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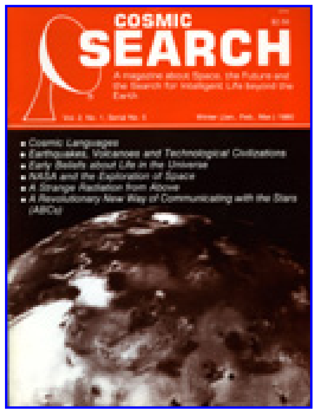

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[Article in magazine started on page 2]

The Grand Analogy: History of the Idea of Extraterrestrial Life

By: Trudy E. Bell

Is there life on other worlds?

As yet we do not know. On the basis of modern-day knowledge of astronomy and biology, the answer "yes" is strongly suspected: enough that the search for extraterrestrial life has already begun.

Bell

The single strongest piece of evidence in favor of the existence of extraterrestrial life is the fact that we exist. From that fact we know that at least once in the history of the universe a system of planets accreted around a warm stable star and that at some moment in prehistory on the surface of one of them life stirred in the primordial ooze. Now, if we are a valid sample of the universe and if planets and life and sentient beings evolved once in one corner of the Milky Way, might they not have evolved elsewhere as well? Indeed, might the event not be quite common? Sum, ergo cogito.

The question "Is their life on other worlds?" is at least as old as human speculation about the possibility of flight. Moreover, the reasoning from analogy with the earth that the answer might be "yes" is equally venerable. In the first century before Christ the honey-tongued Roman philosopher-poet Lucretius declared:

> "It is in the highest degree unlikely that this earth and sky is the only one to have been created ... Nothing in the universe is the only one of its kind, unique and solitary in its birth and growth ... You are bound therefore to acknowledge that in other regions there are other earths and various tribes of men and breeds of beasts."

In the Thirteenth Century a scholar in a totally different civilization, Teng Mu of the Sung Dynasty in China, reached the same conclusion by the same logic:

> "Empty space is like a kingdom, and earth and sky are no more than a single individual person in that kingdom. "Upon one tree there are many fruits, and in one kingdom there are many people. "How unreasonable it would be to suppose that, besides the earth and the sky which we can see, there are no other skies and no other earths."

Nor are these two philosophers unique in the history of thought.

In order to answer the question "Is there life on other worlds?" (indeed, even in order to be able to ask it) one must operate upon three basic assumptions: that there are other worlds, that those other worlds might bear life, and that we have some means of discovering it. Although the first two assumptions appeared and disappeared at various times over the past two-thousand-plus years, the third one did not begin to appear in the modern sense until the first crude telescope was turned heavenward.

Are There Other Worlds?

For one and a half millenia, until the time of Copernicus, the generally accepted cosmology was a geocentric picture of the universe refined by Aristotle and Ptolemy. According to Aristotle's cosmology, the earth—composed of four gross and corruptible elements earth, air, fire, and water—was believed to be poised in the center of the universe. The rest of the universe, composed of a pure and noble fifth element, the aether, was a large sphere enclosing the earth, its boundary being the sphere of fixed stars. The sun, moon, and planets were embedded in concentric spherical shells between the earth and the stars. They revolved with uniform velocity around the earth by virture of motion imparted to them from a *Primum Mobile*, or prime mover, at the periphery of the sphere of fixed stars—needed because in Aristotelian physics there was no concept of momentum. In the Middle Ages, when the early Christians adopted the Aristotelian world picture, they replaced the unpersonified *Primum Mobile* by God; to them this proved that God was the necessary force in perpetual and direct contact with the universe that kept the stars in their courses and the planets harmoniously executing their silent ballet.

Now, the Aristotelian picture of the universe assumed only one abode for mortal life: the earth. The stars and the planets were simply lights composed of the aether, their brilliance produced by friction between the heavenly spheres. The Christians thus inherited from Aristotelian physics the idea of a unique abode of life—the earth—which accorded very well with the Biblical account of the special creation of man by God and with the story of Salvation by God's only begotten son. Such a cosmology did not admit of the possibility that other worlds like the earth even existed, much less that such worlds might bear life.

The Aristotelian cosmology seemed illogical to several medieval and early Renaissance thinkers. In 1440 the Cardinal Nicolas Cusanus wrote an essay, *Of Learned Ignorance*, in which he contended that the universe was indefinitely large with neither a center nor a circumference, that there was no essential difference between the nature of terrestrial matter and celestial matter, and that each star was a sun like our own with its own complement of planets, which were probably inhabited. Cusanus was a man before his time, however, and his ideas didn't have their greatest impact for another century and a half.

Copernicus rearranged the components of the universe and moved the sun to the center of the solar system. Earth was therefore delegated to be one of the solar system's planets. Despite these changes, Copernicus retained the idea of an outermost sphere of fixed stars.

From "De Revolutionibus Orbius Coelestium" courtesy Rare Book Division The New York Public Library, Astor, Lenox and Tilden Foundations.

The real pivot in thought about the existence of other worlds came in 1543, with the publication of *De Revolutionibus Orbium Coelestium*. In this work Copernicus commanded the sun to stand still and sent the earth revolving around it, a planet like all others. He halted the 24-hour revolution of the stars around the earth and started the earth spinning on its axis to create the same effect. But this modest canon of Frauenberg was not a heretic nor was he particularly revolutionary: he still kept the universe spherical and finite (although very large indeed), and he still kept the earth and the other planets embedded in their crystalline spheres and revolving with uniform velocity around the sun.

Whether Copernicus intended it or not, however, his sun-centered cosmology undermined the Aristotelian picture. The most crucial feature was that by arresting the diurnal rotation of the sphere of fixed stars around the earth, he deprived it of its primary physical function: to communicate the motion imparted to it by the *Primum Mobile* (or God) to the rest of the universe. Copernicus's intellectual successors were quick to perceive that, and Copernicus had scarcely been in his grave a decent time before they were shattering the crystalline spheres altogether, scattering the stars at various distances throughout infinite space, admitting a vacuum between them, and dreaming of other worlds inhabited by other men in the vast expanses of the solar system.

First, in 1572 Tycho Brahe observed a new star that flared up as brilliant as Venus and remained visible for over a year in the supposedly immutable realm of the fixed stars. Five years later he discovered that a bright comet exhibited no measurable parallax and from that he concluded that the comet had to be a celestial phenomenon traveling between the planets, puncturing their aethereal spheres—had such existed.

Thomas Digges decided to abandon the notion of a sphere of fixed stars and instead imagined the stars to be scattered throughout the universe to infinity. His diagram of this system was published in 1576 in his book, "A Perfit Description of the Caelestial Orbes."

Meanwhile, in 1576 the leading Elizabethan mathematician Thomas Digges published *A Perfit Description of the Caelestiall Orbes*, in which he exulted that Copernicus's new concepts for the first time allowed the human mind to contemplate overthrowing the classical belief that the universe was spatially bounded by the sphere of fixed stars; in fact, Digges artfully worded his arguments in such a way that he made the notion of an infinite universe seem as though it were an integral part of the heliocentric hypothesis.

A Perfit Description was so popular that between 1576 and 1605 it went through no fewer than seven editions. About the time that the third edition was published, in 1583, a renegade monk from Italy named Giordano Bruno came to the court of Queen Elizabeth. Exposed to Digges's thoughts, which supported his own mystically-inspired view of an infinite universe, partially drawn from Lucretius and Cusanus, he wrote several works that advanced the idea that the universe contained an infinite number of suns, each of which was accompanied by its own retinue of inhabited planets.

And indeed, philosophically, the hypotheses of Cusanus, Copernicus, Digges, and Bruno seemed to be confirmed that frosty January eve in 1610 when Galileo first turned his homemade telescope on Jupiter and discovered that the giant planet was orbited by four unmistakable moons.

The concept of a plurality of worlds in space shook the very foundations of Aristotelian Christianity. In the Christianized Aristotelian cosmology, heaven—the abode of God and the angels—lay outside the sphere of fixed stars; if the stars were strewn throughout infinite space, where was heaven? Without the crystalline spheres how could God directly intervene in life on earth? Indeed, in such a universe what was the necessity and role of God? Dangerous, frightening ideas, these—all direct implications from the cosmological model of a devout canon. It was in part for espousing such frightening ideas implicit in the concept of a plurality of worlds that in the early Seventeenth Century Bruno was burned at the stake, *De Revoluntionibus* was put on the Index of forbidden books, and Galileo—feared as a resurrected Bruno—was shown the instruments of torture and put under permanent house arrest.

But ideas, once they have inflamed the imagination, do not die, nor were they everywhere repressed. Telescopes were becoming available so rapidly that in a few short years hosts of philosophers and ordinary citizens began turning their own marveling eyes toward the moon, the planets, the starry Milky Way ... and began asking the inevitable next question.

Are the Worlds Inhabited?

The telescope revealed beyond doubt that the moon was a world much like the earth, with rugged mountains and large dark flat areas smooth as seas; clearly it was a solid opaque body that reflected the light of the sun and had no light of its own. The changing phases of Venus were so much like the moon's that Venus, too, must be a body like the moon. And if these bodies were so much like the earth in some ways, could it be that indeed they were exactly like the earth in all ways?

A number of Seventeenth Century authors explored that question, cautiously speculative. By far the most famous book on the subject was the engaging *Entretiens sur la pluralité des mondes* published in 1686 (the year before Newton's *Principia*) by a 28-year-old playwright named Bernard le Bouvier de Fontenelle. The book is written in the form of a delightful dialogue over half a dozen starlit evenings between Monsieur L---- and a fictitious quick-minded Marchioness of G----. Both the flavor and the essence of the conversations are embodied in one particularly nice passage:

> "I must tell you [says the monsieur], that in love and the mathematics, people reason much alike: allow ever so little to a lover, yet presently after you must grant him more; nay, more and more, which will at last go a great way; in like manner, grant but a mathematician one minute principle, he immediately draws a consequence, to which you must necessarily assent; and from this consequence another, till he leads you so far, whether you will or no, that you have much ado to believe him.... Now this way of arguing have I made use of. The moon, said I, is inhabited, because she is like the earth; and the other planets are inhabited, because they are like the moon; I find the fixed stars to be like our sun, therefore I attribute to them what is proper to him: you are now going too far to be able to retreat, therefore you must go forward with a good grace."

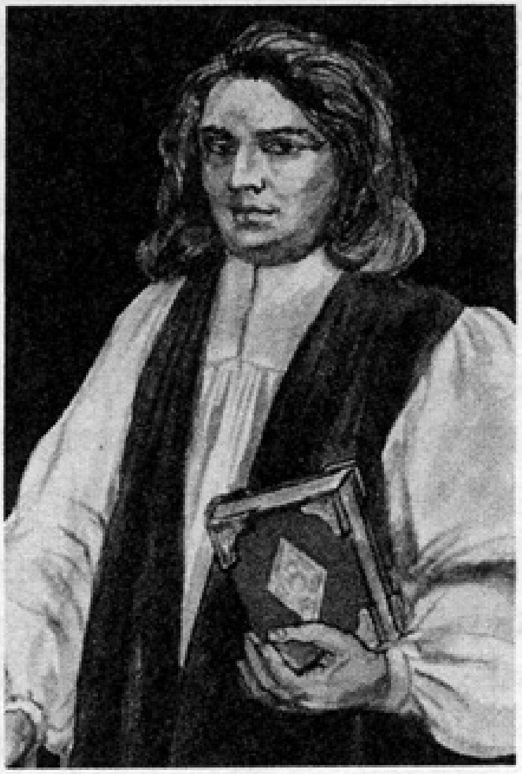
Fontenelle's *Plurality of Words* [sic; "Words" should be "Worlds"], as it was called, was read so avidly that it was translated from French into all the major languages of Europe; it had at least three separate English translations, one of which ran through six editions by 1737. One of its readers was none other than Christian Huygens, who actually felt that Fontenelle did not go far enough in his reasoning. Then in his 60s, Huygens put pen to paper and gave the world *Cosmotheoros* (Latin for "Theory of the Universe") in which he dispassionately and critically examined the possibility of life on other worlds.

Metrodurus (5th cent. B.C.)

Lucretius (1st cent. B.C.)

Teng Mu (13th century)

Bruno (16th century)



Wilkins (17th century)

de Fontenelle (17th century)

Huygens (17th century)

In one of the first attempts at stellar photometry, Huygens tried to determine how far away the stars actually are and concluded from his experiments that if Sirius were the same absolute brightness as the sun, it must by 27,664 times farther away—about a quarter of a light-year in modern terms.* (*In reality Sirius is 8.7 light-years away, but it is some 50 times brighter than the sun; if Sirius were only as bright as the sun, it would have to be seven times closer to the earth in order to have the same apparent magnitude—meaning that Huygens's estimate based on that assumption is impressively close to being correct.) At that distance, he concluded, from the earth no planets would be visible around another star because they would be so close to the star that they would be lost in the glare.

In our own solar system, Huygens methodically reasoned from analogy with the earth that all the planets must have plants and animals and intelligent life, all adapted to the heat or cold of their respective environments. But although the inhabitants must thus be different in some ways from those on the earth, they must also have many similarities: if they are mobile, for example, they must either walk over land or swim through liquid or fly through the atmosphere, meaning that they must have either legs, fins or wings. Huygens extended such arguments of necessity to include the inhabitants' culture, science, and morals. And all through the book he endeavors to show that a plurality of inhabited worlds did not contradict Scripture because

> ... should we allow the Planets nothing but vast Deserts, lifeless, inanimate Stocks and Stones, and deprive them of all those Creatures that more plainly speak their Divine Architect, we should sink them below the Earth in Beauty and Dignity; a thing very unreasonable..."

and also very wasteful, completely uncharacteristic of a God who has a purpose for everything.

Huygens's scientific reasoning about the existence of extraterrestrial life seemed to be confirmed by the rapid astronomical discoveries of the Enlightment. Newton's laws of gravity established a physical connection between all the bodies in the universe, and his first law of motion established the existence of inertia and momentum, thus eliminating the last Aristotelian need for a finite universe and *Primum Mobile*. James Bradley's observations of the aberration of starlight conclusively demonstrated that the earth was indeed moving around the sun. Furthermore, William Herschel's observations of double stars revealed that light-years away from the earth, bodies were behaving according to the same laws of gravity and motion that our own solar system was, proving finally that there was no difference between celestial matter and terrestrial matter—the universe was indeed all of a piece.

What powerful tool that was! It implied for once and for all that reasoning about other planetary systems by analogy with our own was indeed a valid approach. Even more exciting, the nebular hypothesis of Immanuel Kant and later Pierre Simon Laplace that the sun and planets condensed out of a spinning cloud of gas and dust, implied that planetary systems were a natural accompaniment to the formation of stars. These discoveries opened the way for a veritable flood of Eighteenth Century writings—ranging from scholarly treatises to cheerful essays in almanacs—setting out to prove the existence of extraterrestrial life and speculate what it was like.

Huygens's theological reasoning also threw open the way for others to demonstrate that—lo and behold!—the existence of a plurality of inhabited worlds actually glorified Scripture. In an influential work entitled *Astro-Theology* published in 1715, William Derham rushed in where Huygens dared not tread, populating all the bodies in the universe, even the sun and comets. "How can we say they are not inhabited?" he asked. "How can we place such limits on the infinitude of God's capabilities?" With such arguments the question of extraterrestrial life began migrating into a highly theological realm, until in the first half of the Nineteenth Century Thomas Dick unconsciously demonstrated the irony of Bruno's death by declaring in his *Sidereal Heavens*: "...though the Scriptures never directly or explicitly treat of this subject, the doctrine of a plurality of worlds *is embodied in many passages of the sacred writings*" (his italics).

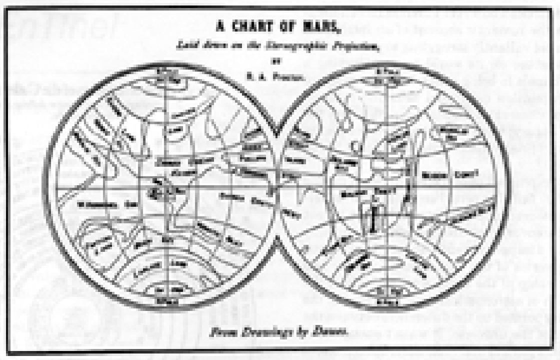
Now, to be sure, not every astronomer felt that the existence of extraterrestrial life was a foregone conclusion. Although by the Nineteenth Century negative views on the subject were prone to attack, there were a minority of dissenters, the most notable of whom was the British philosopher William Whewell. In his *Plurality of Worlds* of 1851 Whewell stated that he was skeptical about the concept of extraterrestrial life on theological grounds because he thought it unnecessary: to him the creation of man was the great event of the universe and he did not think it at all derogatory to divine wisdom to have arranged all the other bodies of the universe to provide an elegant setting for the existence of such a being.

On scientific grounds Whewell did not settle for the assumption of his predecessors that life would arise everywhere and adapt itself to the conditions under which it existed. On the contrary, he felt that certain conditions were necessary for life to arise at all. Neptune, Uranus, Saturn, and Jupiter were simply too far from the sun and too cold and dark for life; moreover, their gravitational fields are so great that at best any life there would not have a skeleton, but would "be cartilaginous and glutinous masses...boneless, watery, pulpy creatures" floating in the liquid environment. On Mars he abstains from commenting: "[We] need not discuss the question whether there are intelligent beings on the surface of Mars...till we have better evidence that there are living things at all." Mercury and Venus he depopulates in a page as being too close to the sun.

> "The earth, alone, is placed at the border where the conditions of life are combined; ground to stand upon; air to breathe; water to nourish vegetables, and thus, animals...; and with this, a due supply of light and heat, and due energy of the force of weight. All these conditions are, in our conception, required for life; that all these conditions meet, elsewhere than in the earth's orbit, we see strong reason to disbelieve...That the earth is inhabited, is not a reason for believing that the other planets are so, but for believing they are not so."

In that passage Whewell distinguishes himself as the first writer to describe what is called the zone of habitability. He also seems to be one of the first to recognize that life on a planet does not necessarily mean intelligent life, an assumption implicit in the writings of his predecessors.

The Nineteenth Century was a bustling, active, exciting era for astronomy. For the first time astronomers possessed big telescopes for gathering light from faint stars and for examining details on planets; for the first time they possessed spectroscopes for sifting the light to determine their chemical constitution. With the advent of tools for probing the physical secrets of the universe, theological arguments about the conditions on the planets began to have less force, and scientific arguments had more.



Richard Proctor compiled the first good map of Mars in 1869. This map, reproduced here from Proctor's "Other Worlds Than Ours", 1871, was in turn based upon drawings of Mars by the keeneyed observer W. R. Dawes. It is notable that Proctor included no canals and no canal-like features. Proctor did believe he was seeing evidence for the presence of continents and oceans on Mars.

The first really good map of Mars was constructed by the British astronomer Richard A. Proctor in 1869 [graphic on the left], but the map that inflamed the world was the one drawn a decade later by the Italian astronomer Giovanni Schiaparelli, showing that the ruddy surface of Mars appeared to be crossed and recrossed by a delicate tracery of dark lines that appeared to be channels, "canali" in his native Italian. In English, however, the word was rendered "canals", implying an artificial origin. Subsequent observations of seasonal changes on Mars by a number of astronomers, and compelling books by the American observer Percival Lowell thrilled the world with the romantic account of an intelligent race on a dying planet valiantly struggling to preserve the last remaining moisture on its world by constructing a heroic network of canals to bring water from the polar ice caps to nourish vegetation cultivated near the equator. Speculation and excitement about Mars ran high into the early Twentieth Century: were we on the threshold, after all these centuries, of finally discovering intelligent life on a neighboring world?

When the photographs and observations of Mars during its opposition in 1907 failed to reveal anything new, different, or exciting, however, popular interest in the planet began to wane. Moreover, that disappointment was only one in a series of disappointments about the planets. Whereas the discoveries of the Eighteenth Century had emphasized the kinship of the earth with the rest of the universe the wealth of astronomical data gathered in the Nineteenth Century pointed up the differences between the earth and the rest of the universe. It wasn't enough that they shared the same physics and chemistry. Spectroscopic observations indicated that Mars was a frigid desert, populated at most by lichens. Venus seemed to be a swamp, at best roamed by dinosaurs as in the earth's own past. The rest of the solar system was totally inhospitable: the moon was airless, Mercury was a heap of slag, Jupiter and the other giant planets were bloated balls of poisonous gases.

Even more disheartening, the prospects outside the solar system also looked grim. By the mid-1800s it had been observed that the sun, which contains the overwhelming majority of the mass in the solar system, has only a small fraction of the angular momentum; the rest was possessed by the planets. Since no way was known for the sun to get rid of angular momentum, that disparity constituted a real objection to the nebular hypothesis. To explain the fact, various catastrophic theories of planetary formation were proposed. One of the most popular was the Chamberlin-Moulton theory, which hypothesized that the planets condensed from material pulled out from the sun by the gravitational attraction of a star passing close by. The implication of all the catastrophic theories, however, was that the formation of a solar system was an exceedingly rare event. How much rarer must be life.

The result of such disappointments was that during the first half of the Twentieth Century the books and articles discussing the possibility of intelligent life in the universe were noticeably less exuberant—some cautious to the point of pessimism.

It is intriguing to note, however, that this pessimism in science coincided with the birth of the lusty, burgeoning genre of early modern science fiction, which had its heroes swashing their buckles in steaming Venusian swamps or on the shifting sands of Mars, rescuing voluptuous damsels in distress from the clutches of green and drooling monsters. Now, science fiction is very old: its roots go back at least to the Seventeenth Century, when the initial speculations about a plurality of inhabited worlds loosed the imaginations of Kepler, Cyrano, and later even Poe. But these older science fiction works were rather isolated phenomena, because, I suspect, the idea of life on other worlds was so widely accepted that people could satisfy their yearnings and curiosity about extraterrestrial life in books of speculative fact. Only when theological arguments lost weight and scientific arguments seemed to indicate that the probability of extraterrestrial life was slim, did science fiction in the modern sense begin to appear—almost as if thwarted hopes and dreams were channeled into speculative fiction.

In the short run the rise of science fiction had a negative effect on the concept of extraterrestrial life: it became associated with LGMs (Little Green Men) and the extravagant exploits of space opera. Moreover after 1947 with the widely publicized sighting by Kenneth Arnold of an unidentified flying object (UFO), the idea of extraterrestrial life was also co-opted by the flying saucer cults. To serious, conservative investigators, the idea of extraterrestrial life had not only been shelved by science, it had fallen off the shelf into bad company—and I suspect that all these associations were what conspired to make the idea temporarily distasteful.* (*This hypothesis seems to be supported by the fact that today, now that extraterrestrial life is once again a reputable field for speculative fact, science fiction is being incorporated into mainstream literature.)

In spite of the fact that the idea of extraterrestrial life per se languished in the early Twentieth Century, astronomers, biologists, and engineers were independently making contributions that eventually met in powerful combination.

By 1931 the spectroscope revealed the curious fact that although hot, brilliant, massive stars were spinning rapidly on their axes, rotating once in a period of hours or days, there was a fairly sharp dividing line below which smaller, cooler stars were spinning very slowly, rotating perhaps only once per month—exactly like the sun. Where did all their angular momentum go? Might all the myriad of slowly spinning stars in the galaxy also be accompanied by systems of planets—exactly like the sun? Within the following decade or two, astronomers returned to the nebular hypothesis, with newly-discovered principles of magnetohydrodynamics playing a key role in solving the angular momentum problem.

In the early Twentieth Century radio developed, and in the 1930s it was discovered that the universe was alive with radio signals. Radio astronomy was born: astronomers began to "listen" to the stars and the gas and dust between them, penetrating regions blocked to the narrow range of visible light.

Meanwhile, biochemists were hypothesizing that life on the earth began spontaneously in a "hot, thin soup" of amino acids, sugars, proteins, and organic compounds in a lightning-stormy hydrogen-rich atmosphere of the primordial earth. Laboratory experiments seemed to verify this, implying that life might be an intrinsic property of molecules past a certain stage of complexity. And subsequently organic molecules were found deep inside certain meteorites and in clouds of dust in interstellar space, suggesting that carbon compounds tend to form even in hostile environments.

But perhaps most significant of all, on October 4, 1957, a Soviet rocket thundered off its launch pad, split the atmosphere, and injected a beeping satellite the size of a basketball into orbit around the earth, Sputnik. With that one decisive stroke the human race "slipped the surly bonds of earth"—and 12 years later reached up and touched the moon.

The impact of space travel on the idea of extraterrestrial life was dizzyingly profound. Suddenly perspective altered: visiting other bodies in the universe was no longer a fantastic dream but was within the grasp of reality—and so for the first time, was the possibility of finding out first-hand whether there was indeed life on other worlds.

Can We Find Out?

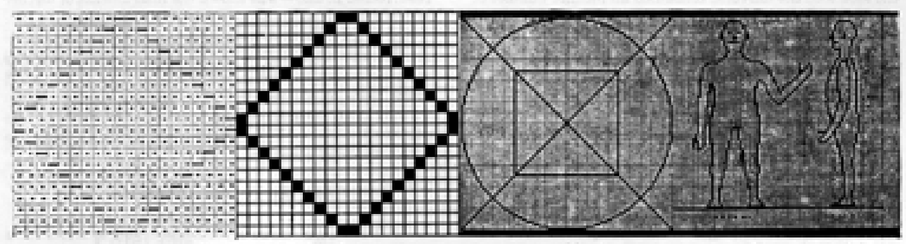
The first human being had not even left the surface of the earth to venture into space when the new hope, the new optimism leapt up to embrace the stars. All the seemingly independent threads of investigation that led to the new optimism were gathered together into one bundle by Harlow Shapley. In 1958, in his delightful book *Of Stars and Men*, Shapley was the first to put numbers to the probability of life on other worlds. Suppose, he estimated, that only one star in a thousand has a planetary system, that only one of those systems in a thousand has a planet in the zone of habitability, that only one of *those* planets in a thousand has the proper chemical composition for life. Why, that meant that one out of a trillion (10^{12}) planets meets all tests for life; and since there are some one hundred million trillion (10^{20}) observable stars in the universe, then that meant there are a minimum of 100 million opportunities for life in the universe. Personally Shapley felt that the estimate was between 1,000 and one million times too *low*.

The effect of Shapley's book was electrifying. In 1959 Giuseppe Cocconi and Phillip Morrison published an article in *Nature* titled "Searching for Interstellar Communications" in which they suggested we listen for intelligent signals from several nearby sun-like stars at the radio wavelength of atomic hydrogen, 21 centimeters. With their last paragraph they threw the question of extraterrestrial life back into scientific repute:

"The reader may seek to consign these speculations wholly to the domain of science fiction. We submit, rather, that the foregoing line of argument demonstrates that the presence of interstellar signals is entirely consistent with all we now know, and that if signals are present the means of detecting them is now at hand...We therefore feel that a discriminating search for signals deserves a considerable effort. The probability of success is difficult to estimate; but if we never search, the chance of success is zero."

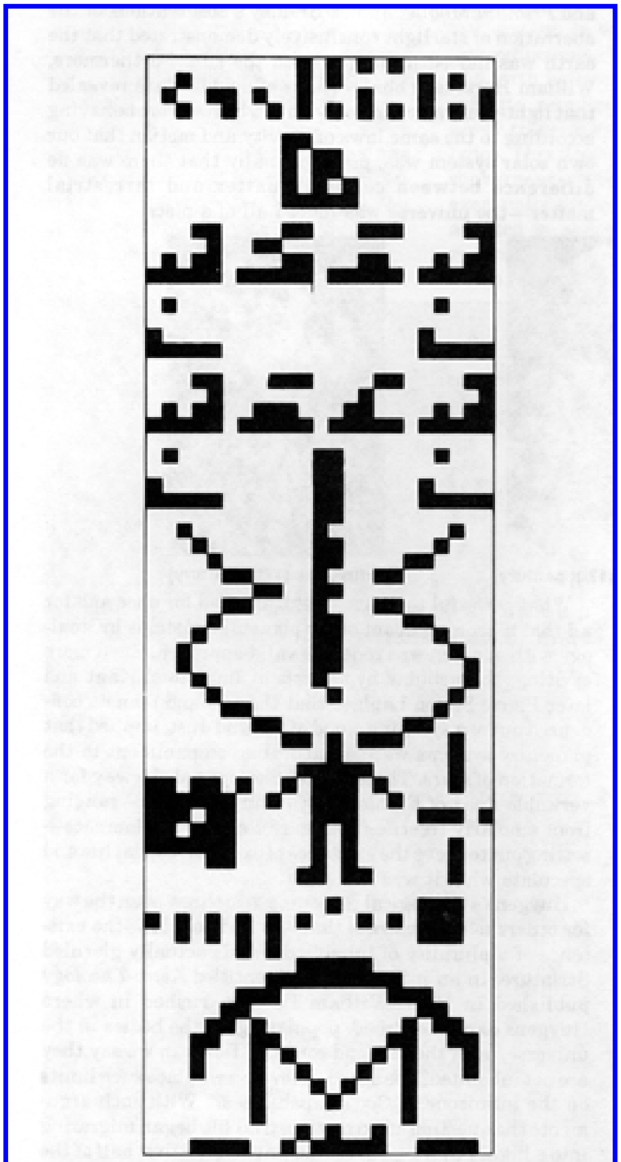
Although the idea of communicating with extraterrestrial beings is not a new one—Gauss, Littrow, and several other Ninteenth Century astronomers entertained various schemes for signalling Mars with light—the suggestions were isolated phenomena until the development of radio in the Twentieth Century.

Apparently the earliest discussion of the problem of building up a "lingua cosmica" was an article in 1920 by H. W. and C. Wells Nieman in *Scientific American*, called "What Shall We Say to Mars?" In it they suggested sending a series of signals that could be combined in such a way that it would form a pictorial message [see graphic to the right]—a message remarkably similar in part to the two-and-a-half-minute message sent in 1974 from the Arecibo radio telescope in Puerto Rico toward the globular cluster M13 in Hercules [see graphic below left]. The problem of an interplanetary vocabulary was discussed at greater length by Lancelot Hogben in his article "Astroglossa, or First Steps in Celestial Syntax" in the *Journal of the British Interplanetary Society* in 1952, and by Hans Freudenthal eight years later in his book *Lincos: Design of a Language for Cosmic Intercourse*.



Dots and dashes arranged to form a simple diamond — Dashes of previous message plotted on quadrilled paper — A more elaborate message, with the dots again eliminated — A still more complicated message, depicting a man

The Arecibo message was constructed in a way very similar to that proposed by H. W. Nieman and C. Wells Nieman in "Scientific American" 55 years earlier. The Niemans, in their article "What Shall We Say to Mars?" suggested that the signals could be combined to form a picture, which presumably would be understood more easily than language or mathematics by an alien intelligence. Illustration courtesy "Scientific American", March 20, 1920, page 187.



In 1975 the giant radio telescope dish at Arecibo sent a $2\frac{1}{2}$ minute message in the direction of the globular cluster M13 in the constellation of Hercules. This transmission built up its pictorial images in a manner suggested 55 years ago.

From "The Search for Extraterrestrial Intelligence" by Carl Sagan and Frank Drake, *Scientific American* © 1975.

Today the problem is receiving considerable study, because only in the 1960s and 1970s has the technology become available for a serious search for extraterrestrial intelligence. In 1974 Carl Sagan pointed out that if on another planet there were another civilization only as advanced as ours with a radio telescope just like the one we already possess at Arecibo, the two radio telescopes could be essentially anywhere in the Milky Way galaxy and still communicate with each other.

Over the past 10 or 15 years scores of technical conferences, hundreds of books, thousands of articles and innumerable lectures have addressed the question of life on other worlds, ways of detecting it, and the implications—both exhilarating and threatening—that its discovery might have on our science and society. The search for it has begun. One of the principal purposes of the Viking mission to Mars was to search for evidence of microbial life—and the results were tantalizingly ambiguous. The plaques attached to the Pioneer spacecraft and the records of terrestrial sights and sounds included with the Voyager spacecraft are as much greeting cards addressed to "Occupant, Universe" as they are interstellar graffiti: "Homo sapiens was here."

On a very modest scale half a dozen astronomers under Stuart Bowyer at the Hat Creek Radio Observatory of the University of California have begun Project SERENDIP: Search for Extraterrestrial Radio Emissions from Nearby Developed Interstellar Populations.

Searches have also been conducted or are in progress at the National Radio Astronomy Observatory at Green Bank, West Virginia, the National Astronomy and Ionosphere Center at Arecibo, Puerto Rico, the Ohio State-Ohio Wesleyan Radio Observatory, Delaware, Ohio, the National Research Council Observatory at Algonquin Park, Canada, and at several observatories in the U.S.S.R.

The subject of searching for extraterrestrial intelligence has become sufficiently reputable that in the past three years an article on it was published in *Scientific American* and an entire number of the *Proceedings of the Royal Society of London* was occupied with "A Discussion on the Recognition of Alien Life." The sheer tonnage of wood pulp and volume-hours of warm air lavished on the subject can easily lead one to the happy assumption that intelligent extraterrestrial life not only exists but is friendly and eager to see us wave to it across the light-years. (Some uncritical minds even assume it has already contacted us.)

In backlash to such confident press, a number of authors have constructed detailed arguments based on contradictions in internal logic, devoted to showing that we have no reason at all to assume that life developed elsewhere in the universe and that even if it had, the structure of its society or the existence of interstellar travel might preclude us from discovering it or communicating with it at all.

"The difference is that today, we have the capability to stop speculating and find out."

Arguments of this type impress me as being the modern-day equivalent of the medieval debates as to how many angels can dance on the head of a pin. On the basis of exactly zero data, careful mathematical formulae are devised to show how many aliens we cannot hope to detect. Although the arguments are phrased in terms of communicating with extraterrestrial life, however, the real issue being argued is nothing less than *the grand analogy* that forms the philosophical foundation of modern astronomy: the assumption that the laws of physics and chemistry and the mathematical probabilities in the universe are everywhere the same. Without that assumption, astronomy would consist only of gathering data about an infinite number of unrelated special cases. The grand analogy has been a fruitful tool for 350 years. If one truly wants to find out if extraterrestrial life exists—and I suspect that the authors of the negative arguments simply do not—one must begin somewhere, and the grand analogy is all we have. It's even been suggested that the search for extraterrestrial life would be an excellent test of our assumption about the universality of the universe.

On the other hand, the fact remains that we still have exactly zero direct evidence in favor of extraterrestrial life. No planet has ever been seen around another star, no LGM has ever radioed to us: "Mind if I drop in for tea?" Too much flashy overconfidence about the existence of extraterrestrial intelligence could whip up public fervor for a great search, only to create a bitter taste if success is not immediate. After all, if we look at all the wrong stars first, or listen at the wrong wavelengths, a search could take years, even decades.

Nonetheless, we have much circumstantial evidence about the universe that gives us hope that indeed there is a plurality of inhabited worlds, Moreover, that hope is held today for the same reason that it sprang eternal centuries ago: the grand analogy. *The difference is that today, for the first time in human history, we have the capability to stop speculating and to find out.*

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