Searching for Life Among the Stars

Will hams be the first humans to receive signals from alien civilizations?

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These are exciting times for space exploration. We've been privileged to witness a perceptual paradigm shift. Just 50 years ago, every credible authority maintained that mankind was alone among the stars, the sole sentient species in the vast cosmos. Today, the overwhelming preponderance of scientific thinking holds that we are not. How quickly we have completed the Copernican revolution!

In this article I'll lay out a strategy for amateur *SETI*, a Search for Extra-Terrestrial Intelligence. With several thousand hobbyists available, such a program could rival any government search ever proposed (and denied funding!). I'll also list the equipment requirements for an amateur SETI monitoring station. Believe it or not, it's all within your grasp.

The Big Ear radiotelescope at Ohio State University, designed and built by John Kraus, W8JK, is home to the world's longest running SETI program. It has an effective capture area of 1000 square meters.

So Who is SETI?

The acronym SETI was coined in the 1960s to describe the use of radiotelescopes to seek out electromagnetic signals of possible extraterrestrial intelligent origin. Dozens of such searches have been conducted over the past 35 years. The results have been interesting, but not conclusive. On the other hand, not only have we not yet scratched the surface, we haven't even found the itch. SETI pioneer Frank Drake, who conducted the first search in 1960, now estimates that there are perhaps 10,000 advanced civilizations in the Milky Way Galaxy.[1] See the sidebar, "The Drake Equation."

But our galaxy contains about 200 *billion* stars! That makes each star we survey a 20-million-to-one long shot. Despite the number of stars surveyed to date, we've hardly begun the search. To have found the elusive needle in the cosmic haystack by now would be equivalent to walking into the Library of Congress blindfolded, selecting one book at random, and getting home to find that we had checked out *Macbeth*. If we try, and fail, does that mean that Macbeth does not exist? The data is incomplete.

Then again, our leaders are hardly averse to acting upon incomplete data. NASA once had a modestly funded SETI office, and initiated a search in October 1992 (significantly, the 500th anniversary of Columbus' first voyage of discovery). Failing to produce immediate results, NASA's search was suspended by Congress just one year later. The SETI League is among the organizations now trying to privatize those efforts. It was founded by hams as a membership supported, nonprofit scientific and educational corporation. Our charter involves organizing and conducting an electromagnetic search of the skies to spot signals of possible intelligent origin. Thousands of microwave hobbyists working in consort now seek to do what hams have often done: accomplish the impossible!

Cosmic Evolution

George Gamov first theorized that the universe began as a single, infinitely dense point in space-time, which exploded nine to eighteen billion years ago, and has been expanding and cooling ever since. His evidence was the consistent red-shift (decreasing frequency Doppler shift) which Edwin Hubble had measured in distant galaxies. Fred Whipple derisively dubbed that universal birth event the Big Bang, and the name stuck. Gamov's theory further predicted that the Big Bang should have left a residue of microwave radiation, which was indeed first measured by Arno Penzias and Robert Wilson in 1965. The so-called Three Kelvin (3K) Background Radiation has been reaffirmed countless times, and stands as the best evidence to date of an expanding universe.

Our uncertainty about the exact age of the universe stems from our inability (thus far) to precisely measure the *Hubble Constant*, the rate of expansion of the universe. Recent measurements from, appropriately, the Hubble Space Telescope are bringing us closer to an answer. We do believe, however, that our planet is about four and a half billion years old. So, the Earth appears to be only half to one-fourth the age of the universe. Which suggests that our Sun and planet are youngsters, recent arrivals on the cosmic scene.

Perhaps a tenth of all stars appear similar in size, heat and composition to our Sun. Although we cannot detect planetary systems optically, they evidence themselves in several other ways. Everywhere we have looked for planets, we have seen indications of their presence.[2]

Planetary formation may be an essential process by which a rotating star dissipates some of its angular momentum. If it is commonplace, we can assume that each of the

[1]Notes appear on page 39.

Sun-like stars in our galaxy has its own retinue of planets. Since the stuff from which our planet is made is hardly unique to Earth, but common throughout the cosmos, we can expect at least some of those hundreds of billions of planets to have a rocky crust, liquid oceans, puffy clouds and nitrogen skies.

Our galaxy is but one of a hundred billion such star groups in the universe. Now there's no reason to expect the laws of physics, or chemistry, to be different in those other galaxies, from the ones we observe on Earth. Which leads us to imagine the existence of countless billions of Earth-like planets circling Sun-like stars. And remember, most of those planets are older than our homeland, and have had more time to spawn their particular versions of life.

The Emergence of Life

Perhaps the most amazing aspect of our existence is that *life evolved from nonliving things*! Not just any nonliving things, mind you, but a specific group of complex organic molecules called amino acids. Recently, dozens of complex molecules, many of them organic, have been detected in the interstellar medium. We now know that interstellar space is anything but an empty void. It is a veritable chemistry set.

But can it spawn life? Nobel chemist and SETI pioneer Melvin Calvin believed so. At Berkeley in 1951, he sparked a mixture of carbon dioxide, hydrogen, and water with an energy burst from a cyclotron, and produced organic chemicals, some of which are known to be precursors of life. In 1955, Miller and Urey at the University of Chicago restructured the Calvin experiment with an even more startling result: using several of the precursors commonly found in space, they produced a wide variety of amino acids!

The chemicals of life may be found on countless planets. Necessary energy sources (lightning, volcanism, whatever) abound. Building amino acids appears relatively easy. In fact "alien" amino acids have already been found in meteorite fragments, so we know they are commonplace in the cosmos. It's a long step from amino acids to living, thinking beings capable of harnessing electromagnetic communication (and hence detection by our radiotelescopes). On the other hand, the number of potential life sites in the universe is truly mind-boggling. There may be on the order of a million million billion (10^{21}) "good" suns among the galaxies. Should life not have evolved on planets orbiting a good many of those suns? If an infinite number of monkeys sits down at an infinite number of typewriters, one of them is bound to write the whole *Encyclopedia Galactica*.

How to Search

We can't say that all species develop electromagnetic communication, but we're betting that some do. Photons are, after all, the fastest space ships we can imagine. Radio communication is cheap, quick and easy to learn. If we can figure it out, the assumption of mediocrity suggests, then so can anybody. Perhaps a technologically advanced civilization adopted, and then abandoned, radio communication a billion years ago. No matter. If they are a billion light-years distant, their photons are just now reaching us, and are falling silently on our heads even as we speak.

The greatest obstacle to interstellar communication is naturally occurring noise. Galactic, cosmic, quantum and synchrotron noise sources span the spectrum, but they are not uniform. The quietest part of the sky, the 1 to 10-GHz microwave window, is a logical starting point, and by no means geocentric. But we're talking an incredible bandwidth here. Can we narrow the search spectrum?

Most SETI scientists think we can. Toward the bottom of the microwave window are two rather strong spectral radiation lines, emanating from hydrogen and hydroxyl, two of the most abundant substances in interstellar space. It has long been suggested that between these two markers falls a natural, universal communications band.

Significantly, hydrogen and hydroxyl are the disassociation products of water. Although we need not limit our search to water-based life, it's interesting to speculate that

The Drake Equation

Is there a way to estimate the number of technologically advanced civilizations that might exist in our galaxy? While working at the National Radio Astronomy Observatory in Green Bank, West Virginia, Dr Frank Drake conceived a means to mathematically estimate the number of worlds that might harbor beings with technology sufficient to communicate across the vast gulfs of interstellar space. The Drake Equation, as it came to be known, was formulated in 1961 and is generally accepted by the scientific community.

$N = R_* f_p n_e f_l f_i f_c L$

where,

N = The number of communicative civilizations

R_* = The rate of formation of suitable stars (stars such as our Sun).

f_p = The fraction of those stars with planets. (Current evidence indicates that planetary systems may be common for stars like the Sun.)

n_e = The number of Earth-like worlds per planetary system.

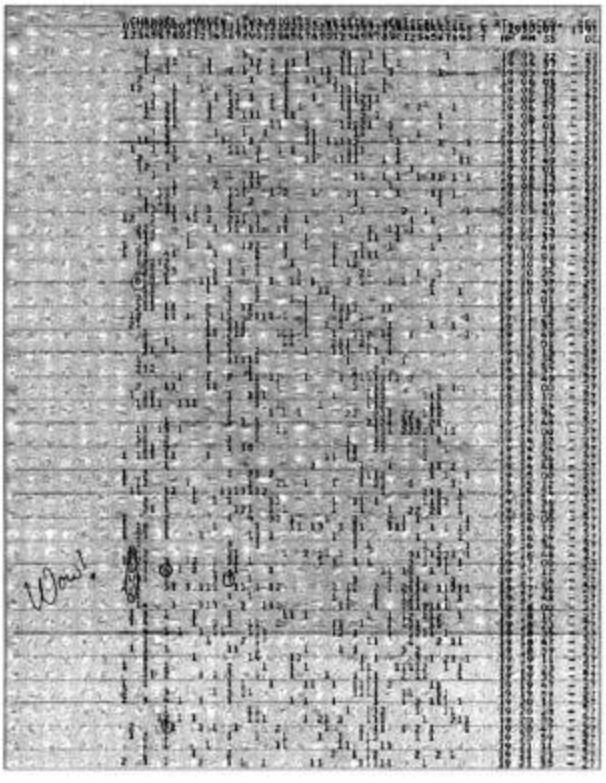
f_l = The fraction of those Earth-like planets where life actually develops.

f_i = The fraction of life sites where intelligence develops.

f_c = The fraction of communicative planets (those on which electromagnetic communications technology develops).

L = The "lifetime" of communicating civilizations.

Frank Drake's own current solution to the Drake Equation estimates 10,000 communicative civilizations in the Milky Way. Dr Drake, who serves on the SETI League's advisory board, has personally endorsed SETI's planned all-sky survey.—*WB8IMY*



This computer printout from the Ohio State radiotelescope shows the legendary "Wow!" signal which many SETI scientists believe represents the best candidate to date for a signal of intelligent extraterrestrial origin. Highly intermittent, the Wow! exhibited all the characteristics expected of a true alien signal, but it never repeated. The Wow! was named for the note in the margin of the printout, scribbled by radioastronomer Jerry Ehman when he discovered it on August 15, 1977. About 15 dB above the background noise level, it represents the type of signal that amateur SETI receivers can hope to detect.

others might recognize a special significance to these two frequencies. Bernard M. Oliver headed NASA's late SETI office. It was he who, in a 1971 study,[3] first suggested scanning the cosmos between the hydrogen and hydroxyl lines. He coined the rather poetic term for this proposed communications band. "Where shall we seek out our kind?" Oliver asked. "At the water hole, where species have always gathered."

There are other interesting frequency regions to explore, but for now let's go with the majority opinion. The water hole extends from roughly 1420 to 1660 MHz, a bandwidth of 240 MHz. Monitoring it in 10-Hz steps means we have 24 million channels to scan!

Now you can understand why so much SETI research has been devoted to developing megachannel real-time spectrum analyzers. This can be approached as a digital signal processing (DSP) problem, an area in which hams are emerging as prime users. Given the appropriate software, it has been shown that DSP systems are capable of recognizing very weak coherent signals.

Numerous *targeted searches* of interesting candidate stars have been conducted in the past 35 years. An all-sky survey, on the other hand, makes no *a priori* assumptions as to the most likely direction to explore. It attempts to sweep the entire sky as seen from a given location. No antenna tracking is required, since it is sky, rather than individual stars, that we seek to survey. Therefore, we can deploy our antennas in a virtual transit mount mode, as Grote Reber did when he invented the radiotelescope,[4] by aiming them due south, letting the Earth turn them, and varying only their elevation.

Because large antennas are quite narrow, the sky survey is better performed with dishes of moderate size. Smaller antennas of course have less gain, so to achieve reasonable sensitivities, they need to scan for extremely long periods of time. The sky survey approach, it would seem, is ideally suited to the community of radio amateurs and microwave experimenters. This is the area in which I feel hams can make their most significant SETI contributions.

What Can *We* Do?

Consider that the average moonbounce or TVRO dish has a beamwidth on the order of 3°. Let's put that dish on a transit mount, and let the Earth be our antenna rotator. Now the dish will be rotating at 15° per hour, which means any star will be within its beamwidth for about 12 minutes. Given existing amateur DSP technology, and employing a few tricks, 12 minutes is enough time to thoroughly scan about 14.4 kHz of spectrum, at 10 Hz resolution (which I consider consistent with the frequency stability of amateur microwave local oscillators). But the water hole is 240 MHz wide, which means to cover our assigned swath of sky at all water-hole frequencies, we need to be listening for *only* 16,667 days. That's a little over 46 years.

Well, perhaps a dedicated experimenter will be willing to devote 46 years of his life to studying the sky. Tycho Brahe did. But a 46-year search at a single antenna elevation will only survey a 3° swath of sky. To cover the range of declinations from the southern to northern horizon, we need to conduct 60 such surveys, which brings the time required for the effort up to about 2760 years! And that only covers the one hemisphere of sky we can see from our part of the world; a complete sky survey demands we spend as long searching from Earth's other hemisphere as well. So, a single dedicated amateur can complete one full sweep of the water hole in just under six millennia!

On the other hand, 5520 experimenters can do that same sky survey in just *one year*. This is why we need to make SETI a broad-based effort. And where but in the Amateur Radio service are we likely to find several thousand dish-equipped experimenters, scattered around the globe, with the means to coordinate their efforts? The SETI search problem is tailor-made for us.

What do you need to join the search? Here's the list:

- A 3 to 5-meter parabolic reflector, with surface smoothness adequate for TVRO, or 23-cm moonbounce.[5]

BETH SHOEMAKER, WILLIAMSPORT SUN-GAZETTE. USED WITH PERMISSION.

The author standing before 5-meter (left) and 3-meter (right) satellite TV dishes. Both antennas have been refitted for amateur SETI. Five thousand such systems around the world can provide real-time all-sky coverage.

- A low-noise preamp that covers the 1.4 to 1.7-GHz range.
- A downconverter (in the manner of the popular Rick Campbell/Jim Davey no-tune transverter boards) to shift the water hole down to a VHF IF.
- A VHF scanning receiver.
- A digital signal processor, spectrum analysis software, and a home computer on which to run them.

All can be purchased at a cost on a par with the typical OSCAR satellite station. Several hundred stations are already so equipped. By the turn of the century, perhaps several thousand, and then—who knows?

Some kind of coordination is required, and that's where the SETI League comes in. We stand prepared to assign participating amateurs specific search declinations, to assure full sky coverage, and will act as a clearinghouse for information and results. Once a suspicious signal is detected, everybody will want to know where to point his or her dish to help confirm it!

A broad membership base will make it possible to put amateur SETI on track. We plan to publish and promote the best hardware and software schemes to come out of the ham community, and will design, prototype and evaluate various detection and signal analysis technologies. To receive further information on joining the SETI League, call 800-TAU-SETI, or e-mail to info@setileague.org. In the immortal words of Rick Blaine, "If that call comes, and you don't answer, you'll regret it. Maybe not today, maybe not tomorrow. But soon, and for the rest of your life."

Notes

[1]Drake bases this estimate on his personal solution for the *Drake Equation*, an elegant tool for quantifying our ignorance, which he developed in 1961 as the agenda for the world's first SETI conference. Today the Drake Equation is a classic, to be found in nearly every astronomy textbook that addresses the question of alien life. See the sidebar, "The Drake Equation."

[2]Viewing a planet orbiting a star is a little like looking at a firefly perched on the rim of a searchlight.

[3]That study, part of a summer faculty fellowship program at Stanford University, brought together some of the leading minds in radio astronomy, to puzzle the problem of interstellar communication. The group's most tangible result, the Project Cyclops report, remains one of the most important SETI publications to date.

[4]Reber, an electrical engineer and radio amateur (W9GFZ), build the first true radiotelescope in his backyard in Wheaton, Illinois, in 1937. Although lacking in formal astronomical training, he is today recognized as the patriarch of a new discipline. His 10-meter-diameter dish (only a little larger than the size that I propose for amateur SETI), on a transit mount, generated the first radio map of the sky. Reber measured radiation levels millions of times in excess of what then-favored theories predicted. His controversial measurements have subsequently been borne out repeatedly. Reber ultimately retired to Tasmania.

[5]If you don't want to dedicate your dish full-time to the SETI effort, no problem. A water-hole feed certainly doesn't preclude installing other feeds at the focal point as well. You can practice what's come to be known as *parasitic* SETI, letting your water-hole receiver scan while your dish goes about its daily business of EME, TV or whatever. QST