[sci.astro] ET Life (Astronomy Frequently Asked Questions) (6/9)

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Subject: Introduction

sci.astro is a newsgroup devoted to the discussion of the science of astronomy. As such its content ranges from the Earth to the farthest reaches of the Universe.

However, certain questions tend to appear fairly regularly. This document attempts to summarize answers to these questions.

This document is posted on the first and third Wednesdays of each month to the newsgroup sci.astro. It is available via anonymous ftp from <URL:ftp://rtfm.mit.edu/pub/usenet/news.answers/astronomy/faq/>, and it is on the World Wide Web at <URL:http://sciastro.astronomy.net/> and <URL:http://www.faqs.org/faqs/astronomy/faq/>. A partial list of worldwide mirrors (both ftp and Web) is maintained at <URL:http://sciastro.astronomy.net/mirrors.html>. (As a general note, many other FAQs are also available from <URL:ftp://rtfm.mit.edu/pub/usenet/news.answers/>.)

Questions/comments/flames should be directed to the FAQ maintainer, Joseph Lazio (jlazio@patriot.net).

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Subject: F.00 Extraterrestrial Life

[Dates in brackets are last edit.]

See also the entry in Section G of the FAQ on the detection of extrasolar planets.

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Subject: F.01 What is life?
Author: T. Joseph W. Lazio <jlazio@patriot.net>

This material is extracted from the review article by Chyba & MaDonald (1995, Annual Review of Earth and Planetary Science).

How might we tell if a future mission to another body in the solar system had discovered life? How do we separate living from non−living? A simple set of criteria for doing so might be, Something that is alive must (1) acquire nutrients from its environment, (2) respond to stimuli in its environment, and (3) reproduce. Unfortunately, with this definition we would conclude that mules are not alive while fire is. Other attempts to define life−−−based on genetic, chemical, or thermodynamic criteria−−−suffer from similar failings.

A working definition used by many attempting to understand the origin of life on the Earth is something like, "Life is a self−sustained chemical system capable of undergoing Darwinian evolution." (Note that this definition, *chemical* systems, would exclude computer life or A−life, but other definitions exist which would not.) Again this definition is not without its difficulties. The emphasis on evolving systems implicitly assumes a collection of entities; Victor Frankenstein's creation would not have been classified as alive. Further, how long must one wait before concluding that a system was not evolving? A recent definition that focusses on individual entities is that a living organism must be (1) self−bounded, (2) self−generating, and (3) self−perpetuating.

Perhaps it is not possible to provide necessary and sufficient criteria to distinguish "alive" from "not alive." Indeed, if life can arise from natural physical and chemical processes, there may be a continuous spectrum of "aliveness," with some entities clearly "alive"−−−humans, trees, dogs−−−some entities clearly "not alive"−−−rocks, pop bottles−−−and some entities somewhere in between−−−viruses.

Operationally, at our current stage of exploration of the solar system, all of the above definitions are probably too detailed. On Earth, we have entities we clearly identify as "alive." Liquid water appears to be a requirement for these living things. Hence, the focus in solar system studies of life has been to target those bodies where liquid water either is possibly now or may have once been present.

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Subject: F.02 Life in the Solar System

Within the past 100−−150 years, the conventional wisdom regarding life in the solar system (beside the Earth) has been on a roller coaster ride. Life on other planets used to be considered likely. Suggestions for sending messages to other planets included cutting down huge tracts in the Siberian forests or filling and setting afire trenches of kerosene in the Sahara. Lowell believed that he could see evidence for a civilization on Mars.

During the Space Age the planets were explored with robotic craft. The images and other measurements sent back by these craft convinced most scientists that only the Earth harbored life.

With even more recent findings, the possibility of life that life exists or existed elsewhere in the solar system is now being re−examined.

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Subject: F.02.1 Is there life on Mars?
Author: Steve Willner <swillner@cfa.harvard.edu>

The Viking landers found conditions on the surface of Mars unlikely to support life as we know it. The mass spectrometer found too little carbon, which is the basis for organic molecules. The chemistry is apparently highly oxidizing as well. Some optimists have nevertheless argued that there still might be life on Mars, either below the surface or in surface regions not sampled by the landers, but most scientists consider life on Mars quite unlikely. Evidence of surface water suggests, however, that Mars had a wetter and possibly warmer climate in the past, and life might have existed then. If so, there might still be remnants (either living or fossil) today, but close examination will be necessary to find out.

More recently, McKay et al. have invoked biological activity to explain a number of features detected in a meteorite from Mars. See <URL:http://www.fas.org/mars/> for additional information.

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Subject: F.02.2 Is there life in Jupiter (or Saturn)?

Jupiter (and Saturn) has no solid surface, like the Earth. Rather the density and temperature increase with depth. The lack of solid surface need not be a deterrent to life, though, as many aquatic animals (e.g., fish, jellyfish) never touch a solid surface.

There has been speculation that massive gas−bag organisms could exist in Jupiter's atmosphere. These organisms might be something like jellyfish, floating upon the atmospheric currents and eating either each other or the organic materials formed in Jupiter's atmosphere.

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Subject: F.02.3 Is there life on Jupiter's moon, Europa?

This article is adapted from NASA Press Releases.

In the late 1970's, NASA Voyager spacecraft imaged Europa. Its surface was marked by complicated linear features, appearing like cracks or huge fractures in the surface. No large craters (more than five kilometers in diameter) were easily identifiable. One explanation for this appearance is that the surface is a thin ice crust overlying water or softer ice and that the linear features are fractures in that crust. Galileo images have reinforced the idea that Europa's surface is an ice−crust, showing places on Europa that resemble ice floes in Earth's polar regions, along with suggestions of geyser−like eruptions.

Europa's appearance could result from the stresses of the contorting tidal effects of Jupiter's strong gravity (possibly combined with some internal heat from decay of radioactive elements). If the warmth generated by tidal heating is (or has been) enough to liquefy some portion of Europa, then the moon may have environmental niches warm and wet enough to host life. These niches might be similar to those found near ocean−floor vents on the Earth.

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Subject: F.02.4 Is there life on Saturn's moon Titan?
Author: T. Joseph W. Lazio <jlazio@patriot.net>

This material is extracted from the review article by Chyba & McDonald (1995, Annual Review of Earth and Planetary Science).

Titan's atmosphere is a rich mix of nitrogen and methane, from which organic molecules (i.e., those containing carbon, not necessarily molecules in living organisms) can be formed. Indeed, there has been speculation that Titan's atmosphere resembles that of Earth some 4 billion years ago. Complex organic chemistry can result from the ultraviolet light from the Sun or from charged particle impacts on the upper atmosphere. Unfortunately, Titan's great distance from the Sun means that the surface temperature is so low that liquid water is probably not present globally. Since we believe that liquid water is probably necessary for the emergence of life, Titan is unlikely to harbor any life. The impact of comets or asteroids on Titan may, however, warm the surface enough that any water ice could melt. Such "impact pools" could persist for as long as 1 thousand years, potentially allowing life−like chemical reactions to occur.

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Subject: F.03 What is the Drake equation?
Author: John Pike <johnpike@fas.org>, Bill Arnett <billa@znet.com>,
Steve Willner <swillner@cfa.harvard.edu>

There are various forms of it, but basically it is a means of doing boundary calculations for the prevalence of intelligent life in the universe. It might take the form of saying that if there are:

X stars in the Galaxy, of which
Y % have planets, of which
Z % can support life, on which
A % intelligent life has arisen, with
B representing the average duration of civilizations

then you fool around with the numbers to figure out how close on average the nearest civilization is. There are various mathematical expressions for this formula (see below), and there are variations on how many terms the equations include.

The problem, of course, is that some of the variables are easy to pick (e.g., stars in the Galaxy), some are under study (e.g., how many stars have terrestrial−like planets), and others are just flat−out wild guesses (e.g., duration of civilization, where we are currently running an experiment to test this here on Terra of Sol).

One useful form says the number of detectable civilizations is:

$$N = R * fp * ne * fl * fi * fc * L$$

where

R = "the average rate of star formation in the region in question",
fp = "the fraction of stars that form planets"
ne = "the average number of planets hospitable to life per star"

fl = "the fraction of those planets where life actually emerges"
fi = "the fraction of life−bearing planets where life evolves into intelligent beings"
fc = "the fraction of planets with intelligent creatures capable of interstellar communication"
L = "the length of time that such a civilization remains detectable".

(If you want some definition of civilization other than detectability, just change your definition of fc and L accordingly.)

Can we provide reasonable estimates for any of the above numbers? The "social/biological" quantities are at best speculative and aren't appropriate for this newsgroup anyway. (For arguments that they are quite small, see biologist Ernst Mayr's article in _Bioastronomy News_, Quarter 1995, <URL:http://planetary.org/tps/mayr.html>.) Even the "astronomical" numbers, though determinable in principle, have considerable uncertainty. Nevertheless, I will attempt to provide reasonable estimates. I'll take the "region in question" to be the Milky Way Galaxy and consider only cases "similar to" our solar system.

For R, I'm going to use only stars with luminosities between half and double that of the Sun. Dimmer stars have a very small zone where Earth−like temperatures will be found, and more luminous stars have relatively short lifetimes. Near the Sun, there are about 4.5E−3 such stars in a cubic parsec. I'm only going to consider stars in the Galactic disk, which I take to have a scale height of 660 pc and scale length of between 5 and 8 kpc. (Stars outside the disk either have lower metallicity than the Sun or live in a very different environment and may have formed in a different way.) The Sun is about 8 kpc from the Galactic center, and thus in a region of lower than maximum star density. Putting everything together, there ought to be around 1.4E9 stars in the class defined. This represents about 1% of the total mass of the Galaxy. The age of the Sun is about 4.5E9 years, so the average rate of formation R is about 0.3 "solar like stars" per year.

Planets are more problematic, since extrasolar planets cannot generally be detected, but it is thought that their formation is a natural and indeed inevitable part of star formation. For stars like the Sun, in fact, there is either observational evidence or clear theoretical justification for every stage of the planet formation process as it is currently understood. We might therefore be tempted to take fp=1 (for stars in the luminosity range defined), but we have to consider binary stars. A second star may disrupt planetary orbits or may somehow prevent planets forming in the first place. Because about 2/3 of the relevant stars are in binary systems, I'm going to take fp=1/3.

Now we are pretty much out of the range of observation and into speculation. It seems reasonable to take ne=1 or even 1.5 on the basis of the Solar system (Earth and Mars), but a pessimist could surely take a smaller number. You can insert your own values for the probabilities, but if we arbitrarily set all of them equal to one

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  N <= 0.1 L
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seems consistent with all known data.

A more detailed discussion of interpretation of the Drake equation and the factors in it can be found in Issue 5 of SETIQuest.

Subject: F.04 What is the Fermi paradox?
Author: John Pike <johnpike@fas.org>,
        Steve Willner <swillner@cfa.harvard.edu>

One of the problems that the Drake Equation produces is that if you take reasonable (some would say optimistic) numbers for everything up to the average duration of technological civilizations, then you are left with three possibilities:

1. If such civilizations last a long time, "They" should be _here_ (leading either the the Flying Saucer hypothesis−−−they are here and we are seeing them, or the Zoo Hypothesis−−−they are here and are hiding in obedience to the Prime Directive, which they observe with far greater fiqdelity than Captain Kirk could ever muster). −or−

2. If such civilizations last a long time, and "They" are not "here" then it becomes necessary to explain why each and every technological civilization has consistently chosen not to build starships. The first civilization to build starships would spread across the entire Galaxy on a timescale that is short relative to the age of the Galaxy. Perhaps they lose interest in space flight and building starships because they are spending all their time surfing the net. (Think about it−−−the whole point of space flight is the proposition that there are privileged spatial locations, and the whole point of the net is that physical location is more or less irrelevant.) −or−

3. Such civilizations do not last a long time, and blow themselves up or otherwise fall apart pretty quickly (... film at 11).

Thus the Drake Equation produces what is called the Fermi Paradox (i.e., "Where are They?"), in that the implications of #3 and #2 are not terribly encouraging to some folks, but the two flavors of #1 are kinda hard to come to grips with.

An alternate version of 2 is that interstellar travel is far more difficult than we think it is. Right now, it doesn't seem much beyond the boundaries of current technology to launch "generation ships," which amount to an O'Neill colony plus propulsion and power systems. An alternative is robot probes with artificial intelligence; these don't seem so difficult either. The Milky Way galaxy is well under 10^5 light years in diameter and over 10^9 years old, so even travel beginning fairly recently in Galactic history and proceeding well under the speed of light ought to have filled the Galaxy by now. (Travel very near the speed of light still seems very hard, but such high speed isn't necessary to fill the Galaxy with life.) The paradox, then, is that we don't observe evidence of anybody besides us.

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Subject: F.05 Could we detect extraterrestrial life?
Author: Steve Willner <swillner@cfa.harvard.edu>

Yes, although present observations can do so only under optimistic assumptions. Radio and optical searches currently underway are aimed at detecting "beacons" built by putative advanced civilizations and intended to attract attention. More sensitive searches (e.g., Project Cyclops) that might detect normal activities of an advanced civilization (similar for example to our military radars or TV stations) have been proposed but so far not funded. No funding of these is likely until the search for beacons is far closer to being complete. Why get involved with the difficult until you are done with the easy?

Ordinary astronomical observations are most unlikely to detect life. The kinds of life we speculate about would be near stars, and the light from the star would conceal most signs of life unless a special effort is made to look for them.

Within the solar system, the Viking landers found conditions on the surface of Mars unlikely to support life as we know it. The mass spectrometer found too little carbon, which is the basis for organic molecules. The chemistry is apparently highly oxidizing as well. Some optimists have nevertheless argued that there still might be life on Mars, either below the surface or in surface regions not sampled by the landers, but most scientists consider life on Mars quite unlikely. Evidence of surface water suggests, however, that Mars had a wetter and possibly warmer climate in the past, and life might have existed then. If so, there might still be remnants (either living or fossil) today, but close examination will be necessary to find out.

Other sites that conceivably could have life include the atmosphere of Jupiter (and perhaps Saturn) and the presumed liquid water under the surface ice of Jupiter's satellite Europa. Organisms living in either place would have to be very different from anything we know on Earth, and it's hard to know how one would even start to look for them.

Concepts for specialized space missions that could detect Earth−like planets and return spectral information on their atmospheres have been suggested, and either NASA or ESA may launch such a mission some time in the next two decades (see

<URL:http://techinfo.jpl.nasa.gov/www/ExNPS/HomePage.html> and <URL:http://ast.star.rl.ac.uk/darwin/>). The evidence for life would be detection of ozone (implying oxygen) in the planet's atmosphere. While this would be strong evidence for life−−−oxygen in Earth's atmosphere is thought to have come from life−−−it would not be ironclad proof, as there may be some way an oxygen atmosphere could form without life.

For more information, see references at the end of F.06. Also, check out the SETI Institute Web site at <URL:http://www.seti−inst.edu>.

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Subject: F.06 How far away could we detect radio transmissions?
Author: Al Aburto <aburto@nosc.mil>,
David Woolley <david@djwhome.demon.co.uk>

Representative results are presented in Tables 1 and 2. The short answer is

(1) Detection of broadband signals from Earth such as AM radio, FM radio, and television picture and sound would be extremely difficult even at a fraction of a light−year distant from the Sun. For example, a TV picture having 5 MHz of bandwidth and 5 MWatts of power could not be detected beyond the solar system even with a radio telescope with 100 times the sensitivity of the 305 meter diameter Arecibo telescope.

(2) Detection of narrowband signals is more resonable out to thousands of light−years distance from the Sun depending on the transmitter's transmitting power and the receiving antenna size.

(3) Instruments such as the Arecibo radio telescope could detect narrowband signals originating thousands of light−years from the Sun.

(4) A well−designed 12 ft diameter amateur radio telescope could detect narrowband signals from 1 to 100 light−years distance assuming the transmitting power of the transmitter is in the terawatt range.

What follows is a basic example for the estimation of radio and microwave detection ranges of interest to SETI. Minimum signal processing is assumed. For example an FFT can be used in the narrowband case and a bandpass filter in the broadband case (with center frequency at the right place of course). In addition it is assumed that the bandwidth of the receiver (Br) is constrained such that it is greater than or equal to the bandwidth of the transmitted signal (Bt) (that is, Br >= Bt).

Assume a power Pt (watts) in bandwidth Bt (Hz) radiated isotropically. At a distance of R (meters), this power will be uniformly distributed (reduced) over a sphere of area: 4 * pi * R^2. The amount of this power received by an antenna of effective area Aer with bandwidth Br (Hz), where Br >= Bt, is therefore:

Pr = Aer * (Pt / (4 * pi * R^2))

If the transmitting antenna is directive (that is, most of the available power is concentrated into a narrow beam) with power gain Gt in the desired direction then:

Pr = Aer * ((Pt * Gt) / (4 * pi * R^2))

The antenna gain G (Gt for transmitting antenna) is given by the following expression. (The receiving antenna has a similar expression for its gain, but the receiving antenna's gain is not used explicitly in the range equation. Only the effective area, Aer, intercepting the radiated energy at range R is required.)

Gt = Aet * (4 * pi / (w^2)), where

Aet = effective area of the transmitting antenna (m^2), and
w = wavelength (m) the antenna is tuned to.
f = c / w, where f is the frequency and c is the speed of light.
c = 2.99792458E+08 (m/sec)
pi = 3.141592654...

For an antenna (either transmiting or receiving) with circular apertures:

Ae = <eta> * pi * d^2 / 4

<eta>r = efficiency of the antenna,
d = diameter (m) of the antenna.

The Nyquist noise, Pn, is given by:

Pn = k * Tsys * Br, where

k = Boltzmann's constant = 1.38054E−23 (joule/kelvin)
Tsys = is the system temperature (kelvins), and
Br = the receiver bandwidth (hertz).

The signal−to−noise ratio, snr, is given by:

snr = Pr / Pn.

If we average the output for a time t, in order to reduce the variance of the noise, then one can improve the snr by a factor of sqrt(Br * t). Thus:

snr = Pr * sqrt(Br * t) / Pn.

The factor Br*t is called the "time bandwidth product," of the receive processing in this case, which we'll designate as:

twp = Br * t.

We'll designate the integration or averaging gain as:

twc = sqrt(twp).

Integration of the data (which means: twp = Br * t > 1, or t > (1 / Br)) makes sense for unmodulated "CW" signals that are relatively stable over time in a relatively stationary (steady) noise field. On the other hand, integration of the data does not make sense for time−varying signals since this would distroy the information content of the signal. Thus for a modulated signal twp = Br * t = 1 is appropriate.

In any case the snr can be rewritten as:

snr = (Pt * Gt) * Aer * twc / (4 * pi * R^2 * Br * k * Tsys)

Pt * Gt is called the Effective Isotropic Radiated Power (EIRP) in the transmitted signal of bandwidth Bt. So:

EIRP = Pt * Gt, and

snr = EIRP * Aer * twc / (4 * pi * R^2 * Br * k * Tsys)

This is a basic equation that one can use to estimate SETI detection ranges.

```
########################################################################
# If Rl is the number of meters in a light year (9.46E+15 [m/LY]), #
# then the detection range in light years is given by #
# #
# R = sqrt[ EIRP * Aer * twc / (4 * pi * snr * Br * k * Tsys) ] / Rl #
# #
# If we wanted the range in Astronomical Units then replace Rl #
# with Ra = 1.496E+11 (m/AU). #
########################################################################
```

Note that for maximum detection range (R) one would want the transmit power (EIRP), the area of the receive antenna (Aer), and the time bandwidth product (twp) to be as big as possible. In addition one would want the snr, the receiver bandwidth (Br), and thus transmit signal bandwidth (Bt), and the receive system temperature (Tsys) to be as small as possible.

(There is a minor technical complication here. Interstellar space contains a plasma. Its effects on a propagating radio wave including broadening the bandwidth of the signal. This effect was first calculated by Drake & Helou and later by Cordes & Lazio. The magnitude of the effect is direction, distance, and frequency dependent, but for most lines of sight through the Milky Way a typical value might be 0.1 Hz at a frequency of 1000 MHz. Thus, bandwidths much below this value are unnecessary because there will be few, if any, signals with narrower bandwidths.)

Now we are in a position to carry out some simple estimates of detection range. These are shown in Table 1 for a variety of radio transmitters. We'll assume the receiver is similar to Arecibo, with diameter dr = 305 m and an efficiency of 50% (<eta>r = 0.5). We'll assume snr = 25 is required for detection (The META project used a snr of 27−−33 and SETI@home uses 22; more refined signal processing might yield increased detection ranges by a factor of 2 over those shown in the Table 1.) We'll also assume that twp = Br * Tr = 1. An "educated" guess for some of the parameter values, Tsys in particular, was taken as indicated by the question marks in the table. As a reference note that Jupiter is 5.2 AU from the Sun and Pluto 39.4 AU, while the nearest star to the Sun is 4.3 LY away. Also any signal attenuation due to the Earth's atmosphere and ionosphere have been ignored; AM radio, for example, from Earth, is trapped within the ionosphere.

The receive antenna area, Aer, is

Aer = <eta>r * pi * dr^2 / 4 = 36.5E3 m^2.

(Scientific notation is being used here; 1E1 = 10, 1E2 = 100, 1E3 = 1000, so 36.5E3 is 36.5 times 1000.) Hence the detection range (light years) becomes

R = 3.07E−04 * sqrt[EIRP / (Br * Tsys)].

Table 1 Detection ranges of various EM emissions from Earth and the Pioneer spacecraft assuming a 305 meter diameter circular aperture receive antenna, similar to the Arecibo radio telescope. Assuming snr = 25, twp = Br * Tr = 1, <eta>r = 0.5, and dr = 305 meters.

Source	Frequency Range	Bandwidth (Br)	Tsys (Kelvin)	EIRP	Detection Range (R)
AM Radio	530−1605 kHz	10 kHz	68E6	100 KW	0.007 AU
FM Radio	88−108 MHz	150 kHz	430	5 MW	5.4 AU
UHF TV Picture	470−806 MHz	6 MHz	50 ?	5 MW	2.5 AU
UHF TV Carrier	470−806 MHz	0.1 Hz	50 ?	5 MW	0.3 LY

WSR−88D Weather Radar	2.8 GHz	0.63 MHz	40	32 GW	0.01 LY
Arecibo S−Band (CW)	2.380 GHz	0.1 Hz	40	22 TW	720 LY
Arecibo S−Band (CW)	2.380 GHz	0.1 Hz	40	1 TW	150 LY
Arecibo S−Band (CW)	2.380 GHz	0.1 Hz	40	1 GW	5 LY
Pioneer 10 Carrier	2.295 GHz	1.0 Hz	40	1.6 kW	120 AU

It should be apparent then from these results that the detection of AM radio, FM radio, or TV pictures much beyond the orbit of Pluto will be extremely difficult even for an Arecibo−like 305 meter diameter radio telescope! Even a 3000 meter diameter radio telescope could not detect the "I Love Lucy" TV show (re−runs) at a distance of 0.01 Light−Years!

It is only the narrowband high intensity emissions from Earth (narrowband radar generally) that will be detectable at significant ranges (greater than 1 LY). Perhaps they'll show up very much like the narrowband, short duration, and non−repeating, signals observed by our SETI telescopes. Perhaps we should document all these "non−repeating" detections very carefully to see if any long term spatial detection patterns show up.

Another question to consider is what an Amateur SETI radio telescope might achieve in terms of detection ranges using narrowband FFT processing. Detection ranges (LY) are given in Table 2 assuming a 12 ft (3.7 m) dish antenna operating at 1.42 GHz, for various FFT binwidths (Br), Tsys, snr, time bandwidth products (twp = Br*t), and EIRP values. It appears from the table that effective amateur SETI explorations can be conducted out beyond approximately 30 light years provided the processing bandwidth is near the minimum (approximately 0.1 Hz), the system temperature is minimal (20 to 50 Degrees Kelvin), and the EIRP of the source (transmitter) is greater than approximately 25 terawatts.

Table 2 Detection ranges (LY) for a 12 foot diameter amateur radio telescope SETI system, operating at 1.420 GHz.

				EIRP			
				100TW	25TW	1TW	100GW

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  Br | Br*t | Tsys | snr | Detection Range |
 (Hz) | | (kelvin) | | (LY) |
−−−−−−+−−−−−−+−−−−−−−−−+−−−−−+−−−−−−+−−−−−−−+−−−−−+−−−−−−+
 0.1 | 2 | 50 | 25 | 28 | 17 | 3.4 | 1.1 |
−−−−−−+−−−−−−+−−−−−−−−−+−−−−−+−−−−−−+−−−−−−−+−−−−−+−−−−−−+
 0.1 | 1 | 50 | 25 | 20 | 12 | 2.4 | 0.76 |
−−−−−−+−−−−−−+−−−−−−−−−+−−−−−+−−−−−−+−−−−−−−+−−−−−+−−−−−−+
 0.5 | 2 | 50 | 25 | 12.7 | 6.4 | 1.3 | 0.4 |
−−−−−−+−−−−−−+−−−−−−−−−+−−−−−+−−−−−−+−−−−−−−+−−−−−+−−−−−−+
 0.5 | 1 | 50 | 25 | 9 | 4.5 | 0.9 | 0.3 |
−−−−−−+−−−−−−+−−−−−−−−−+−−−−−+−−−−−−+−−−−−−−+−−−−−+−−−−−−+
 0.1 | 20 | 50 | 25 | 90 | 54 | 11 | 3.4 |
−−−−−−+−−−−−−+−−−−−−−−−+−−−−−+−−−−−−+−−−−−−−+−−−−−+−−−−−−+
 1.0 | 200 | 50 | 25 | 90 | 54 | 11 | 3.4 |
−−−−−−+−−−−−−+−−−−−−−−−+−−−−−+−−−−−−+−−−−−−−+−−−−−+−−−−−−+
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Subject: F.07 What's a Dyson spheres?
Author: Anders Sandberg <nv91−asa@nada.kth.se>

Freeman Dyson noted that one of the limiting resources for civilizations is the amount of energy they can harness. He proposed that an advanced civilization could harness a substantial fraction of its sun's energy by enclosing the star in a shell which would capture most of the radiation emitted by the star. That energy could then be used to do work.

As originally proposed a Dyson sphere consisted of many solar collectors in independent orbits. Many science fiction writers have modified the idea to make a Dyson sphere one complete shell. In addition to capturing all of the available energy from the star, such a shell would have a huge surface area for living space. While Dyson's original proposal of a number of solar collectors is stable, this later idea of a complete shell is not stable. Without some stablizing mechanism, even small forces, e.g., a meteor hit, would cause the shell to drift and eventually hit the star. Also, the stresses on a complete shell Dyson sphere are huge and no known material has enough strength to be used in the construction of such a shell.

There have been searches for Dyson spheres. Such searches typically take place in the infrared. Because the shell is trapping energy from the star, it will begin to heat up. At some point it will radiate as much energy as it receives from the star. For a Dyson sphere with a radius about the radius of Earth's orbit, most of the radiation emitted by the shell should be in the infrared. Thus far, no search has been successful.

Considerably more discussion of Dyson spheres is in the Dyson sphere FAQ, <URL:http://www.student.nada.kth.se/~nv91−asa/dysonFAQ.html>.

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Subject: F.08 What is happening with SETI now?
Author: Larry Klaes <larryk@cambridge.village.com>

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Project BETA (Billion−channel ExtraTerrestrial Assay) is a radio search begun 1995 October 30. It is sponsored by the Planetary Society and is an upgraded version of Project META (Million...). (Actually META I; see below for META II.) META I/BETA's observatory is the 26−meter radio antenna at Harvard, Massachusetts. Their Web site is <URL:http://planetary.org/BETA/>.

META II uses a 30−meter antenna at the Argentine Institute for Radio Astronomy, near Buenos Aires, Argentina, and provides coverage of the southern sky. <URL:http://seti.planetary.org/META2/>

META I/II monitored 8.4 million channels at once with a spectral resolution of 0.05 Hz, an instantaneous bandwidth of 0.4 MHz, a total frequency coverage of 1.2 MHz, a maximum sensitivity of 7x10^−24 W m^−2, and a combined sky coverage of 93 percent. After five years of observations from the northern hemisphere and observing 6x10^13 different signals, META I found 34 candidates, or "alerts". Unfortunately, the data are insufficient to determine their real origin. Interestingly, the observed signals seem to cluster near the galactic plane, where the major density of Milky Way stars dwell. META II, after three years of observations and surveying the southern hemisphere sky almost three times, found nineteen signals with similar characteristics to the META I results. META II has also observed eighty nearby, main sequence stars (less than fifty light years from the Sun) that have the same physical characteristics as Earth's star. These observations were performed using the tracking mode for periods of one hour each at two different epochs.

On 1992 October 12, NASA began its first SETI program called HRMS−−−High−Resolution Microwave Survey. Unfortunately for all, Congress decided the project was spending way too much money−−−even though it received less funds per year than your average big league sports star or film actor−−−and cut all money to NASA for SETI work. This act saved our national deficit by all of 0.0002 percent.

Fortunately, NASA SETI was saved as a private venture called Project Phoenix and run by The SETI Institute. It operates between 1.0 and 3.2 GHz with 1 Hz resolution and 2.8E7 channels at a time. Rather than trying to scan the entire sky, this survey focusses on approximately 1000 nearby stars. They began observations in 1995 February using the Parkes 64 m radio telescope in New South Wales, Australia, and have since moved to the 42 m radio telescope in Green Bank, West Virginia. After completing about 1/3 of their targets, they had found no evidence of ET transmissions. More details are in SETIQuest issue 3 and at the Project Phoenix home page <URL:http://www.seti−inst.edu/phoenix/Welcome.html>. The Web site has lots of general information about SETI as well as details of the survey.

Since 1973, Ohio State University had conducted a radio search with a telescope consisting of a fixed parabolic reflector and a tiltable flat reflector, each about 110 m wide and 30 m high. Information is available at <URL:http://everest.eng.ohio−state.edu/~klein/ro/> or a longer version in SETIQuest issue 3. The "wow!" signal, detected in 1977, had the appearance of an extraterrestrial signal but was seen only briefly and never repeated. However, the Ohio State University administration decided to let the landlord who owns the property on which Big Ear resides tear down the radio telescopes and put up condos and a golf course instead. OSU SETI is considering its next step, Project Argus, at an undetermined location.

The UC Berkeley SETI Program, SERENDIP (Search for Extraterrestrial Radio Emissions from Nearby Developed Intelligent Populations) is an ongoing scientific research effort aimed at detecting radio signals from extraterrestrial civilizations. The project is the world's only "piggyback" SETI system, operating alongside simultaneously conducted conventional radio astronomy observations. SERENDIP is currently piggybacking on the 300 m dish at Arecibo Observatory in Puerto Rico, the largest radio telescope in the world. Information at <URL:http://albert.ssl.berkeley.edu/serendip/>, from which this paragraph was extracted. SERENDIP operates at 430 MHz; more information is given in SETIQuest issue 3.

Project BAMBI is an amateur SETI effort operating at a radio frequency of 4 GHz. See SETIQuest issue 5 and <URL:http://wbs.net/sara/bambi.htm> for status reports.

The Columbus Optical SETI Observatory uses visible light instead of radio waves. The COSETI Observatory is a prototype observatory located in Bexley, Ohio, USA. Telescope aperture size is 30 cm. More information in SETIQuest issue 4 and at <URL:http://www.coseti.org/>. Much of the work on "Optical SETI" comes from Dr. Stuart A. Kingsley <skingsle@magnus.acs.ohio−state.edu>, who also maintains BBS on Optical SETI.

The Planetary Society maintains a list of online SETI−related material at <URL:http://seti.planetary.org/>.

And of course SETIQuest magazine, Larry Klaes, Editor. For subscription or other information, contact Helmers Publishing, 174 Concord Street, Peterborough, NH 03458−0874. Phone (603) 924−9631, FAX (603) 924−7408, Internet: sqinqnet@pixelacres.mv.com or see <URL:http://www.setiquest.com/>.

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Frank Drake, Dava Sobel, Is Anyone Out There: The Scientific Search For Extraterrestrial Intelligence, 1992, Delacorte Press, ISBN 0−385−30532−X.

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Donald Goldsmith and Tobias Owen, The Search For Life in the Universe, Second Edition, 1992, Addison−Wesley Publishing Company, Inc., ISBN 0−201−56949−3.

Walter Sullivan, We Are Not Alone: The Continuing Search for Extraterrestrial Intelligence, 1993, Dutton, ISBN 0−525−93674−2.

G. Seth Shostak, Editor, Progress In The Search For Extraterrestrial Life, 1993 Bioastronomy Symposium, Santa Cruz, California, 16−−20 August 1993. Published in 1995 by The Astronomical Society of the Pacific (ASP). ISBN 0−937707−93−7.

The journals Icarus, <URL:http://astrosun.tn.cornell.edu/Icarus/>, and Astronomy & Geophysics often feature papers concerning SETI.

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Subject: F.09 Why search for extraterrestrial intelligence using radio? Why not <fill in the blank> method?
Author: Joseph Lazio <jlazio@patriot.net>

There are two possibilities for sending information to other technological civilizations over interstellar distances: send matter or send radiation. The focus in SETI has been on detecting electromagnetic radiation, particularly radio, because compared to all other known possibilities, it is cheap, easy to produce, and can travel across the Milky Way Galaxy.

Compared to radiation, most matter has a distinct disadvantage: it is slow. Radiation can travel at the speed of light whereas (most) matter is constrained to travel slower. Distances between stars are so large, it makes no sense to use a slow mode of communication when a faster one is available. The speed at which spacecraft travel is the primary justification why there is little effort spent within the SETI community searching for interstellar spacecraft (that and the fact that there is no evidence that there are any such interstellar spacecraft from other civilizations in our vicinity). A secondary justification is that spacecraft are relatively expensive. The launch of a single Earth−orbiting spacecraft can cost US $100 million. It is difficult to imagine building and launching a fleet of interstellar spacecraft for US $500 million, yet this is the estimated cost of a next−generation radio telescope capable of detecting TV signals over interstellar distances. It is possible that future technology will make spacecraft cheaper. It is difficult to imagine a technology that would make spacecraft cheaper without also lowering the cost of a new telescope.

Although chunks of matter, i.e., spacecraft, seem a rather inefficient way to communicate across interstellar space, what about a beam of matter. Most often suggested in this context is a beam of neutrinos. Neutrinos are nearly massless so they travel at almost the speed of light. They also interact only weakly with matter, so a beam of neutrinos could cross the Milky Way Galaxy without any significant absorption by interstellar gas and dust clouds. This advantage is also a disadvantage: The weakness of their interaction makes it difficult to detect a beam of neutrinos, far more difficult than detecting a beam of electromagnetic radiation.

(A beam of electrons or protons could be accelerated to nearly the speed of light and would be far easier to detect. However, electrons and protons are charged particles. When travelling through interstellar space, the direction of their travel is influenced by the magnetic field of the Milky Way Galaxy. The Milky Way's magnetic field has "small−scale" irregularities in it that would divert and scatter such a beam. The result is that one could not "aim" such a beam in any particular direction [except possibly to the very closest stars] because its actual path would be influenced by the [unknown] direction[s] of the magnetic field it would encounter.)

The known forms of radiation are electromagnetic and gravitational. Electromagnetic radiation results from the acceleration of charged particles and is used commonly: Radio and TV broadcasts are radio radiation, microwave ovens produce microwave radiation, X−ray machines produce X−ray radiation, overhead lights produce visible radiation, etc. Gravitational radiation results from the acceleration of massive objects. Gravitational radiation has never been detected directly, and its indirect detection resulted in the 1993 Nobel Prize. Gravity is a much weaker force than electromagnetism. Thus, detectable amounts of gravitational radiation result only from events like the explosion of a massive star or the gravitational interaction between two closely orbiting neutron stars or black holes. Again, it is possible that a future technology might result in gravitational radiation becoming easier to detect. It is still difficult to imagine that it would not also result in electromagnetic radiation.

Of the various forms of electromagnetic radiation−−−radio, microwave, infrared, visible, ultraviolet, X−ray, and gamma−ray−−−only radio and gamma−ray can cross the Milky Way Galaxy. The other forms suffer varying amounts of absorption by interstellar dust and gas clouds (though they could still be used to communicate over shorter distances). Gamma rays are extremely energetic and are produced by events like the explosion of nuclear bombs. Radio radiation is far less energetic. Thus, to send the same amount of information requires far less energy (i.e., it's cheaper) to send it via radio than gamma ray.

The above are merely plausibility arguments to suggest why radio is likely to be a preferred method of communication among technological civilizations. Of course, they may reason that they are only interested in communicating with other civilizations technologically advanced enough to transmit and detect neutrino beams or gravitational radiation (or maybe even some undiscovered method). If so, the existing radio SETI programs are doomed to failure. Nonetheless, it does seem sensible to search first using the most simple technology.

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Subject: F.10 Why do we assume that other beings must be based on
carbon? Why couldn't organisms be based on other substances?
Author: Joseph Lazio <jlazio@patriot.net>

[A portion of this entry is based on a lecture by Alain Leger (IAS) at the SPIE Astronomical Telescopes and Instrumentation 2000 Conference.]

As far as SETI, the search for extraterrestrial intelligence, is concerned, we do not assume that other being must be based on carbon. In fact, SETI is a bit of a misnomer. We are searching for extraterrestrial *technological* intelligences, technological intelligences capable of broadcasting their existence over interstellar distances. Whether the technological civilizations is based on carbon or some other substance is largely irrelevant. (Of course, one might worry that intelligences based on some substance other than carbon might have such different perspectives on the Universe that, even if they broadcast electromagnetic radiation, they would do so in a fashion that we would never consider.)

However, when one moves to finding life on other bodies in the solar system or traces of life on extrasolar planets, there is a definite carbon chauvinism in our thinking. The most commonly mentioned alternate to carbon (C) is silicon (Si). It has similar chemical properties as C, lying just below C in the periodic table of the elements.

Carbon chauvinism has arisen because C is able to form quite complicated molecules, in part because its atomic structure is such that C can bond with up to four other elements. Not only can it bond with up to four other elements, but C can form multiple bonds with other elements, particularly itself. (Atoms bond by sharing electrons, when two atoms share more than one electron they have a multiple bond. For instance, water is formed by an oxygen atom sharing the two electrons from two hydrogen atoms. In contrast, there are many C compounds in which a single C atom shares multiple electrons with other atom.)

A clear indication of the versatility of C is found in interstellar chemistry. Interstellar chemistry typically occurs on the surface of microscopic dust grains contained with large clouds of gas between the stars. The physical conditions are much different than anything on the surface of a habitable planet. Nonetheless, of the molecules identified in interstellar space as of 1998, 84 are based on C and 8 are based on Si. Moreover of the eight Si−based compounds, 4 also include C.

Thus, while there is definitely a C bias in our thinking, there is at least some evidence from Nature supporting this bias.

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Subject: F.11 Could life occur on an interstellar planet?
Author: Joseph Lazio <jlazio@patriot.net>

This question has taken on increased importance with the discovery of giant planets close to their primary stars. It is thought that these giant planets did not form this close to their host stars but migrated. (See the FAQ entry on the formation of the solar system.) In general, the possibility of migration has alerted (or re−awakened) astronomers to the possibility that a planetary system can change over time. If a giant planet migrates inward from the position at which it formed, it can scatter terrestrial planets. These terrestrial planets might plunge into the host star or be kicked into interstellar space. (Another possibility, though probably even less likely, is for a passing star to disrupt a planetary system.)

What would happen if the Earth were kicked into interstellar space? Life on the surface would certainly be doomed as it gets its energy to survive from the Sun. In fairly short order, the oceans would freeze over. However, the Earth is still generating heat by radioactive decay in its interior. Some of this heat leaks out through hydrothermal vents on the floors of the oceans. Thus, the lower levels of the oceans would remain liquid, and the hydrothermal vents would remain active. Organisms that depend only on the hydrothermal vents could survive probably quite happily for several billion years after the Earth was ejected from the solar system. (Indeed, since the oceans will probably boil away in the next few billion years as the Sun's luminosity increases, these organisms might prefer the Earth to be ejected into interstellar space!)

For additional reading see "The Frozen Earth" by Adams & Laughlin,
<URL:
http://adsabs.harvard.edu/cgi−bin/nph−bib_query?bibcode=1999AAS...194.1511A
> and Stevenson, "Life−sustaining planets in interstellar space?",
Nature, v. 400, 1 Jul 1999, p. 32.

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