

The Arecibo Message of November, 1974

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On November 16, 1974, the Arecibo Observatory transmitted at 2380 MHz at an effective bandwidth of 10 Hz a message directed at the globular cluster M13. The message consists of a 1679-bit picture portraying a counting scheme, five biologically significant atoms (H, C, O, N, and P), the generic structure of the four purines and pyrimidine bases of DNA; a schematic of the DNA double helix with an order-of-magnitude estimate of the number of base pairs; a representation of a human being and his or her dimensions; a depiction of the solar system with an indication that human beings inhabit the third planet and an estimate of the human population of the Earth; and finally, a schematic representation of the Arecibo Observatory and a description of its dimensions.

INTRODUCTION

Major improvements have been made to the facilities at the Arecibo Observatory (Lalonde, 1974), which permit the generation of a radio transmission beam of unprecedented strength. Utilizing maximum transmitter power, the effective radiated power in the beam is approximately 2×10^{13} W, a power some 20 times the generating capacity of the totality of terrestrial electrical generating stations. With bandwidths of the order of 1 Hz or less, this signal is detectable by radio telescopes of the order of sensitivity of the Arecibo instrument throughout the Milky Way Galaxy. As the first use of this remarkable new facility, the Arecibo staff thought it was highly appropriate to send a simple and brief signal to the fringes of the Galaxy telling of the existence and nature of human life.

As part of the ceremonies to dedicate the newly upgraded Arecibo 1000-ft radio/radar telescope, at 1700 GMT on November 16, 1974, the telescope was so used to transmit a message for possible reception by other intelligent creatures. The transmission was made at a radio frequency of 2380 MHz and bandwidth of some 10 Hz. It utilized the new telescope reflector surface

supported by the National Science Foundation, and was the first use of the new radar transmitter supported by the National Aeronautics and Space Administration. The effective average radiated power in the direction of transmission was 3×10^{12} W, which was, we believe, the strongest signal yet radiated by our civilization. The transmission was directed at a globular cluster of stars, the Great Cluster in Hercules, Messier 13, a group of some 300 000 stars 25 000 light years distant whose apparent size closely matches the beamwidth of the transmission. A radio telescope in M13 operating at the transmission frequency, and pointed toward the Sun at the time the message arrives at the receiving site will observe a flux density from the message which will exceed the flux density of the Sun itself by a factor of roughly 10^7 . Indeed, at that unique time, the Sun will appear to the receptors to be by far the brightest star of the Milky Way.

The Message

The message describes some characteristics of life on Earth which members of the staff of the National Astronomy and Ionosphere Center feel would be of most interest and relevance to other civiliza-

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FIG. 1. The 1679 character message transmitted on November 16, 1974. The characters were sent sequentially, with the transmitter frequency switching between two nearby radio frequencies to perform the transmission of a "0" or a "1."

tions in space. It consists of 1679 consecutive characters, written in a format such that only two different characters are used. The two characters are denoted "0" or "1" in the message (Fig. 1). In the actual transmission each character was represented by one of two specific radio frequencies, and the message was transmitted by shifting the frequency of the radio transmitter between these two radio frequencies in accordance with the plan of the message. The frequencies transmitted were continuously adjusted to correct for the Doppler effect of the orbital motion and rotation of the Earth so that none of the frequencies as observed outside the solar system varies from a specific fixed value.

The message is decoded by breaking the message up into 73 consecutive groups of 23 characters each, and arranging these groups in sequence one under the other. That 73 and 23 are prime numbers facilitates the discovery by any recipient that the above format is the correct way to interpret the message. Figure 2 shows the message so laid out, with the first character sent or received in the upper right-hand corner. The interpretation of the message is as follows.

The message begins with a "lesson" describing the number system to be used. This system is the binary system, believed to be one of the simplest number systems. Written across the top of the message,

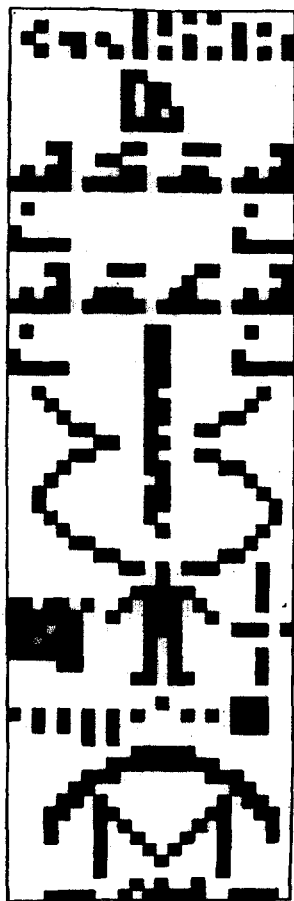


FIG. 2. The message of Fig. 1 laid out in a format of 73 lines of 23 characters per line. Zeros are shown as white, and ones as black. The first character sent is in the upper right-hand corner, and the message reads from right to left and down.

from right to left, are the numbers 1-10 in binary notation. Each number is marked with a "number label," a single character which marks the start of a number. A problem which must be dealt with carefully is the writing of a number so large that all its digits cannot be fitted into the available space. The solution to this is a particular point of the number lesson, and is shown in the numbers 8, 9, and 10. The number sequence has purposely been written so that there is not enough room to write 8, 9, and 10 on a single line. The means of dealing with this problem is revealed with numbers

8, 9, and 10, where the digits for which there is not room are written "below" the least-significant digits. In the figure these digits appear to the left of the least-significant digits. An important point made here is that the second and successive lines of digits are not written under the number label, but only under characters denoting numerical values. This means that, as we would describe it, the number label always stands by itself in the upper right-hand corner of a number. This then marks a number, the orientation of a written number, and where the number begins. As will be seen, this is necessary to make the interpretation of numbers clearcut and to economize in the use of message characters.

Description of Fundamental Terrestrial Biochemistry

The second key lesson is the next prominent group to be sent, the one just below the numbers. This is recognizable as five numbers: from right to left, the numbers 1, 6, 7, 8, and 15. This otherwise unlikely sequence of numbers is to be interpreted as the atomic numbers of the elements hydrogen, carbon, nitrogen, oxygen, and phosphorus.

There are 12 groups on lines 12-30 which are similar groups of five numbers. Each of these groups represents the chemical formula of a chemical molecule or radical, with the numbers from right to left in each case giving the number of atoms in the radical or molecule of hydrogen, carbon, nitrogen, oxygen, and phosphorus, respectively.

Since the limitations of the message do not allow us to describe the physical structure of the radicals and molecules, the simple chemical formulas do not in all cases define the precise identity of the radical or molecule. However, these structures are arranged as they are organized in the macromolecule here described, and knowledgeable organic chemists anywhere should be able through simple logic to arrive at a unique solution for the molecular structures described here.

The most specific of the structures, which should point the way to the correct

pictures of the others, is the structure which appears four times on lines 17–20 and 27–30. This is a structure containing one phosphorus atom and four oxygen atoms, the well-known phosphate group. The outer structures on lines 12–15 and 22–25 give the formula for the sugar molecule deoxyribose. The two sugar molecules on lines 12–15 have between them two structures; the chemical formulas given are, for the left structure, thymine, and for the right, adenine. Similarly, the molecules between the sugar molecules on lines 22–25 are, on the left, guanine, and on the right, cytosine.

This chemical structure is that of deoxyribonucleic acid, DNA, the molecule which contains the genetic information controlling the form, living processes, and inherited behavior of all life on Earth. This structure is actually wound as a double helix, as shown in lines 32–46. The complexity and degree of development of intelligent life on earth can perhaps be described by the number of base pairs in the genetic code, the number of adenine–thymine and guanine–cytosine combinations in the DNA. That there are some 4 billion such pairs in a single human chromosome is shown by the number given in the center of the double helix between lines 27 and 43. Note the use of the number label to establish this as a number and to show where the number begins.

The double helix leads to the head in a crude sketch of a human, establishing the connection between the DNA, the complexity of the helix, and the intelligent creature. To the right of the human is a line extending from the head to the feet of the human, and accompanied by the number 14. This means that the human is 14 units of length in size; the only possible unit of length is the wavelength of the transmission, 12.6 cm, which makes the human 5'9.5" tall. To the left of the human is a number, approximately 4 billion, which denotes the human population. Note that in this number and in the number in the double helix a few insignificant bits have been written as zeros. This is to make these groups look like numbers and not perhaps a drawing of some object.

The Location and Status of Human Civilization

Below the human is a sketch of the solar system—the Sun to the right, then the nine planets with some indication of relative sizes. Planet 3, Earth, is displaced to indicate that there is something special about it. It is displaced toward the human, who is centered on it, and this would suggest that planet 3 is the home of the creatures which sent the message.

Below the solar system, and again centered on planet 3, is an image of a telescope. The concept “telescope” is described by showing a device which directs rays to a point. The mathematical curve which leads to such a diversion of paths is crudely indicated; accurately, of course, it is a parabola. Note that the telescope is not upside down, but “up” with respect to the symbol for the planet Earth.

At the very bottom of the message the size of the telescope is shown; in this case it is the size of both the largest telescope on Earth and the telescope which sent the message. It is 2430 wavelengths across, or 1004 ft. A number giving a result closer to the correct 1000 ft can be constructed, but infelicitously, it turns out to be uncertain whether the number is 1 or 2 separate numbers. The number actually given in the message can only be interpreted plausibly in one way. Of course, great accuracy is of no importance here. This information tells indirectly, when taken with the strength of our signal, a great deal about the level of our technology. If the message is transmitted repeatedly, a desired impression is made that the message emerges from the telescope.

Message Significance

As the choice of frequency, duration of message, and distance of the target clearly shows, the Arecibo message is very unlikely to produce interstellar discourse in the foreseeable future. Rather it was intended as a concrete demonstration that terrestrial radio astronomy has now reached a level of advance entirely adequate for interstellar radio communication over immense distances. More extensive attempts at the transmission of radio messages from the

Earth to extraterrestrial civilizations should be made only after international scientific consultations as recommended by the first Soviet-American conference on communication with extraterrestrial intelligence (Sagan, 1973).

Message Construction and Transmission

The content of the message was constructed primarily by Frank Drake, Richard Isaacman, Linda May, and James C. G. Walker. Valuable suggestions for improvements were given by a number of people, but particularly by Carl Sagan. The computer programming of the message and of the automatic transmitter control program was made by Bernard Jackson. The high-quality operation of the transmitter owes much to Robert McDonald of Continental Electronics Mfg. Corporation, and Thomas Dickinson of the NAIC. The high-power aberration-correcting line feed was designed and constructed under the supervision of Merle Lalonde.

The message was transmitted on November 16, 1974, at a rate of ten characters a second. It took 169 sec to send. One minute after completion of the transmis-

sion, the message was as far from the Sun as the orbit of Mars. After 35 min it passed the distance of Jupiter, and after 71 min, Saturn. It had already overtaken the two previous potential communications with extraterrestrial intelligent life, the plaques on the Pioneer 10 and 11 spacecraft. Five hours and 20 min after transmission it passed the distance of the outermost planet, Pluto, and thus left the solar system. It became forever the vanguard of what we hope will be a growing body of human intelligence transmitted to space for the benefit of others.

ACKNOWLEDGMENT

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REFERENCES

- LALONDE, L. M. (1974). The upgraded Arecibo Observatory. *Science* **186**, 213-218.
- SAGAN, C. (1963). *Communication with Extraterrestrial Intelligence* (C. Sagan, Ed.). MIT Press, Cambridge, Mass.