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Using Radio in the Search for Extraterrestrial Intelligence

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The question of whether we share the universe with other intelligent beings is of long standing. Written speculation on this subject stretches back to the classical Greeks, and it hardly seems unreasonable to suppose that even the earliest *Homo sapiens* gazed at the night sky and wondered if beings as clever as themselves dwelled in those vast and dark spaces.

What is different today is that we have both sufficient scientific knowledge and adequate communications technology to permit us to address this question in a meaningful way.

Finding extraterrestrial intelligence would calibrate humanity's place in the cosmos. It would also complete the so-called Copernican revolution. Beginning about 470 years ago, observation and scientific reasoning led to an accurate understanding of our place in the physical universe. The goal of SETI – the Search for Extraterrestrial Intelligence – is to learn our place in the intellectual universe. Are our cognitive abilities singular, or are they simply one instance among many?

Just as large sailing ships and the compass inaugurated the great age of terrestrial exploration at the end of the 15th century, so too does our modern technology – coupled to a far deeper understanding of the structure of the universe than we had even two decades ago – give us the possibility to discover sentient life elsewhere. SETI is exploration, and the consequences of exploration are often profoundly enlightening and ultimately of unanticipated utility. We know that our species is special, but is it unique? That is the question that SETI hopes to answer.

Why we think that life exists elsewhere

There is, as of now, no compelling evidence for biology beyond Earth. While the widely reported claims of fossilized microbes in a martian meteorite generated great excitement in 1996, the opinion of most members of the astrobiology community today is that the claims are unconvincing.

Nonetheless these same astrobiologists, if asked if they think it likely that extraterrestrial life is both commonplace and discoverable, would nod their heads affirmatively.

They would do so largely because of what we've learned in the past two decades concerning the prevalence of life-friendly cosmic habitats. Until 1995, we knew of no planets around other stars, habitable or otherwise. And yes, there was speculation that such worlds might be common, but that sunny thought was *only* speculation.

In the last two decades, astronomers have uncovered one so-called exoplanet after another. The current tally is approximately two thousand, and many more are in the offing thanks to continued analysis of data from NASA's enormously successful Kepler space telescope.

Estimates are that at least 70 percent of all stars are accompanied by planets, and since the latter can occur in systems rather than as individuals (think of our own solar system), the number of planets in the Milky Way galaxy is of order one trillion. It bears mentioning that the Milky Way is only one of 150 billion galaxies visible to our telescopes – and each of these will have its own complement of planets. This is plentitude beyond easy comprehension.

The Kepler mission's principal science objective has been to determine what fraction of this planetary harvest consists of worlds that could support life. The usual metric for whether a planet is habitable or not is to ascertain whether liquid water could exist on its surface. Most worlds will either be too cold, too hot, or of a type (like Jupiter) that may have no solid surface and be swaddled in noxious gases. Recent analyses of Kepler data suggest that as many as one star in five will have a habitable, Earth-size planet in orbit around it. This number could be too large by perhaps a factor of two or three, but even so it implies that the Milky Way is home to 10 to 80 billion cousins of Earth.

There is, in other words, more than adequate cosmic real estate for extraterrestrial life, including intelligent life.

A further datum established by recent research is that the chemical building blocks of life – the various carbon compounds (such as amino acids) that make up all terrestrial organisms – are naturally formed and in great abundance throughout the cosmos. The requisites for biology are everywhere, and while that doesn't guarantee that life will be spawned on all the worlds whose physical conditions are similar to our own, it does encourage the thought that it occurs frequently.

If even if only one in a thousand "earths" develop life, our home galaxy is still host to tens of millions of worlds encrusted by flora and fauna.

However, SETI is a class of experiments designed to find not just life, but technologically sophisticated life – beings whose level of intellect and development is at least equal to our own. So it is germane to ask, even assuming that there are many worlds with life, what fraction will eventually evolve a species with the cognitive talents of *Homo sapiens*? This is a question that's both controversial and difficult to answer.

As some evolutionary biologists (including most famously Ernst Mayr and Stephen Jay Gould) have pointed out, the road from early multicellular life forms (e.g., trilobites) to us is an uncertain one with many forks. For example, if the asteroid that wiped out the dinosaurs (and two-thirds of all other land-dwelling species) 65 million years ago had arrived in our neighborhood 15 minutes later, it could have missed the Earth. The stage might never have been cleared for the mammals to assert themselves and eventually produce us. This simple argument suggests that, while life could be commonplace, intelligence might be rare.

On the other hand, recent research has shown that many different species of animals have become considerably more clever in the last 50 million years. These include of course simians – but also dolphins, toothed whales, octopuses, and some birds. One plausible interpretation of these findings is that intelligence has so much survival value that – given a complex biota and enough time – it will eventually arise on any world.

We don't know what the truth is regarding the emergence of cognition. But finding another example of an intelligent species would tell us that *Homo sapiens* is not singular. The possibility of elucidating this evolutionary question is one of the most enticing motives for doing SETI experiments.

Finding extraterrestrial intelligence

Although encounters with intelligent aliens are a frequent staple of movies and television, the idea of establishing the existence of these putative beings by traveling to their home planets is one that will remain fiction for the foreseeable future. The planets that orbit the Sun may include other worlds with life (Mars, various moons of the planets Jupiter and Saturn). But they are surely devoid of any life that would be our cerebral equals. Intelligent beings – assuming they exist – are on planets (or possibly large moons) orbiting other stars. Those are presently unreachable: Even our best rockets would take 100 thousand years to traverse the distance to the nearest other stellar systems. The idea that extraterrestrials have come here (the so-called UFO phenomenon), while given credence by approximately one-third of the populace, is not considered well established by the majority of scientists.

However, the methods used by SETI to discover the existence of intelligence elsewhere don't require that either we or they pay a visit. All we need do is find a signal, come to us at the speed of light. The first modern SETI experiment was conducted in 1960, when astronomer Frank Drake used an 85-foot diameter antenna at the newly constructed National Radio Astronomy Observatory in West Virginia in an attempt to "eavesdrop" on signals either deliberately or accidentally transmitted by beings light-years away. Drake used a very simple receiver, and examined two nearby star systems.

By contrast, later SETI experiments have made use of far more sensitive equipment, and have greatly expanded the scope of the search. Project Phoenix – a survey by the SETI Institute of 1,000 star systems – used antennas that ranged from 140 – 1,000 feet in diameter with receivers that could look for weak signals in ten million radio channels simultaneously. Today's efforts by the Institute use a small grouping of 42 antennas known as the Allen Telescope Array, situated in the Cascade Mountains of northern California. The advantage of this instrument is that it can be used for a very high percentage of time for SETI experiments, unlike previous campaigns that relied on antennas that were shared with radio astronomers doing conventional research projects. This latter circumstance greatly constrained the number of possible searches.

The other large radio SETI group in the U.S. is at the University of California, Berkeley. Their long-running Project SERENDIP uses the very large (1,000-foot diameter) antenna at Arecibo, Puerto Rico in a commensal mode. By piggybacking on this antenna, the Berkeley group gets virtually continuous use of the antenna, but the price is that they have no control of where it is aimed. However, over the course of several years, this random scrutiny covers roughly one-third of the sky. The receiver can simultaneously monitor more than 100 million channels, and some of the Berkeley data are made available for processing by individuals on their home computers using the popular screen saver, SETI@home. Approximately ten million people have downloaded the screen saver.

At the moment, the only other full-time radio SETI experiment is being conducted by a small group at the Medicina Observatory of the University of Bologna, in Italy.

Radio SETI searches preceded efforts to look for brief laser light pulses, known as optical SETI, largely because the development of practical radio occurred more than a half-century before the invention of the laser. Nonetheless, radio remains a favored technique for establishing the existence of intelligence beyond Earth. The amount of energy required to send a bit of information from one star system to another using radio is less than other schemes, and therefore it seems plausible that, no matter what other communication technologies intelligent species might develop, radio will always have a function. As a simple analogy: the wheel is an ancient technology for us, yet we use it every day and undoubtedly always will.

Radio SETI experiments have not yet detected a signal that is unambiguously extraterrestrial. Some people, both in and out of the science community, have ascribed undue significance to this fact, claiming that it indicates that no one is out there. While this may be comforting to those who would prefer to think that our species is the only one with the wit to comprehend the cosmos, it is a thoroughly unwarranted conclusion. Despite a many-decades long history of effort, our scrutiny of star systems still remains tentative. The number of star systems carefully examined over a wide range of the radio dial is no more than a few thousand. In the Milky Way, there are hundreds of billions of star systems. Consequently, our reconnaissance is akin to exploring Africa for megafauna, but one that has so far been limited to a square city block of territory.

While no one knows how prevalent signal generating civilizations might be, the more conservative estimates suggest that – to find a transmission that would prove others are out there – requires surveillance of a million star systems or more. This could be done in the near future, given the relentlessly increasing power of digital electronics. It is not hyperbolic to suggest that scientists could very well discover extraterrestrial intelligence within two decades' time or less, given resources to conduct the search.

However, funding for SETI is perennially problematic. The most ambitious SETI program, the one planned by NASA in the 1980s and 1990s, had scarcely begun observations when Congress canceled funding in the Fall of 1993. Since then, SETI efforts in this country have either been privately funded, or been an incidental part of university research. As a telling metric of the limitations of this approach, note that the total number of scientists and engineers doing full-time

SETI in this country is approximately one dozen, or comparable to the tally of employees at a car wash.

Progress and evolution of radio SETI

A rough and ready estimate suggests that today's radio SETI experiments are about 100 trillion times more effective – as judged by speed, sensitivity, and range of radio frequencies investigated – than Frank Drake's pioneering 1960 search. The rapid development of both analog and digital electronics has spinoffs that are accelerating the capabilities of SETI.

As example, in 1980 typical SETI efforts sported receivers able to monitor 10 thousand channels simultaneously. Today's experiments sport 10 – 100 million channels, causing a thousand-fold increase in search speed.

Speed is essential to success. As mentioned above, conservative estimates of the prevalence of broadcasting societies hint that – in order to find a signal from another species – our SETI experiments will need to "listen" in the direction of at least 1 million stellar systems. Cheaper digital technology, which can be read as greater compute power, immediately leads to receivers with more channels – which means that it takes less time to check out all the interesting frequencies for a given SETI target.

In the case of antenna arrays, cheaper computing can also speed observations by increasing the number of star systems looked at simultaneously. As example, the Allen Telescope Array currently has the ability to examine three such systems at once. But this could be increased to hundreds or even thousands with more computing power – bringing with it a concomitant augmentation of speed.

Current and future resources

As noted above, the level of radio SETI effort today is small, employing roughly a dozen full-time scientists and engineers. At the height of the NASA SETI program (1992), the annual budget for this activity was $10 million, or one-thousandth of the space agency's budget. This supported equipment development and observations for a two-pronged strategy – a low-sensitivity survey of the entire sky, and a high-sensitivity targeted search of the nearest thousand star systems. The number of scientists involved was five times greater than today.

The financial support for all radio SETI efforts in the United States now is approximately 20 percent of the earlier NASA program, and comes from either private donations or from research activities at the University of California. This is, frankly, a level inadequate for keeping this science alive. The cost of developing and maintaining the requisite equipment and software, as well as paying for the scientists and engineers who do the experiments, is – at minimum – $5 million annually. Without this level of funding, the U.S. SETI efforts are likely to be overtaken by Asian and European initiatives (such as the Square Kilometer Array) in the next decade.

ETI is exploration. There's no way to guarantee that if only sufficient effort is made, success will inevitably follow. Like all exploration, we don't know what we'll find, and it's possible that we'll not find anything. But if we don't search, the chances are good that the discovery of intelligence elsewhere in the cosmos will be made by others. That discovery will rank among the most profound in the history of humankind. The first evidence that we share the universe with other intelligence will be viewed by our descendants as an inflection point in history, and a transformative event.

The public's interest

The idea of extraterrestrials resonates with the public in a way that little of the arcane research of modern science does. While much was made of the discovery of the Higgs boson in 2012, people who weren't schooled in advanced physics had a difficult time understanding just why this was important, and what justified the multi-billion dollar price tag of the collider used in its discovery.

The idea of life in space on the other hand is science that everyone grasps. Countless creatures from the skies infest both movies and television. In addition, the techniques of SETI – while complex in detail – are simple in principle. Carl Sagan's novel and movie, "Contact", enjoyed considerable popularity, and familiarized millions with the technique of using radio to search for extraterrestrials. Documentaries on SETI and the search for life in general can be found on cable television every week. Compare that with the frequency of programming on, say, organic chemistry.

In other words, SETI is an endeavor that everyone "gets". And that includes school kids. This makes the subject an ideal hook for interesting young people in science. They come for the aliens, but along the way they learn astronomy, biology, and planetary science. Even if SETI fails to find a signal for decades, it does great good by enticing youth to develop skills in science.

It's even possible that we are hard-wired to be interested in extraterrestrial life, in the same way that we are programmed to be interested in the behavior of predators. The latter has obvious survival value (and might explain why so many young people are intrigued by dinosaurs!) Our interest in "aliens" could simply derive from the survival value of learning about our peers. Extraterrestrials are the unknown tribe over the hill – potential competitors or mates, but in any case someone we would like to know more about.

There's no doubt that SETI occasionally provokes derision. It's easy to make fun of an effort whose goal is to find "space aliens." But this is to conflate science fiction with science. As our telescopes continue to peel back the film that has darkened our view of the cosmos since *Homo sapiens* first walked the savannahs, we are learning that the Earth is only one of 100,000 billion billion planets, spinning quietly in the vast tracts of space. It would be a cramped mind indeed that didn't wonder who might be out there.