North American AstroPhysical Observatory
(NAAPO)

Cosmic Search: Issue 3
(Volume 1 Number 3; Summer 1979)
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Extraterrestrial Life: Where is Everybody?

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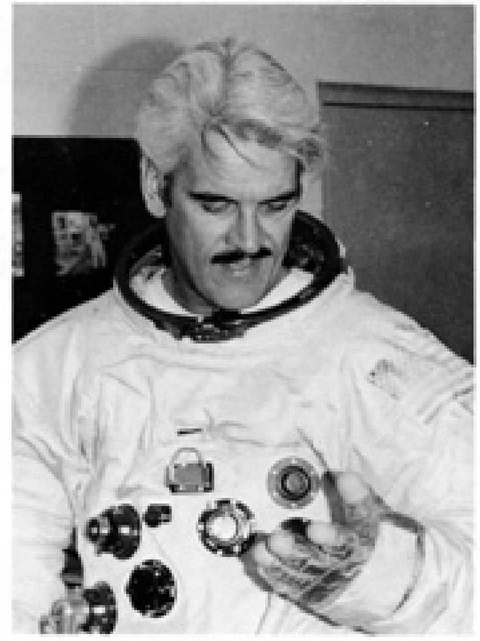
The results from the Viking search-for-life experiments on Mars will undoubtedly continue to fuel fierce debate among exobiologists for a long time.


von Puttkamer

For science, the discovery of life on Mars would have been a momentous achievement, adding immeasurably to our understanding of the nature of living beings on earth and the origin of life. For humankind at large, it would have been a monument to our time with lasting impact on our view of nature and our philosophical beliefs. As it is, one of the greatest scientific and engineering enterprises of the 20th century has yielded results that, in their final consequence, are neither positive nor negative but inconclusive—and very definitely far from final.

While the Viking robots may have dealt a crushing blow to overly optimistic expectations about the existence of Martian life, the search for extraterrestrial life goes on unabated, perhaps even with increased vigor, driven by the immense importance to humankind which a positive result would have. With highly complex organic molecules, possible building blocks of life, being discovered constantly between the stars by radio-astronomy, exobiologists view life in the universe today as a common occurrence. Since conditions in the immense reaches of the cosmos are increasingly found to be similar to the conditions that prevailed on earth when life originated here, they feel that the universe must be teeming with it.

Man's conviction about the existence of other life forms beyond earth is not a development of our modern, scientific age. As early as in the 4th century B.C. the Epicurean philosopher Metrodoros wrote,

> "To consider the earth as the only populated world in infinite space is as absurd as to assert that in an entire field sown with millet only one grain will grow."

And on 17 February 1600, early in the morning in Rome, Italy, after eight years of interrogation and solitary confinement, the "renegade" Dominican monk Giordano

Bruno was burned alive at the stake on the Campo dei Fiori by the Roman Inquisition for—among other things—supporting the Copernican view that the earth revolved around the sun and that the universe was full of planets populated with living beings. (History has it that Giordano died after scoffing at his executioners and averting his eyes from the proffered crucifix.)

Unfortunately, while all modern astrophysical facts back Giordano's view today, evidence is still lacking, and exobiology remains a science that "has yet to demonstrate that its subject matter exists," as paleontologist George Gaylord Simpson put it. In the absence of life forms other than those on earth, all discussions about extraterrestrial life can only be speculative.

What makes the problem so intractable is the random nature of biochemical evolution itself. We know that for life to emerge, matter must interact in all three of its basic interactions: gravitational, nuclear, and chemical. While gravitational interaction, described by Newton's law, is simple to predict, and nuclear interactions, despite their very great number, also can be listed in all possible ways, the number of chemical reactions, both organic and inorganic, is so astronomically high that the prediction of the evolution of living organisms is an impossible task. The definition of a living system, thus, is saddled with a certain degree of subjective arbitrariness, to say the least.

Without ignoring the possibility that totally unearthly life forms could exist in the universe, our search for extraterrestrial life will be of considerably less speculative nature if we restrict it to biological forms known, beyond the shadow of a doubt, to exist in the universe—namely, creatures on Planet Earth, built from carbon-containing molecules and water.

While silicon has been regarded by some (especially science fiction writers—remember the Horta from *Star Trek*?) as another likely candidate for a base of life in the universe where its abundance is as much as 1/5th that of carbon, only carbon is known to form such highly complex molecules as proteins (from amino acids) and nucleic acids (from sugars and nitrogenous bases, i.e., nucleotides) which can store and transfer the energy and the information that life appears to require to live up to its basic definition as a system of matter having mutability and heritability.

But while being "carbon chauvinists" about extraterrestrial biochemistry, we do not presume that its products would necessarily look like terrestrial forms. In fact, due to the randomness of biological evolution, they will almost certainly be different. Chauvinistically speaking, the bestiary out there, if any, will be exotic in the truest sense of the word!

For example, do they require an oxygen atmosphere? Not necessarily. Even on earth there are many life forms, such as certain bacteria and protozoans, which use inorganic materials for metabolic chemosynthesis without oxygen; and, of course, there are those plants that use photosynthesis. While life on earth almost certainly originated in a primeval non-oxygen atmosphere of hydrogen, ammonia, water vapor, and methane, higher life forms would have had a hard time to make a living if that atmosphere hadn't changed, over the millenia, to an oxidizing environment. That is because oxidation (combustion) of sugar (glucose, $C_6H_{12}O_6$) into CO_2 and water liberates over eleven times as many calories of energy as the fermentation of glucose into ethyl alcohol and CO_2 in a reducing atmosphere (like Jupiter's, for instance.) Beings on such a world, to derive the same amount of free energy, may conceivably be too preoccupied with seeking food to develop a higher mind, technology, and civilization.

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In the absence of any clear evidence for or against the occurrence of extraterrestrial life forms, scientists had to begin their search by taking recourse to logical reasoning based on statistics, the game of juggling the odds of various astrophysical, biological, and social developments in Creation which are presumably necessary to biological and civilizing evolution. The overall estimate is obtained by multiplying many conditional probabilities of these outcomes, but there is a catch: in multiplying odds we are also multiplying possible goofs in our estimates, and so the likelihood of deriving a good judgment decreases as we proceed.

There are about 200 billion stars in our galaxy alone (and there are at least 100 billion other such galaxies in the universe.) But how many of those stars have planets with a mass not excessively different from that of the earth, with an adequate axial rotation and an atmopshere, which lies in the temperature zone permitting sustained carbon/water-based life, i.e., not too far from its sun to be permanently frozen nor too near it for its surface to be scorched?

Life on earth took an estimated 4 billion years to evolve from the earliest molecular system which we would call alive, to present-day humans. Prior to that, spanning at the most about one billion years, there was a period of chemical evolution, preceded by the initial condensation of the sun and its planetary system from glowing stellar gas. Thus, life must have originated hard and fast as soon as conditions were right—additional evidence for its suspected abundance in the universe—but it took many billions of years to evolve through its random processes of mutation and selection. Hence, we must look for stars that shine dependably steady, retaining constant radius and luminosity by burning hydrogen in nuclear reactions into helium over many billions of years.

Such stars are found on the so-called Main Sequence of the Hertzsprung-Russell diagram of brightness vs. surface temperature, classified in spectral types O, B, A, F, G, K, M, and N but only stars cooler than late F-stars and hotter than late K- or early M-stars may provide the temperature regime agreeable to higher protein life forms.

Another possible limitation is the existence of multiple stellar systems, especially binary stars which consist of two stars revolving around each other at separations ranging from virtual contact to half a light year or more. They are quite frequent; it is known that at least half the stars in the solar neighborhood are binary systems. To permit stable planetary orbits, the two stars must either be quite close together or very far apart. Because of the complicated orbits planets around many of these double stars would have, they may be less suited to be associated with life-bearing planets.

Are single stars always accompanied by planets? There is no definite answer but the currently valid theory of the origin of stars would suggest that planetary systems are widespread. Planets form from dust and gas that is either left over from the process of star condensation or that has been acquired from the gases in interstellar space. If the dust/gas cloud is massive enough, another star could form instead of planets, creating a binary system. Thus, planetary systems and double stars appear to have the same origin, and since binaries are very numerous, planetary systems should also occur frequently. It is likely that the majority of all single stars plus many double stars have planetary systems, and we are probably quite safe in assuming, for statistics' sake, that each star—on the average—has one habitable planet.

But what are the chances that life would indeed develop on such a planet? And that it would evolve into a civilization of intelligent beings? Estimation of these numbers is an even less definite exercise. But scientists today see life as a common occurrence in the universe—in fact, amino acids, the building blocks of life, have been found in space, and perhaps even life itself may have formed not on earth at all but out in space in the stellar nebula during the formation of the solar system—and it is likely that the appearance of intelligence, as a selective advantage of evolution, is the rule rather than the exception in the life history of a planet. And while technology is neither necessary nor sufficient for intelligence, all intelligence based on some form of genetic memory that wants to grow into society and civilization, must sooner or later apply natural laws through technology and engineering to assure its survival and protect its evolutionary potential by dealing with its enviromnent, expanding and diversifying it.

In a "Cultural Evolution Workshop" in 1975, chaired by Joshua Lederberg, scientists from NASA and various universities agreed that better than one in one-hundred of living species in space develop both intelligence and a technology corresponding at least to the electromagnetic communication phase.

With 200 billion suns in our galaxy, of which the oldest are about 12 to 18 billion years old, the average rate of star formation over the galactic history must have been about 10 stars per year. Applying our odds from above, we would then arrive at the conclusion that every 10 years one civilization must have appeared (10 stars per year x .01 civilizations per star). If we further assume that after the birth of the universe in the "Big Bang" it took 5 billion years for conditions to settle down enough for life to burst forth, we are left with 10 billion years during which as many as *one billion* civilizations could have appeared. How many supercivilizations (i.e., civilizations that are substantially in advance of our own), then, exist in our galaxy today?

That number obviously depends on the average lifetime of your typical civilization and, thus, on how much faith one has in technological intelligence. Our species has managed to survive 33 years since the development of the A-bomb. Can we make 100 years? What if the average life of a technological civilization cannot exceed 100 years because of self-destruction in one way or other? There would then be only 10 coexisting civilizations in the entire galaxy! To demonstrate how subjective this type of judgment really is, the reader may choose his/her own estimate of the mean longevity of a civilization and select the appropriate value for the number of presently existing supercivilizations in our galaxy from the table given here.

MEAN LIFETIME OF CIVILIZATION	NUMBER OF COEXISTING SUPERCIVILIZATIONS
100 years	10
1000 years	100
10,000 years	1,000
100,000 years	10,000
1 million years	100,000
10 million years	1 million
100 million years	10 million
1 billion years	100 million

What do exobiologists think? The opinions differ widely, but leading U.S. and Soviet scientists, like I.S. Shklovsky, Carl Sagan, Frank Drake, Cyril Ponnamperuma, Melvin Calvin, N. S. Kardashev, Joshua Lederberg, and A. W. Cameron, to name just a few, generally agree on a "best guess" of one million civilizations at or beyond our present level of technological development, based on a mean longevity of ten million years.

The central question and main dilemma today, first expressed in this form by Enrico Fermi, is, "Where is Everybody?" Civilization appears to be a universal phenomenon, and yet there are no currently observed signs of cosmic activity of intelligent creatures. If there are at least one million supercivilizations in our galaxy alone, how can we explain the conspicuous absence of what Shklovsky has called "Cosmic Wonders"?

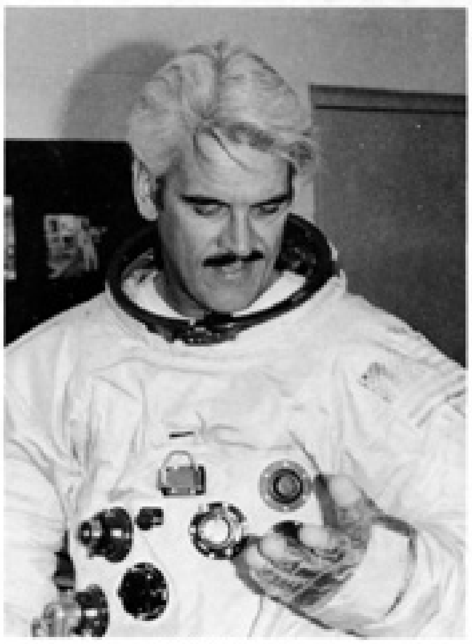
One answer has to do with the sheer size of the Milky Way galaxy. If one million civilizations are distributed randomly through space, the distance between us and the nearest of them would be *about 300 light years*. Another possibility is that supercivilizations may pass relatively rapidly through the stage where they radiate observable electromagnetic energy into space; even on Earth, we are approaching the time when such advances as cable-TV and communications satellites with directed spot beams will reduce sharply the amount of signals sent wastefully into outer space. Thirdly, would we recognize intelligent cosmic activity when we see it? What exactly is life, what is intelligence? Or—worst of all—the answer may be in our table above: lack of longevity of civilizations.

The possibility of receiving signals from extraterrestrial communities is one of the most intriguing problems raised by modern science. What are those signals, where and how are we to look for them, and should we devote time and effort to this search? The success of exobiology in solving its fundamental problem, to prove the existence of extraterrestrial life, depends largely on the level of our space technology—but are we ready? Contacting intelligent beings on another planet is undoubtedly the most fascinating aspect of space exploration, but what are the chances of success? There are 14 stars within a radius of 22 light years from our sun which may have inhabited planets (out of 111). Can we ever reach any of them? What about interstellar flight between civilizations? And would first contact, at least at the present critical stage of our development, have a salutary influence on humankind,—would it be beneficial or harmful? It's an area of inquiry which is as full of the stuff that wild-eyed fantasy is made of as it is braced with realistic, but exciting facts.

"Chauvinistically speaking, the bestiary out there, if any, will be exotic in the truest sense of the word."

For now, one final thought about our own existence and destiny: What if we are being too humble by assuming that ours is only a rookie civilization in a universe populated with a million or more supercivilizations? In our preceding analysis we used a rate of star formation averaged over the age of the universe, but in reality the number of suns in the beginning, billions of years ago, must have been quite small —and so may have been the opportunities for life to evolve. Maybe conditions for life, too, were unfavorable for longer than we have assumed above; maybe the threshold was not 10 billion years ago but more like 5 billion years. Then ours could be one of the very first planets with life in the universe, as Krafft Ehricke has pointed out. We could be privileged to be among the earliest intelligences, standing in the dawn light of life in the universe.

And the vigorous emergence of millions of other civilizations may take place in the billions of years to come—opening for us a future of truly breathtaking magnitude.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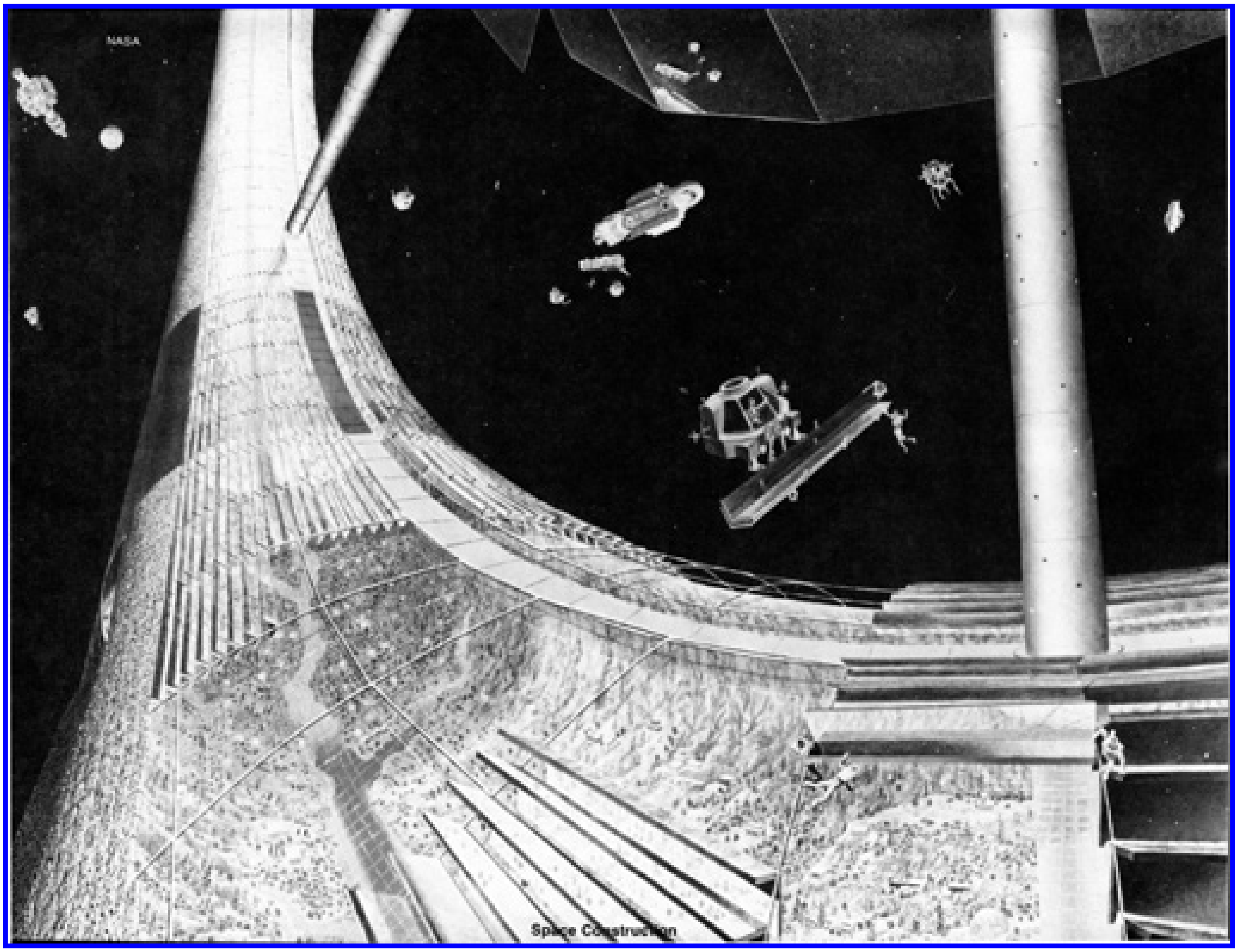

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Last modified: November 21, 2005.