SETI:
Search for Extraterrestrial Intelligence

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Topic at the moment and vast cultural implications, supported thanks to the recent discoveries of extrasolar planetary systems and the growth of the young science of bio-astronomy. Research in the cosmos of other forms of life represents one of the great challenges of science today. The ability to pick up a radio signal produced by extraterrestrial intelligence is the goal of SETI, a worldwide program of astronomical research that uses the powerful means of radio astronomy and information technology. We present a series of articles to inform fans of electronics, radio communications and more exciting science adventure developments of the third millennium.

In a previous work (EF Riv. N. 196, p. 17) we talked about a fascinating and innovative experiment: SETI @ home. Fascinating because it ventures into a field with deep cultural implications that can disrupt our philosophical, religious and social innovation because it represents the first scientific experiment that expressly requires the involvement (not without a few drawbacks and limitations) of the common people. In an attempt to frame the SETI @ home program in the broader context of SETI research world, I thought I would talk about the topic in general, starting from the history and significant milestones, highlighting in particular the technological aspects that may most interest to readers of EF As stated by J. Heidmann, world-renowned astrophysicist and radio astronomer: at the beginning of the third millennium ".. our vision of the cosmos took a new turn, and the possibility that the world opens it is enlarged. Life, now, there appears to be a natural phenomenon caused by the evolution of the cosmos in its entirety. If so, the great adventure that was his appearance, and then its evolution, it could well have developed elsewhere, as well as on Earth. The life has therefore ceased to be for us a phenomenon exclusively terrestrial in order to become a cosmic possibility that is necessary to consider on the scale of the entire universe."

With powerful telescopes and radio telescopes, using it without reservation the most advanced methods of research, numerous scientific organizations around the world are probing the interstellar spaces. An analysis of the probability dictates that by now we should not be too far away from a shocking discovery: we are not alone in the universe! In such a landscape, new questions lie ahead: what is missing

"meeting" with new extraterrestrial intelligence? How can we communicate with them? In the event that this happens, we are ready to get in touch by managing the consequences?

I fully realize how to evoke these images inevitably calls to mind a huge amount of science fiction literature and in particular the most strange and fantastic stories of UFO: without precise insights, designed to clear up misunderstandings and easy misunderstandings, confusion between SETI and UFO would be at least catastrophic for the development and survival of the research. Without going into detail, it is easy to imagine how great it would be the damage caused to the SETI project from confusion with the study of unidentified flying objects. It is important to mention the passionate speech of a member of the House of Representatives of the United States (1990) that aims to push through a drastic reduction in research funding SETI: according to the America he would not have to spend precious taxpayer dollars to try the green men. He pointed out how only the block of these funds would have proven that on Earth there is still intelligent life.

The first theoretical hypotheses working on SETI were developed by physicists G. Cocconi and P. Morrison who, in an article in the journal "Nature", have demonstrated the possibility, thanks to new techniques of radio astronomy, to communicate over interstellar distances with any extraterrestrial civilizations. These gentlemen have calculated that if the universe had other radio astronomers had access to radio telescopes and receivers comparable to those available in 1959, along with radio transmitters with radiated powers similar to those of the best land-based plants, it would have been possible, despite the big distances between the stars, exchanging radio signals to communicate. According to the two authors, given that hydrogen is the most abundant element in the cosmos, its wavelength (21 cm), physically significant, could serve as a universal reference for a communication between galactic civilizations. In the same year, following a road experimental rather than theoretical, F. Drake proposed to the rapporteur of his doctoral thesis (the famous astronomer Otto Struve) to build a special radio receiver with the specific aim to experience listening to any signs of intelligent extraterrestrial nature. Struve supported the project by providing the new 24 meter diameter radio telescope of the NRAO (National Radio Astronomy Observatory) in Greenbank in Virginia. This was the first SETI experiment, called Project Ozma, led working at a frequency of 1420 MHz (wavelength 21 cm) and pointing the antenna of the radio telescope and the two nearby stars similar to the Sun: τ-Ceti and ε- Eridani. A search of this kind is called "a target."

A different approach was developed by Soviet scientists. It originated from an idea launched in the sixties by N. Kardashev, to classify the technological civilizations existing in three types, according to their degree of use and their ability to manipulation of energy. A Type I civilization would be able to manipulate the environment on the scale of their planet: our civilization has reached such a level of technology as a human activity is able to significantly change the state of the Earth, raising the question of a controlled and sensible management of these interventions in order not to cause disasters. A Type II civilization would be able to manipulate its central star using and managing an amount of energy comparable to that produced from its sun: it would manifest a degree of technological development billions of times more advanced than ours. A Type III civilization would eventually be able to manipulate an entire galaxy, reaching a level of development a hundred billion times greater. The approach followed by Kardashev is of exploratory: it attempts to locate a Type II civilization intercepting its "products" energy, on the assumption that even if it is not intentionally targeted messages outside still produces significant leak technologies that are immediately available as, for example, a considerable amount of radio-emitted energy for internal use, well observable at millimeter wavelengths.

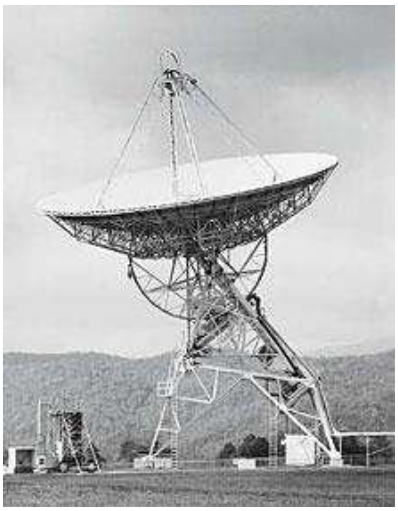

Fig. 1: Greenbank radio telescope used by Drake for the project Ozma.

According to the Russian astrophysicist J.Š. Shklovsky the true hallmark of the presence of a technological civilization on a planet would be just the dispersion of electromagnetic energy (radiative waste products typical of a technologically advanced civilization) due to the local communications used in radio, television, satellite and radar . If our civilization much more advanced they are, in principle, more rare, their technological means should be more powerful: from these considerations is justified as the Soviet program has initially turned its attention to the Andromeda galaxy, about two million light-years from us. From that time to the present have been significant developments in technology applied to the various SETI projects scattered 'throughout the world. Of this and the main "strands" of ongoing research we will discuss in the articles that follow. Now press especially highlight the basic philosophy that has inspired and guide the various SETI programs.

Like any serious scientific project, SETI develops some hypotheses reasonable working and try to verify it by observation and experimentation. The basic ideas are the following:

- life on Earth is the result of the natural evolution of the physical processes that characterize the world as a whole;
- what happened on Earth did that happen elsewhere;
- human intelligence is not necessarily the "product" better evolution of the cosmos;
- (a consequence of the hypothesis above) may exist in the universe stages of development considerably more advanced than ours.

The experimental verification of the above hypotheses is precisely implemented in the SETI research. This seems, in fact, the only available means trying to check with the observation the existence of extraterrestrial intelligence. The idea is to use every means that the current electronic and information technology provide for groped to pick up radio emissions, whether intentional or not, of any extraterrestrial civilizations. The electromagnetic waves are, in fact, carriers of information privileged and accessible to our current technology that propagate at the maximum possible speed (the speed of light). If you succeed to capture some interesting signal of extraterrestrial and artificial nature, will be demonstrated the validity of the underlying assumptions of the SETI project.

It is important to highlight some fundamental differences between radio emission of artificial nature and natural:

1. The artificial radio emission is concentrated in a narrow frequency channel (transmission narrowband), while the natural radiation of the radio sources takes place in a very broad spectral range. It is very likely that, for reasons of energy nature, a "smart" possible radio signal from some extraterrestrial civilization (and intentionally transmitted) is composed of a regular succession of pulses: for example a sequence of pulses that corresponds to a series of prime numbers or a sequence easily identifiable as a series of mathematical operations easy. The signals with the bandwidth closer in nature are those known from so-called interstellar maser and have an extension spectral order of a hundred Hz signals searched by SETI should (for the above considerations) have a bandwidth of few Hz, then the discrimination between natural and artificial signals would be almost immediate. One of the requirements instrumental essential for all experiments SETI is, in fact, the adoption of multichannel radio-spectrographs able to decompose the incident radio signal in a large number of smaller frequency ranges, each with amplitude of the order of 1 Hz or less.

2. The radio transmissions are artificial directives, in order to concentrate the radiated power in preferred directions useful to communication by avoiding any dispersion in unwanted directions (this also minimizes the negative effects of radio interference). Natural radiation, on the other hand, are generally isotropic, that is equal in all directions. Any intentional radio transmission concentrates most of the energy in the so-called carrier wave, almost monochromatic signal that acts as a medium for the information. The message is contained in appropriate modulations of the carrier (variations of some parameters in function of the information signal) that, in addition to be very weak, are dispersed in a wider band. The experiments SETI are initially aimed at the detection of any bearing radio waves, not the decoding of messages associated with them: the reasons for this choice are due to the fact that the greater amount of energy associated with this carrier makes it more easily detectable.

With these features in mind it is easy to understand how the space radio communication not present, for the purposes of transmission power is used, insurmountable difficulties. Using, for example, the Arecibo (Puerto Rico), characterized by a diameter of 305 meters, it is possible to concentrate the power of the transmitted signal in a beam steering greatly able to cover distances of the order of several hundreds of light years, if even within the entire Galaxy.

The laws of physics are universal: the same scientific discoveries made on Earth may have been made (or will be made) by other civilizations, though not necessarily in the same sequence. One of these discoveries is the ability to generate and receive radio waves for communication purposes or for transport of energy. In this sense, the Hertzian electromagnetic radiation seems the most natural, economical and easy to use for interstellar communications: the present state of our knowledge there are types of communications that can be performed on radio, such as space communications and radar transmissions. It seems reasonable to the hypothesis that each of these signal sources is a constant presence in the history of any technologically advanced civilization. The advantages of radio waves are remarkable: the signal propagates at the maximum possible speed (the speed of light) and the energy can be concentrated using antennas sufficiently directives, in relatively small areas without significant leakage to undesired directions. It also has the great advantage of being able to use, at least initially, the same tools used for radio astronomy research.

Fig. 2: The big radio telescope at Arecibo, a reference point for many SETI searches.

The search for extraterrestrial radio signals of artificial nature involves a detailed assessment of the following issues:

- position in the sky toward which to direct research;
- frequency (or frequencies) most appropriate for communication with any extraterrestrial civilizations;
- bandwidth to be used at the receiving facility;
- polarization to be used;
- type of modulation of the carrier that the receiving system must be able to reveal.

The main obstacles to SETI are the number of stars kept under observation and the wide range of possible frequencies on which the signal may be transmitted ("needle in a haystack" problem).

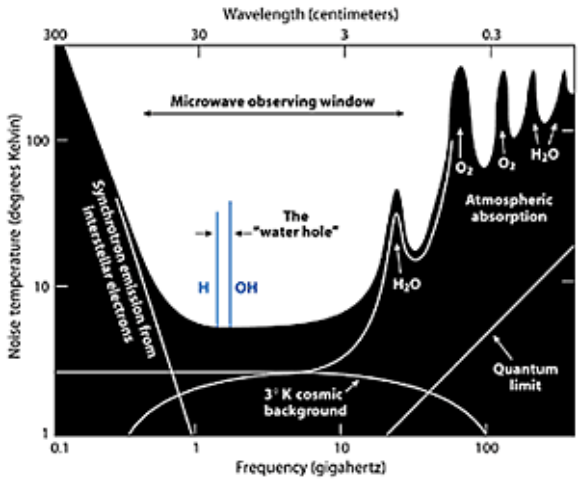

Fig. 3: Radio window can be used for SETI searches.

Due to the absorption and diffusion through the work of the interstellar medium and the atmospheres of the planets, not all radio frequencies are efficiently used. The frequencies below 10-20 MHz is absorbed by the charged particles of the planetary ionospheres (it is assumed that all the planets capable of hosting an advanced civilization have an ionosphere that acts as a shield to radio waves). The same

upper planetary atmosphere would limit the usable frequencies (around 10 GHz) for molecular absorption phenomena (water vapor and oxygen - Fig 3). The conclusion is that, most likely, in all the planets capable of hosting advanced civilizations there is an atmosphere that opens a "spectral window" to the Hertzian radiation with characteristics broadly similar to that of Earth, limiting the useful frequency range from about 10 ÷ 20 MHz to about 10 GHz This problem does not arise, of course, if the receivers and transmitters are placed in orbits of artificial satellites.

The cosmic microwave radio emission background that interferes the useful signal is undoubtedly the strongest source of interference. Using existing radio telescopes is possible to detect intelligent signals from distances of the order of hundreds or thousands of light years, that interstellar distances: these distances can be improved by increasing the sensitivity of the receivers, concentrating all the power of the transmitter in an amplitude of very narrow band antennas and using a lot of directives. A big problem is that the choice of the most appropriate frequency for communication. It is almost impossible that a civilization that has sent a radio message to discover it, unless the transmission frequency is not in advance known, the range of possible frequencies is still too wide. The problem would be greatly simplified if all the intelligent civilizations of the universe reach the same conclusions about the adoption of certain natural frequencies "privileged" that can be used as a standard and as a reference for communications. As mentioned, the first frequency suggested was that of the line at 21 centimeters (1420 MHz). According to scientists it is very likely that any extraterrestrial civilizations are aware of this fundamental line of the spectrum that would be a "single and objective frequency standard, necessarily known to any observer in the universe." "... It's also reasonable to expect that at this frequency receivers are built from the beginning of the evolution of radio astronomy ...".

Have been proposed, however, other natural frequencies corresponding to the same spectral lines of molecules discovered in interstellar space, such as those issued by the OH molecule. With modern receivers developed for this type of analysis can plumb simultaneously numerous channels of the spectrum simultaneously collecting information in a wide range of frequencies. The interval between 1420 MHz and 1721 MHz is referred to as "waterhole", the "water hole" around which, like animals in the jungle, gather the galactic civilizations. If the water does have a vital role in the life, considering the advantages of communications in this frequency range and the fact that the emission originates from hydrogen to 1420 MHz to 1665 MHz and that the OH molecule (the components that form water) can in fact agree that these frequencies represent the most likely choice for efficient cosmic radio. The goal of the SETI project is to identify artificial signals of extraterrestrial origin: if you receive any messages will require a considerable amount of time before being able to correctly interpret the meaning. Several researchers are of the opinion that any extraterrestrial signal would be very "cryptic" for men: it is very likely that any information contained in it have been encoded by a civilization more advanced than ours. Having much time and the right tools you might even able to do so, but it would take many decades (if not centuries) work. It should be born in mind that humanity has discovered the radio for a little less than a century and then the weak signals are now come to about a hundred light years from Earth: it is obvious that the increase of the distance to a possible source of signals (advanced civilization), also increases the age of its technology.

The problem of the discovery of alien civilizations has been well formulated in the famous Drake equation which, because of its importance, it will be specific subject of the next article. This simple equation gives the number of extraterrestrial civilizations in our galaxy, based on a life comparable to our own, able to communicate over interstellar distances. The equation takes into account:

- Physical factors: the speed with which they are generated at the stars in the universe, the percentage of those with planetary systems, the number of planets with physical conditions compatible with life.

- Biological factors: how many of these planets may have developed life and how life could have become "smart".
- Social factors: how many planets inhabited by intelligent life forms could have developed technological civilizations, the duration of these civilizations, then the possibility of communicating with them.

Each term represents the possibility of a key step in the evolution of a civilization. According to an optimistic assessment made by the famous astrophysicist C. Sagan (who was one of the most active promoters of SETI and popular of science in general), the probability that a planet has developed an intelligent civilization would be roughly equal to 1 in 1000000. Given that only in our galaxy should be several billions of planets (some already discovered), the probability that there are different extraterrestrial civilizations is not at all remote. The numerical estimates that you can do on the equation of Drake have value only to the extent that they are supposed to acceptable values for the parameters: it is obvious that these values are necessarily arbitrary since it is difficult to correlate experimental evidence. If these estimates are acceptable we can certainly agree on the opportunity (and the great scientific, philosophical, and, more generally, cultural) to invest resources in the various SETI projects.

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