TARGETS AND SETI:
SHARED MOTIVATIONS, LIFE SIGNATURES AND ASYMMETRIC SETI

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1. Abstract

The argument proposed in this paper is that conventional assumptions which underpin SETI can be revised in ways which permit a more nuanced approach to the enterprise. It is suggested that sensible assumptions based on adventurous science include the notion that we can conjecture helpfully about what we can know about SETI, and that probably the ETIs for which we are looking are sending signals to us because they know they are not alone, and are interested to help us learn that we are not alone. Additionally, existing work using Pulsars as Beacons for SETI is reviewed in the context of what we can now call Asymmetric SETI, the term coined to reflect that we are merely seeking to determine what ETI already knows.

2. Introduction

Searching for Extraterrestrial Intelligence is essentially a scientific enterprise. It is unusual in its poverty of theory and concomitant weakness in experimental paradigm – consequently it is rich in speculation and assumption. In the second half of the 20th century various attempts were made to supply the semblance of scientific respectability to SETI, notably Cocconi and Morrison's paper in Nature (1959), Drake's equation in 1961 (see Dick 1998), and serious analytic discussions of probabilities, transmission frequencies, travel, technical advancement, and so forth (for a discussion of the history of SETI and ideas from Bracewell, Dyson, Hoerner, Shklovskii and others, in the 1960s, see Dick 1998). However, forceful arguments were put forward in the 1970s and 1980s which claimed the enterprise was futile simply because if ETIs did exist they would be here by now, but they are not so they don't (Fermi's conjecture from 1950 was re-energised to become the primary argument against SETI; on "Fermi's paradox" see also Webb 2002). Nonetheless, actual observations, and the development of various observational programmes, continued and some of the enduring themes in SETI work were widely accepted at this time. For example, the assumption that the 21cm wavelength will be universally recognized – and thus is sensible for SETI – was made in the 1960s. And of course there continue to be both RF and Optical searches – so there are sufficient resources available both in terms of equipment and people to keep a scientific debate alive, if not to conduct SETI with the level of intensity some people would like.

Much more detail about all these issues can be found in the literature (Dick 1998 is a good place to look, as is Webb 2002), and my purpose here is not to write a history of SETI. What does concern me, however, is the need to re-consider assumptions and the need to inject more scientific caution into the enterprise. On the issue of transmission frequencies, and Optical versus RF searching, one can maintain a reasonable level of detachment – the searching has to start somewhere and 1420MHz is as good a place as any. One could argue in favour of the two OH lines around 1666MHz – either with or in place of the H line. In favour is the scientific belief that such frequencies will be obvious to any civilization capable of radio astronomy and of signalling to anyone. The disadvantage is that such frequencies are important for radio-astronomy – just as we Earthlings prohibit pollution of such frequencies one might assume an ETI would do the same [Eric Gerard, personal communication]. Optical signalling is technically feasible, and OSETI is by now unexceptional, with much to recommend it. These issues matter as practical examples of a general question: How can we make scientific caution work alongside speculation to yield plausible assumptions?

However, what matters at least as much are questions such as: What can we know about an ETI's motives, ways of thinking, and the like?; How can we make assumptions about ETIs serve SETI effectively in terms of

understanding options for signalling? In more general terms: Can we engage more adventurous science in the refinement of speculation to yield more unusual assumptions to guide novel SETI? The remainder of this paper is in four parts: first we look at some common assumptions (section 3); second we reconsider those assumptions in the light of recent scientific developments, and arrive thereby at some thinking about how to do SETI (sections 4 & 5); third we look at the details of a specific search technique which reflects the reanalysis of assumptions (section 6); finally we consider some implications of the search technique (sections 7 & 8).

3. Assumptions

SETI inevitably entails assumptions, as noted above in relation to frequencies, and before considering some novel assumptions it is necessary to look at the more conventional assumptions. Typically these cluster around several themes and we will deal with them in the following order: biology, technological advance, communication, travel, search strategy. One over-arching theme will be drawn out as the opportunity arises – assumptions are not always explicitly stated, and are sometimes inconsistent with one another.

3.1 - Biology

A widely shared assumption – only sometimes explicitly stated – is that what we Earthlings know of biology (that it is water/carbon based, and evolution operates) is sensibly thought of as being universal. "Follow the water" as a search paradigm in astrobiology is considered sensible because it is well-grounded (cf. Baross et al 2007). Instrumentation follows theoretical pre-supposition, of course, so detection of non-water/carbon life on earth would require skill and imagination. The assumption that on Earth we only have water/carbon life is very plausible – we do have the skills we need to find other life-forms. A more realistic concern is that these might not be ubiquitous so lack of discovery is simply a sampling issue. Nonetheless – astrobiology presumes water/carbon life. Additionally, astrobiology assumes the importance of evolution in the development of life-forms (this might seem to be a consequence of presuming water/carbon as the basis for life, but is not). The appeal is that Earth-based science can help the search for life off-planet: "astrobiology begins at home" might be a motto for astrobiology. More remote consequences (not often discussed explicitly) are that life-forms will be embodied and necessarily will evolve to include forms which have sensory organs, articulators, brains, and etc., (otherwise evolution won't work; cf - the '4 Fs' assessment of behavioural motivation for a successful member of a species: feeding, fighting, fleeing, reproducing).

3.2 - Technology

Another domain for assumptions in SETI research concerns the conjectured ETI's "advanced technology". It is frequently claimed that when found ETI will demonstrate "advanced technology", "superior science", and so on and so forth. It is not so usually noted that these terms are very vague even whilst also being limited – for example, there is usually no mention of "advanced socio-political organization or planet management". When the general expression "more advanced than us" is used it mostly refers to technology, science and medicine.

The most frequent conjecture in relation to "advanced" technology and science is that ETI will have solved the problem of super-luminal travel (and see below section 3.4). This puts SETI firmly in the SciFi domain and thereby undermines the work of more serious scientists. Recent work on SL travel (Obousy and Cleaver 2008) – looking at the Alcubierre warp – seems scientifically encouraging but fails to consider the navigational issues attendant on SL travel (information is limited to light speed so SL travellers are, essentially, lost). In addition the energy released when the warp collapses will surely engulf the travellers! Other assumptions concern prodigious energy resources, communications technologies, and etc. Sometimes the claim is made more or less explicitly that the life-form itself will have evolved to be "superior" to

humans in various ways - "more intelligent", for example, leading inevitably to more advanced science and technology.

Set alongside the science fiction are assumptions which seem more obviously plausible – ETI will know about stuff we call physics, engineering, etc., and will be doing astronomy and so forth. These assumptions are unremarkable except when elaborated in more fanciful SciFi. A novel assumption about "advanced technology" will be offered below. Of note here is the problem that whilst super-luminal travel might freely be assumed by some doing SETI it will remain recognized by such people that transmissions are limited by light speed (perhaps only because we don't know how to make transmissions work faster than light – unlike SciFi authors we cannot just conjure an "ansible" into production).

3.3 - Communication

In addition to assuming that ETI will have a recognizable life-form and an incomprehensible technology (magic – cf. A.C.Clarke), it is generally assumed that ETI will want to communicate. Currently the search for ETI is, predominantly, a search for a message. There are several aspects to this. As noted earlier, the transmissions can be sought at specific RF wavelengths and/or optically (more assumptions). Of more concern is the issue of "content" and "language". This is readily examined by looking at proposals for transmissions from Earth. Typically these focus on intentional, or otherwise, cryptographic challenges and the development of artificial languages. Enough is known about semiotics and symbol systems to show such proposals to be worthless. However, of greater concern is that the search for messages is motivated by the same thinking. Assumptions in this domain are questionable because they are usually linked (not always explicitly) to notions of ETI saving humans from themselves.

3.4 - Travel

It has famously been suggested that because ETI is not with us, they do not exist. This is the so-called "Fermi Paradox" and is best discussed in Stephen Webb's book "Where is Everybody?" (Webb 2002). The assumptions of ETI's interest in and capability for galactic travel and/or colonization are well located in the SciFi domain. Difficulties with super-luminal travel technology were noted earlier. Dick (1998) has an informative discussion of this aspect of SETI and Webb (2002) successfully presents a wide range of "stories" told around the theme – but his conclusion (human uniqueness) is, within the domain if not more widely, disappointing and unconvincing.

3.5 - Search strategy

One widely held view in SETI is that because we know nothing about ETI (despite the assumptions considered above) so it must be that the only way to search is through surveys and without any pre-conceived notions of targets/sources. Others prefer targeted searching of identified star systems with potential life-supporting characteristics. Further – assumptions will necessarily be made about frequencies/techniques to be used, about the nature of signals to be expected, and etc., and even about the motivations which might drive ETI to send signals at all.

The "look everywhere for anything" strategy supposedly does scientific justice to the thought that as we don't know anything about ETI we have no reason for being selective or specific. The problem with this view is that as soon as a portion of the RF/Optical spectrum is selected for the SETI activity we imply we do know something about ETI after all – so we should really work harder to be more specific about what we might know (this inconsistency is addressed below). If we do not attempt to provide reanalysis of the assumptions we might justly be thought to be looking under the street-lamp because that is where the light is. We will review and revise assumptions relevant to SETI, including those concerned with strategy, in the next section.

4. Revised assumptions

In this section of the paper we will look at revising/extending the assumptions set out in section 3 above, to guide novel SETI. We will

be addressing points brought up in each of the above sections. Before getting into the detail it is helpful to be clear about what is assumed to be the overall goal of SETI. The goal is to find an interesting (negative) answer to the question "Are we alone?". The motivation is well captured in A. C. Clarke's words:

> *"Sometimes I think we're alone in the universe, and sometimes I think we're not. In either case the idea is quite staggering."*

We should note, in passing, that of course by the time we discover a civilization elsewhere in our galaxy it may have ceased to exist, just as humanity may have ceased to exist by the time ETIs get to know about us. Issues of synchronicity don't actually undermine the quest although they add subtlety to Clarke's words. In addition – we need to think about ETI's motives for transmission of signals, and about other ways of doing SETI. This will help us review our own strategy for SETI (see section 6 below). We start by looking at the domains where assumptions have been made.

4.1 - Biology reconsidered

The primary concern in this domain is just how far we can go making assumptions about ETI. If we assume some sort of embodied life-form with brain, sensory apparatus, and etc., as the outcome of evolution, can we go further to say something about ETI's behaviour and motivations? It has been proposed that ETIs – as much as TIs – are governed by some General Cognitive Principles (Edmondson 2007). These license the assumption that ETIs will know about distributed cognition (cf. Hutchins 1995). With this assumption it can be argued that ETI will know that we know that they know we both share a problem and need a shared solution. This in turn licenses discussion about ETI's motivations for sending signals (see section 5), but here it is enough to say that ETI would do so as part of a shared solution to a shared problem.

An additional point to keep in mind under the general heading of biological assumptions is that evolution will have evolved to a stall, as it has for the human race (cf. the views of Steve Jones – URL in reference list) in technologically favourable settings. Technology develops to neutralize evolutionary pressures, it can be argued, by prolonging life, reducing pressures to produce offspring, and etc. Indeed – it could even be argued that socio-technology has a primary motivation to neutralise evolutionary pressures and thus stall the process; much of what we currently enjoy in technology (convenience equipment in the home, entertainment technology) just occupies the spandrels in the more structural socio-technological edifice. An analysis/history of socio-technology would need to see this developed in detail, but the idea is useful: we cannot assume that ETI will be an organism with a vastly superior intelligence or greater muscular strength or whatever. Note that the alternative assumptions discussed above have plausibly more scientific support than the more conventional assumptions – but the science is more adventurous and the implications for SETI lead us in new directions. We will see this again in the discussions below.

4.2 - Advanced technology reviewed

Within the socio-technological context set out above it can be argued that the notion of "advanced technology" doesn't have to deal with stories of super-luminal spaceships, fusion power, or whatever. It could be enough that a society with "advanced technology" is one which knows it is not alone in the universe. This can come about in a variety of ways, including the use of extremely large telescopes for direct observation of intelligent life-form behaviour, i.e. artefacts, on other planets (a telescope 1 km across could resolve a 1km feature at 100pc). Discovery does not have to be via transmission and reception of signals. This definition encompasses the idea that more advanced societies/technologies will be older than ours (on the basis that we have only just reached the point of making plausible SETI efforts). A milestone for such advancement for an ETI is simply that they now know they are not alone. This is my preferred limit for socio-technical conjecture – at once more focussed and less technically specific, and leading SETI in new directions.

If we try to specify other aspects of what it is to be technologically advanced we are quickly in the realm of SciFi. It is not clear what we gain by making conjectures in this domain. One example, not infrequently cited, is that of self-replicating technological probes (presumably with advanced AI technology on board as well). These, it is supposed, will flood the galaxy and report back on what they find (the so-called Bracewell probes, or Bracewell - von Neumann probes (Webb 2002:79-84)). That we haven't encountered them means they don't exist, and therefore ETIs don't exist. This is unhelpful conjecture, and indeed any such conjecture about possible technologies reduces, in the limit, to science fiction. For example, an equally plausible science fiction scenario is that ETI experimented with such probes and found them uncontrollable and only just succeeded in wiping them all out before they ran amok!

4.3 - Communication and signalling

It was noted earlier that as part of the overall context within which communication with SETI is discussed one finds the urge to send messages "about us" and likewise to envisage ways in which ETI would be communicating about themselves. Message structure and content have been considered in great detail, e.g. Freudenthal published (1960) a proposal for a self-explanatory language dubbed 'Lincos'. The assumptions underpinning such work seem weak – we know enough about semiology to know that we could not share experiences with ETI (and thus not share linguistic understanding) other than in domains where other evidence is more readily established. For example – that ETI can do astronomy presumes an enormous background in technology and science which does not, therefore, need a linguistic account or description or explanation to make it known to us. Why would an ETI seek to tell us what they can reasonably expect us to know already? If aspects of their world/existence are local to their circumstances then we will not be able to understand them on the basis of a linguistically coded message. Other aspects will, to a significant extent, be obvious and require no extra explanation.

But in point of fact, the primary question – "Are we alone?" – does not require us to know if ETI has three purple eyes or whatever. It is addressed by signalling presence, unambiguously, or by observation. Indeed – it is entirely plausible that for the most part other intelligences have answered the question observationally and that they seek to signal their existence in order to assist any ETI to answer the question sooner rather than later. We will take up this theme later when we consider motivations for active and passive SETI – suffice to say here that assumptions about the purpose of sending signals need to be reconsidered and that doing so changes our efforts at SETI.

Technically, therefore, the issue for SETI should be the search for Signals not Messages, and it should do this on the basis of reasoned analysis about why and to what such signals might be sent. See below at 4.5 - Search strategy renewed.

4.4 - Travel revisited

It has already been noted that travel – whether using super-luminal techniques, or using indirect representation in the form of probes – is an unlikely option for any ETI. The primary issue is motivation - "going boldly" anywhere is never going to be a good way to address the big question, whatever the makers of TV programmes might like to think. However, assuming for the sake of discussion that such travel is contemplated other issues arise. For example, ETI could have visited earth a million years ago because it looked promising a couple of million years ago, but found nothing exciting, and moved on. How would we know? Why would they leave anything for us to find if they don't know there is going to be anyone around to do the finding/interpreting?

Galactic travellers would have socio-technical sustainability issues significantly more complex than those required of planetary based civilizations – and of course the motivation for the trip, if nothing other than answering the basic question, has to be sustained for as long as it takes to get somewhere interesting and

then to get back (this theme is well known to SciFi fans). The Drake equation assumptions might need to be elaborated if travel speeds are not very high – which is to say, the Drake equation itself might need to be rethought in the context of extended voyages involving substantial communities. In short, aside from motivational implausibilities the technical problems seem unlikely to be worth over-coming.

One might want to promote the travel option on the basis of re-defining "advanced technology" to be interstellar travel technology. But, if we assume that energy and life-support and speed and communications technology…. have all been addressed as issues and the problems solved, then we are asked to suspend belief in our understanding of the world. This is not to say that ETI's physics will be based on an ETI equivalent of Newton or Einstein, merely that the phenomena they account for will be familiar to us. So far our review of assumptions has asked us to suspend disbelief – a somewhat more cautious step. Suspension of belief in our current understanding of phenomena is implicit in many accounts of doing SETI and really takes the work into the realms of SciFi.

4.5 - Search strategy renewed

The discussions above concerning revised assumptions in the light of more adventurous science appear to lead SETI in new directions. For example, it seems plausible to suppose we know more about ETI's cognition than we might have once thought, and that evolution will have served its purpose for them as much as for us; it seems plausible to suppose that ETI will have answered the big question and thus will have a motive to help us answer it (ETI will know we exist, through observation), and that help is more likely to take the form of signalling than travel. What remains is for us to reconsider the strategies we use for SETI.

Long-term the pursuit of advanced observational technology looks sensible, and to a degree inevitable (the timescales will reflect the motivational energy). In terms of looking for signals of one sort or another – the primary concern is going to be the need to understand what it means to be the target of transmissions. We need to work out where we should be looking, and for what. A proposal was made (Edmondson and Stevens 2003) to use Pulsars as beacons – relying on alignments between Habstars, Earth and Pulsars to provide specifications for directions and signal properties in a novel SETI paradigm (see the next section). There may well be other similar proposals which achieve the same goals – directing searching towards specific targets which, it can be supposed, could harbour an ETI which would have identified us as a target for a signal (not a message).

The most radical revision of assumptions which arises from the foregoing discussions is that the distinction between Active and Passive SETI – between sending signals/messages in active mode, and listening/looking for such signals in passive mode – becomes secondary. Whilst it can be argued that Passive SETI is best done by thinking about how one would do Active SETI, it turns out that a more important characteristic to understand is that the situation is Asymmetric.

Asymmetric SETI is the circumstance we should assume defines the enterprise and shapes our efforts within it. This comes from considering as plausible the assumption that ETI elsewhere is likely to know we exist – it will have answered the big question for itself and will have identified target worlds to which it makes sense to send signals. Their motivation is simply to help others answer the question. For them it makes sense to target transmissions – omnidirectional interstellar shouting is unlikely to appeal to them, and their own 'babble bubble' of radar, TV, radio broadcasting will have dissipated to become worthless (and in the big scheme of things is merely a brief RF 'flash').

The suggestion was made earlier that shared understanding of distributed cognition, and thus of the problem known to be shared – we know that ETI knows that we know that we both share the problem of finding each other and thus need a solution known also to be

shared – leads to a mutually interchangeable reciprocity of understanding, or situational symmetry. This remains valid if we consider specific strategies for SETI, such as signalling. However, it is not the case that thinking about distributed cognition only works in cases of situational symmetry. We have been conjecturing that ETI's advanced technology has led it discover it is not alone, perhaps on the basis of extremely large optical telescopes. We don't have such telescopes so the situation is not technologically symmetric – but for ETI to deploy signalling technology on the basis of its understanding of distributed cognition renders the situation technically symmetric in a sense. However, this is not the thinking behind the use of the term Asymmetric SETI. This term reflects the fact that ETI knows it is not alone, and thus needs a different motive for its signalling effort. We Earthlings don't yet know; ETI knows – that is the deep asymmetry which matters, and which leads us to suppose that ETI is signalling to help us answer the question. Of course ETI could simply wait for us to build bigger and better instruments.

5. Life signatures

There is one implication of the revised strategic view which deserves comment – before we move on to consider details of how searching can be done using pulsars. From the point of view of doing SETI from/on earth, ETI is presumed to know about our planet – much as it might have an inventory of what we call exoplanets. It is further assumed on this basis that ETI considers it worthwhile to send signals to likely/plausible exoplanets. But the list of such targets could be large, and the technical problem of transmission unappealing without more target refinement. So, assume further that ETI knows about us, and has assessed that we are deserving recipients of signals. ETI knows about intelligent life here on earth – how and when did it learn this?

Recent studies of global warming data, for example, indicate that around the middle of the 19th century atmospheric carbon dioxide levels started to rise above normal. This would be detectable at a distance with suitable instrumentation. Does this constitute the first reliable remotely observable evidence of intelligent behaviour on our planet? What could be the life signatures we might suppose we are (or have been) projecting over the centuries? Would a sufficiently advanced observational technology enable observation of human activity – e.g. canal building in Europe in the 18th century, de-forestation in Roman times, Egyptian pyramids thousands of years ago? This matters because of the issue of timing – how long ago did the earth first provide observable evidence that it harboured intelligent/human life? Half that length of time, in light years, is the distance of the furthest habstar from which we might suppose we could receive a signal. ETI will only consider transmissions when it has good reason to suppose that at the target there might be an intelligence capable of receiving them. That is the profound implication of considering SETI to be Asymmetric.

We end up reasoning our way to two detailed processes for *passive* SETI. The first assumes ETI is *actively* transmitting in order to help us with our *passive* SETI. We need to refine our "listening" strategy to account for this, but ideas exist and data can be collected (see the discussion of Edmondson & Stevens above, and see below in section 6). We develop an interesting view on the concept of "life signatures", namely that it is the signatures of the existence of terrestrial intelligent life forms that we should be thinking about. These signatures will determine how it is that ETI might learn about us. And the conception of such life signatures leads directly to the second process for *passive* SETI – the life signatures will shape our observational studies of habstars and exoplanets as we look for life elsewhere in observational mode, becoming ever more technically advanced until we reach the stage of "advanced technology" defined earlier when we discover we are not alone.

6 Pulsars as Beacons

It was noted above that a proposal had been made (Edmondson & Stevens 2003 – henceforth E&S) for using Pulsars as Beacons. This introduced a targeting scheme *ex caeruleo* and discussed the production of target lists.

This scheme is based on the idea that Pulsars can be used as Beacons if they line up with Habstars and Earth:

i) Pulsars are rapidly rotating, and thus apparently pulsing, radio sources (see Lorimer and Kramer 2005). Each pulsar has its own periodicity and periods found range from a little more than a millisecond to several seconds. Those which are not too distant are reasonably isotropically distributed in relation to our Sun.

ii) Catalogues of 'habitable' stars have been compiled (see for example Turnbull and Tarter 2003) where it is understood that such stars are not themselves habitable, but that they could support life on an appropriately orbiting planet. These too are isotropically spread around us – but nothing like as far as the pulsars. These stars are called 'Habstars'.

iii) The proposed scheme is to look for straight-line alignments featuring Earth, a Habstar, and a Pulsar. The alignment can be to arbitrary precision – E&S chose alignment within a cone of 1º radius and produced inventories of alignments where the Habstar is between Earth and the Pulsar, and also where Earth is between the Habstar and the Pulsar.

iv) The scheme supposes that the ETI will have similar lists of Pulsars and Habstars, and will know of our Sun as a Habstar. Further, the scheme supposes that the ETI will think of these straight-line alignments and produce lists of them, in accordance with the presuppositions about distributed cognition in relation to finding a shared solution to the shared problem.

v) The alignments provide the basis for specification of a predictable and entirely artefactual signal for transmission by the ETI (toward the Habstar). All the ETI needs to do is pick one of the 'obvious' frequencies (see above, typically one might think of the 1.42GHz H line, or the OH lines, or both) and produce a pulsed transmission at the periodicity determined by the relevant Pulsar in the alignment (optical transmissions of pulses are also feasible of course).

vi) The pulsed signal, if not corrected for the ETI's relative motion around its star, provides information about that motion – and also details like its planetary rotation period, the presence of a moon (and its period), and so forth. Should the ETI choose to transmit from some technology orbiting its planet or star then some of this information is lost, but reliability might be gained (and indeed with sufficient power resources and automated technology the transmitter might be left to do its work for a long while).

vii) We Earthlings work out where to point our telescopes, and what sort of signal to look for. If we assume that the ETI transmits continuously for a few hundred years (because it knows we are likely to exist) then we just have to tune in to each star, so to speak, looking for a known periodicity. If the ETI timeshares its transmitter efforts between different Habstars then we have to observe Habstars repeatedly and for extended sessions to be confident of the possibility of an overlapping moment of transmission and reception.

viii) 'Pulsars as Beacons' provide a good mutually understandable scheme but it is technologically asymmetric. The transmitting ETI invests much more and learns nothing unless the recipient returns a signal. It can be assumed that the transmitting ETI already has a positive answer to the basic question, and it is transmitting to help "spread the news". This deepens the notion of asymmetry. Indeed, it can be assumed that ETI knows that it is transmitting to an intelligent civilization, but one which is not yet aware that it is not alone. It must make sense for an ETI to reserve its resources to start transmissions when it believes the recipient is able to receive them – but even in this scenario it is still required that the ETI and its target have some reason to identify themselves as "set up" for such an

exchange. The Pulsar as Beacon scheme serves this purpose.

ix) The E&S Pulsar as Beacon scheme described above has been couched in terms of RF transmissions and indeed has been used as the basis for using the Arecibo radio telescope. In reality this is not a necessary component of the scheme. Optical transmissions at the Pulsar rate suffice as well as RF transmissions, and might in fact be easier to set up and to detect.

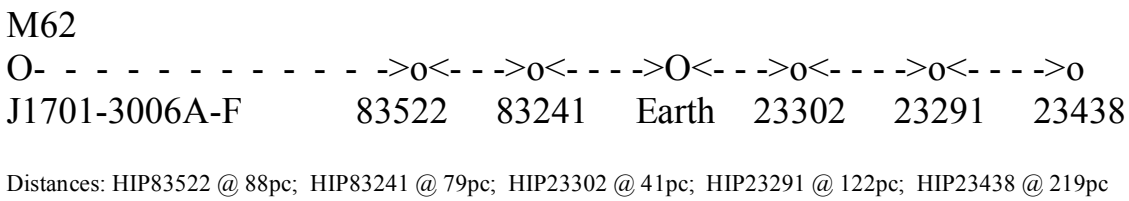

Figure 1. This illustrates the multiple alignment case involving six pulsars in M62 aligned with 6 Habstars, of which Earth is one. Distances are given for the locations of the Habstars relative to Earth.

7 Deployment of Pulsars as Beacons

In the original conception of the scheme the benefit was thought to be just that a mutually intelligible targeting strategy could be made to work for the identification of targets in our searching – targets who could be targeting us. The major consequence is that because the number of Habstars (potential targets) is rather large it provides a principled way of cutting down the number to be considered in detail as targets. However, the number is still large (~1800) so it becomes necessary for practical reasons to consider principled ways of cutting it further. We should note also that the number of known Pulsars is increasing, and this increases the size of the target list. There are some refinements that can be made to the basic scheme which serve our purposes (e.g. only consider fast pulsars). And of course it is always possible that someone else will come up with a different scheme considered also to be 'obvious', but which delivers more directly the list of only those targets *really* worth looking at.

7.1 - Mutiple alignments

The scheme as described implies that finding alignments is difficult and that each case will consist of a Pulsar and two Habstars (of which our sun is one). Three objects in a straight line serve to identify a target Habstar (and distance can be used to work through the set of alignments to cut numbers further if required, in line with conceptions of life signatures, as discussed in the previous section). In addition, to keep numbers down we restrict attention to rapidly spinning Pulsars with short periods (in E&S the list of such alignments is rather short – 113). Therefore, it is remarkable that Pulsars and Habstars occur in multiple alignments. This happens because in some cases Pulsars exist in remote clusters (e.g. 47 Tuc) which line up within the limit set for defining 'straight line alignment', and because in other cases a chance co-alignment of Habstars provides for multiple alignments. In one particularly interesting example there are 6 fast Pulsars in M62 which line up with 6 Habstars (of which our sun is one). See Figure 1. This arrangement is unique in the dataset produced by E&S and thus it constitutes a primary case for further observational study (see below). Suffice to say here that multiple alignments serve to cut down the observational target list to manageable proportions.

The use of these alignments played a part in target selection for a SETI programme conducted at Arecibo in 2005 (see AOProp in the reference list). Data are still being analysed.

7.2 - Exoplanets

The Pulsars as Beacons scheme can be refined in two ways by considering exoplanets. The most obvious technique is to look for alignments with Habstars that have known exoplanets orbiting them. This will cut down the number of targets independently of the consideration of multiple alignments – the shorter list is thus a different short-list. If there are Habstars which are present on both short-lists they become favoured targets for our attention. A more intriguing opportunity for refining the list of alignments will actually increase the number of targets. The technique here is to use the set of Pulsar as Beacon alignments to produce targets for exoplanet searches – e.g. the Habstars shown in Figure 1. This technique has much to recommend it despite the prospect of more targets, namely that the eventual list of targets will be better defined as plausibly life supporting.

It should be noted that the opportunity to contribute to the exoplanet search effort, by identifying Habstars to be the focus of specific efforts to find exoplanets, is a valuable and novel extra benefit derived from the Pulsars as Beacons scheme. This was not part of the original conception.

7.3 - Alternative schemes

The Pulsars as Beacons scheme is the only one anyone has thought of so far – there are likely to be others, but probably not many. The same sorts of argument would have to be worked through, but it seems unlikely that without some sort of external reference beacon the guarantee of artefactuality will be difficult to sustain, let alone specification of any other characteristics of the life signal.

8. Life Signatures - pulses

The scheme described above assumes that any ETI using it will transmit pulses at the pulse rate which it knows for the Pulsar in the alignment. It will have its own calculated barycentric rate for the Pulsar, which will not be corrected for the relative motion of its sun with respect to the Pulsar – just as our notion of the pulse rate will not be corrected.

In the case where ETI's Habstar is aligned with a Pulsar but in the opposite direction, from our point of view, their relative motion could yield a pulse rate closely related to the Pulsar rate but measurably different. This complicates the pulse signal detection but not unduly. In the case where ETI's Habstar lies between the Earth and the Pulsar it will be the case that ETI's pulse transmissions will automatically be compensated for any relative motion because its notion of the Pulsar pulse rate will be similarly affected.

Significant data gathering needs to be attempted if weak pulse streams from ETI are to be detected in noise. Knowing something about the desired frequency of the pulse train can help for signal processing techniques like folding (see Lorimer and Kramer 2005), but ultimately conventional signal processing techniques using FFT are the most flexible. Knowing the desired/expected pulse rate/frequency is obviously helpful in rejecting false detections due to 'birdies' or whatever. In addition, because we know something about how far away candidate sources are located we can make appropriate adjustments to corrections for dispersion.

9. Summary and conclusions

Throughout this paper we have contrasted the notion of SETI research which is driven by scientifically justifiable assumptions with the situation where SciFi seems to be the driving force. But of course, SETI is, in some real sense, SciFi. The point being made here is that the sort of scientific extrapolation we see in some SETI work (and that advocated here) is believable – so the reader is only asked to suspend disbelief. More fanciful SciFi would have the reader abandon much that is needed for conceptualising the world as we know it – that is, to suspend belief (in physics, for example). If, as proposed at the outset, the reader accepts the notion that SETI is a scientific enterprise then it matters how we extrapolate science. The consequences may be unexpected, but that is only to be expected!

Motivations for Earthlings to do SETI need to be derived from informed/scientific conjecture

about an ETI's motivations for doing SETI, as well as conjecture about the ETI's techniques. If we are to do passive SETI we have two choices – either we "listen/look" for transmitted signals using radio/optical telescopes, or we build sufficiently powerful instruments that we can answer the "Are we alone?" question observationally. If we are to attempt to detect a signal we must assume that an ETI is transmitting, and further that it is targeting transmissions to us directly. A targeting strategy is discussed in this paper and presented in detail elsewhere (Edmondson and Stevens 2003).

In this paper we have looked at some of the relevant factors for an ETI's approach to SETI to work for us when we do passive SETI. The asymmetry in SETI reflected in the terms active and passive is simply the difference between who transmits. The notion of Asymmetric SETI is deeper and covers the situation where an ETI knows that it is not alone and thus is motivated to signal its existence to help us answer the question "Are we alone?".

10. References

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