionary path that life may follow is highly complex. To understand it, we need to forget the little green men that otherwise haunt our imaginations.

The adventure is, moreover, all the more fascinating – because it is true.

Viewed on a cosmic scale, the evolution of life consists of five principal stages:

A *cosmic stage*, beginning with the Big Bang (when space and matter appeared), followed by the synthesis of the chemical elements such as carbon – which are of fundamental importance for life as we know it – together with the formation of stars and planets.

An *organic stage* that saw the formation of the first molecules that were to become the basis of our own life forms. These are molecules like those that radio astronomers have found in interstellar space, space probes have detected in comets, and biochemists have discovered in meteorites that have reached the surface of the Earth.

A *prebiotic stage* that saw the creation of the 'building blocks' of life, which were more complex molecules, but still devoid of life itself. Such molecules include the amino acids, which are essential components of proteins, and the nitrogenous bases that form the 'rungs' of the double helix of DNA. Such a prebiotic chemistry may be taking place today on Titan, the largest of Saturn's satellites.

A *primitive biological stage*, with life forms like those of bacteria, which ruled our own Earth for the first few billion years, and which astronomers hope to discover, perhaps in a rather different form, in the permafrost layers of Mars.

And, finally, an *'advanced' stage*, perhaps even more highly evolved than our own. Nothing in our study of the universe suggests that we are the pinnacle of cosmic evolution. Quite the contrary, in fact.

Apart from the exploration of space, sustained by our knowledge of biology, physics and chemistry, the only method at our disposal of detecting advanced life forms that may have developed beyond our own atmosphere is by patiently searching for the radio signals that they may emit. Behind their giant radio telescopes, astronomers have become spies, electronic eavesdroppers ... What is now known as SETI (the Search for Extraterrestrial Intelligence) was born in 1959. More recently, in 1982, the International Astronomical Union set up a Commission devoted to bioastronomy. Above all, however, in 1992, NASA commissioned a wide-ranging program, based on new technology, which was intended to scan tens of millions of channels at radio frequencies between then and the year 2000. Various other countries including France are also involved.

Before we attempt to visualize the day when someone may actually capture an artificial signal coming from space, let us explore both the intellectual implications of this work, and also the very latest developments in bioastronomy, astronomers' search for life in the universe.

FROM THE PHYSICAL WORLD TO THE BIOLOGICAL UNIVERSE

The idea of extraterrestrial intelligence has a long history, because it goes back to the Greek atomists and Aristotle, in the 4th century BC. Revived and given fresh impetus by the work of Copernicus and Galileo, which revealed the similarities between the Earth and the five 'wandering stars' (the planets Mercury, Venus, Mars, Jupiter, and Saturn) that had been known since antiquity, it was well-established among philosophers in the 18th century. In 1859, however, two crucial advances occurred: in that year, Charles Darwin published his *Origin of Species*, and Gustav Kirchoff used spectroscopy to identify chemical elements in the Sun. Thenceforward, everyone knew that life could arise through the processes of physical evolution, and that matter is everywhere the same*.

Jeans' Tidal Theory

Despite these advances, theories developed at the beginning of the 20th century were nearly fatal to the idea of life in the universe. In particular, around 1920, Sir James Jeans developed a theory,

* At the Third International Symposium on Bioastronomy, which was held in 1990 at Val Cenis in Haute-Maurienne, France, the astronomer and historian of science Steven J. Dick, of the US Naval Observatory in Washington, gave a fascinating review of this modern concept of the universe.

known as the Tidal (or Catastrophe) Theory, of the origin of the Earth. The latter was thought to have condensed from a stream of material pulled from the Sun by a star that had brushed past it. But such encounters must be extremely rare. As a result, planets and extraterrestrial life would be the exception rather than the rule.

Jeans' eminence was such that his ideas were widely disseminated. In 1943, however, a complete reversal took place: two planetary companions were discovered apparently orbiting the stars 61 Cygni and 70 Ophiuchi. Jeans refined his calculations and had to admit that the 'catastrophe' might have affected one star in every six. Even more significantly, however, Carl von Weizsäcker had proposed a revised form of the theory of a primordial nebula, a concept that may be traced back to the philosopher Immanuel Kant and the astronomer and mathematician Pierre-Simon Laplace. In addition, it was realized that Jeans' theory suffered from a serious fault: an encounter between two stars could not produce planets with nearly circular orbits around the Sun.

The explosion of ideas

Progress by astronomers thus breathed new life into the theory that billions of planets might exist. About the same time (in 1938), Alexander Oparin published his work on the origin of life, Stanley Miller achieved the first synthesis of the building blocks of life, and the first international symposium on the origin of life was held. The stage was set for the arrival of SETI.

In 1959, Giuseppe Cocconi and Philip Morrison published the first scientific study of the possibility of exchanging radio signals over interstellar distances. In the same year, Frank Drake built a special receiver and made the first attempt to monitor two of the closest stars. Since then some 30 years have passed, and SETI, strengthened by the progress made in bioastronomy, is beginning an observational attack on the old question: 'Are we, or are we not, alone in the universe?' In this field perhaps more than any other, science joins forces with some of the most fundamental questions about the What?, the How? and – above all – the Why? of our humble human condition.

FACTS, SPECULATION, FICTION, AND MONEY

Unfortunately, we have only a single example of life, that found on Earth, to guide our search for life in the universe. We can, of course, try to extrapolate from the form we know, which is based on the chemistry of carbon, to other potential pathways. Why not imagine life based on the chemistry of silicon? Similarly, life on Earth depends on chemical reactions that take place in water. Why not consider other solvents?

Such extrapolations may be supported or refuted quite rapidly by undertaking laboratory experiments. In fact, these concepts are not so very far removed from the basic characteristics of our own life forms, in particular from our methods of reproduction or bodily repair, of energy transformation, of sustenance, and of processing information about the external world. They do not suggest any really new or exotic pathways that life might take. Even while considering them, we still retain the model of life as it has developed on Earth.

More daring extrapolations are possible. For example, astronomers have envisaged life based on the neutron-rich material found on neutron stars. It is, in fact, possible to conceive of systems that are, to a greater or lesser extent, capable of sustaining the main functions of life. Such an environment involves energy and particles that are subject to some extraordinary physics, under what quantum physics describes as 'degenerate' conditions. The overall system could give rise to complex structures and to information-processing.

Hoyle's 'Black Cloud'

One of the oldest and, from the point of view of physics, one of the most credible possibilities, was the main theme of *The Black Cloud*, a science-fiction novel written by the famous, and extremely original, British astrophysicist Fred Hoyle. He invented beings that consisted of clouds of magnetized interstellar gas. Flux tubes within the magnetic fields acted as channels for charged particles (electrons and ions), just as blood corpuscles flow through a network of arteries and veins. Information was stored and manipulated as if by a computer, whose electronic components were not solid but consisted of this plasma, frozen in place by magnetic fields. In addition, the clouds could store energy. They led an ideal life, communicating through space by means of radio waves. When their energy reserves began to decline, they propelled themselves into the neighborhood of a star by ejecting a stream of particles. This is how human beings entered the story: one of these clouds had encircled the Sun to capture its energy, spreading panic by obscuring the Sun and causing gravitational perturbations of the Earth's orbit.

Scientists are not prohibited from indulging in outrageous speculations. The latter may, in fact, open up new ideas or points of view. By way of compensation for the aberrations that are only too likely to arise, and which are inimical to knowledge itself, researchers owe it to themselves to suggest, as soon as possible, ways in which their theories may be tested. They need to obtain specific deductions that may be tested observationally.

Dyson spheres

A good example of an attempt at verification has been carried out with respect to the 'Type II' civilizations proposed by Nikolai Kardashev. (These are discussed in detail later, see p. 108.) He described a Type II civilization as one that has been able to master, for its own ends, all the energy produced by its central star. According to the laws of thermodynamics, any civilization of this type would be forced to radiate a substantial fraction of this energy away to space in the form of infrared radiation. According to the cosmologist Freeman Dyson, civilizations of this sort may have been able to use the materials in their asteroids to construct a gigantic shell surrounding their star, enabling them to capture its energy. Such spheres would be infrared sources, and could thus be detected.

Subsequently, IRAS (the Infrared Astronomical Satellite) made a survey of the sky, detecting 130 375 infrared sources that corresponded to stars. From these, Jun Jugaku, Professor of Astronomy at Tokai University in Japan, selected 594 stars that resemble our Sun, and which might therefore shelter some form of life. To detect any additional, i.e., artificial, infrared radiation, he needed to compare the measurements with others of the ordinary radiation from the stars themselves, and these had to be taken from another catalog. Once this had been done, only 54 candidates remained. Eventually, only three of these were shown to have an infrared excess.

After closer examination, however, even these proved to be explained by natural causes. Jugaku concluded that there was no evidence for a Dyson sphere among the 54 candidate stars. One recommendation that arose from this study, however, was that the ordinary radiation from many more stars should be measured. This would enable the rich resources of the IRAS catalog to be utilized to the full. Kardashev and Dyson's speculations may not have been confirmed, but it would be interesting to continue this line of research, which has, so far, been the subject of relatively little effort.

The question of money

As we can see, searching for life elsewhere in the universe requires the development of new observational and experimental instruments and technologies. It therefore naturally requires finance. Science is generally organized in such a way that the finance comes from governmental sources; sources that are responsible to taxpayers, and which only disburse funds to projects that appear really sound. We may conclude that because it is difficult to obtain funds for even the most rigorous scientific projects, suggesting research programs that are based on speculation – far less on fiction – is out of the question.

As a result, in searching for life in the universe, scientists must turn to facts for support. Unfortunately, once again we have only one example to point to: that of life on Earth.

THE EARTH AS AN EXAMPLE

The age of the Earth

The Earth was formed 4 555 000 000 years ago. This is 1000 times as long as the time when the earliest of our own ancestors walked upright. It is a million times as long ago as the first historical civilizations. Its age is known with an accuracy that is astonishing to astrophysicists, who, in general, have to rest content with values accurate to a few tenths, both because it is difficult to wrest data from the cosmos, and also because of problems in devising suitable theoretical frameworks. By way of comparison, the Big Bang cannot, as yet, be dated more accurately than having taken place between 12 billion and 20 billion years ago.

Where measurements concerning our own world are concerned, an accuracy of tenths of 1% is attained, thanks to methods of determining the radioactivity of the oldest atomic nuclei that it contains. Their half-lives are well known, and they are not sensitive to any outside influences. All that we need do is to measure, as accurately as possible – and not without problems – the relative abundances of the nuclei that have been produced by radioactive disintegration and of the original nuclei, and we can establish the age of the Earth.

This corresponds to the period when our planet became an individual condensation, isolated from the rest of the primordial nebula; in other words, when practically all the Earth's mass had gathered together into a relatively dense sphere. It is estimated that between the beginning and the end of the condensation phase (that is, between the collapse of the protosolar nebula and the agglomeration of the Earth), about 100 million years elapsed, which is a fairly short time on a cosmic scale.

The primitive stage

When it was born, the Earth was completely molten because of the heat produced by the impact of planetesimals (primitive, small planetary bodies), cometary nuclei, and clumps of dust and gas, all of which were attracted by the young Earth's force of gravity. This molten state led to the globe becoming differentiated: the heavy elements, mainly iron and nickel, gathered in the center, where they formed the core, around which there was a thick layer of primitive magma. The thick primordial atmosphere that surrounded the globe arose from degassing of the molten material. It was similar to the gases ejected by volcanic eruptions today, and consisted of carbon dioxide, nitrogen, and other, more complex, molecules, such as methane and sulfuric acid.

Most of this primordial atmosphere was blown away into space by the powerful 'wind' arising from the violent activity undergone by the Sun when it passed through the temporary T-Tauri stage of its evolution (see p. 12). It is possible that later, during the next 100 million years, a second primitive atmosphere, consisting mainly of water vapor and carbon dioxide, may have arisen through the impact of comets that originated beyond the orbit of Jupiter.

Subsequently, the globe began to cool; silicates rose to the surface of the magma and began to solidify. The oldest rafts of granite that are known – those forming the base of the Canadian Shield, for example – are 3.8 billion years old. The atmosphere cooled sufficiently for the water vapor to condense into liquid droplets. Torrential rain began to fall, and some geophysicists estimate that it lasted, without stopping, for 10 million years. If there had been any microscopic ancestors of the human race to witness this torrential rain, it could well have been the basis for the traditional myth of the Deluge.

The ocean planet

Nevertheless, this unique rainfall did leave a souvenir, or rather a present, behind it. Thanks to its existence the atmosphere lost nearly all its carbon dioxide. Without it, the gas, which was extremely abundant, would have blanketed the Earth in a dense layer, and the surface pressure would have been around 100 atmospheres (approximately 10^7 Pa), producing a catastrophic greenhouse effect. The Earth would have suffered the same fate as our neighboring sister planet, Venus, where the surface temperature is 450 °C – and we should not be here!

How did it come to bequeath us this precious inheritance? The rain, which was a mixture of water and sulfuric acid, dissolved the calcium from the basalts and granites in the primitive crust. The calcium reacted with the atmospheric carbon dioxide to give calcium carbonate, which was deposited at the bottom of the early oceans, where thicker and thicker carbonate sediments accumulated.

This transformation of atmospheric carbon dioxide into subterranean carbonate rocks changed the Earth's destiny. It became an ocean planet. Its residual atmosphere produced a slight greenhouse effect, far less than that on Venus, but enough to protect the world from the cold of interplanetary space. The Earth was therefore able to press on with the grand adventure of life, because its temperature range remained between 0 and 100 °C, as required for liquid water to exist at normal atmospheric pressure.

Less than 700 million years after its birth, the Earth became more temperate. The early cores of lifeless continents emerged from a global ocean, beneath an atmosphere that consisted largely of nitrogen, with minor contributions from water vapor, carbon dioxide, and methane. Dense plumes of smoke rose into the sky from raging volcanoes, and from giant meteorite impacts.

In fact, the bombardment, which was extremely intense during the Earth's formation, did not cease suddenly: it decayed over several hundreds of millions of years. Even today, we still see shooting stars, and occasional meteorites such as the one that created Meteor Crater in Arizona, and the suspected giant impact at the boundary between the Cretaceous and Tertiary periods, as well as the fragment of a comet or stony asteroid that fell over Tunguska in Siberia in 1908.

The sky above the rocky landscape 3.8 billion years ago was dominated by the Moon that we know today. It would have seemed gigantic, because it was much closer than it is now, and had not been pushed out into space by tidal effects. Despite this, its actual appearance closely resembled the one we know. An observer would have been able to see the occasional impact of one of the bodies during the later stages of the cosmic bombardment: an immense conical halo of molten fragments would suddenly erupt, only to fall back to the surface within a few minutes, leaving a glowing patch on the surface that would slowly die away over the succeeding months.

The first stage of the Earth's history passed in this fashion. This was the cosmic stage, which progressed solely in accordance with the physical laws governing the universe as a whole. It set the stage for the second act: the organic phase. Yet the first act was the most grandiose of all: it involved the universe as a whole.

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