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When to Look Where

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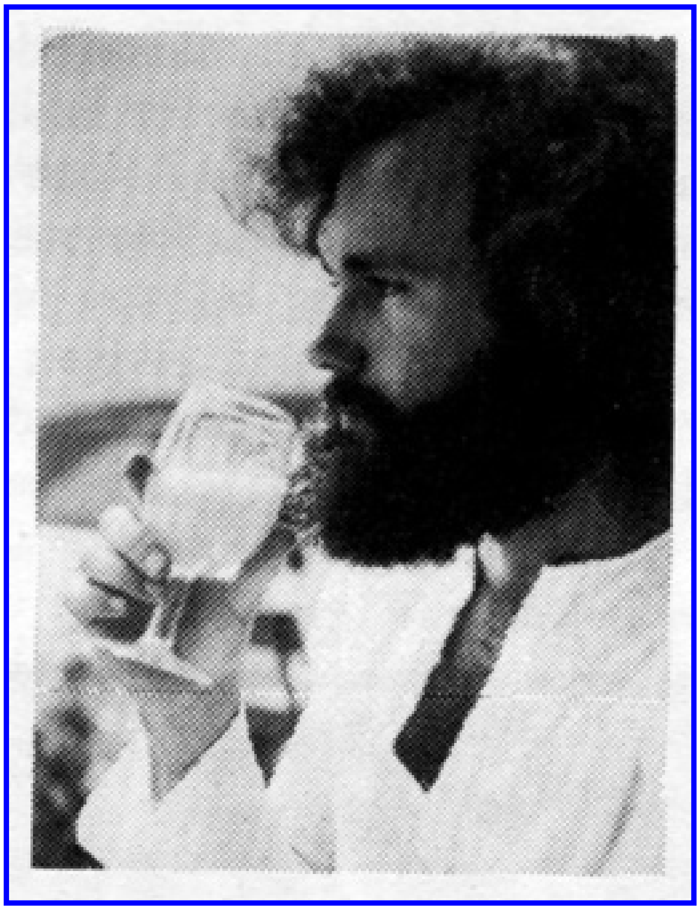
In a search it is important to know *where* to look (see Frank Drake in **COSMIC SEARCH** no. 12, page 7) and also on *what channel* (see the Waterhole in **COSMIC SEARCH** no. 2, page 39). It is also important to know *when* to look. Dr. Singer addresses this problem.



The next round of searches for ExtraTerrestrial Intelligence (ETI) will use two strategies. One strategy is to search small areas of the sky in the galactic plane in the hopes that one area will contain a strong source. This strategy is called the **survey mode**. The other strategy is called the **serial search mode** in which nearby stars are examined serially, that is, one by one.

The serial search mode is more interesting to exobiologists because the search must be guided by our knowledge of astronomy and our speculations about the origin and evolution of ETI. This article will be concerned only with the serial search mode assuming for the sake of argument that a serial search is a good idea, and asking only if present plans give the best way to conduct the search.

Any search for signals from ETI faces two major problems. The **first** problem is how to select the search targets. The **second** problem is how to search each target. The second problem is discussed in an extensive literature, the proposed solution being to use common astrophysical knowledge which allows us and ETI to guess at a set of preferred frequencies to broadcast and attempt to receive. On the other hand, the only astrophysical knowledge used so far to guide the order in which targets are searched is the spectral type and luminosity of each star. The strategy has been simply to search the nearest likely targets first.* (* The probability of success of serial search is discussed by the author in the *Journal of the British Interplanetary Society* (in press) 1981.)

The problem with this simple method of ordering the search targets is that it overlooks another important piece of astrophysical knowledge which should be common to both us and ETI. This common piece of knowledge is the motion of the sun as it wanders across the transmitter's sky. We shall see that this common knowledge can be used to define a preferred set of times to listen to each star and, thereby, increase the probability of success in a serial search by many orders-of-magnitude. Before going into more detail, we need to review the assumptions which are being used to guide serial searches over the next one or two decades.

SETI Scenario

From our point of view, an aggressive serial search involves looking at up to a million of the best candidates among stars up to as much as 1,000 light years from the Sun. This could require several decades of observing time on large radio telescopes. Success requires that at least one ETI in the search volume broadcasts to us at one of our favorite combinations of frequency, polarization, and modulation mode. Success also requires that they send us signals which arrive exactly in the relatively short interval we devote to them in our search.

Now consider the problem from the point of view of the ETI which transmits to us. (For simplicity, we temporarily assume they are the only ETI in the sphere of radius 1,000 light years which defines our search volume.) We are assuming they are going to send us a signal which we detect in our first aggressive search. Unless they know exactly when we start looking at them, this means they must broadcast to us continually over a galactic evolution timescale, on the order of a billion years. But following the evolution of our pretechnological civilization and predicting its maturity up to 2,000 years in the future from a distance of 1,000 light years is a formidable problem. No solution short of sending an interstellar probe has been proposed, and, if this solution were available, the ETI could easily use the probe as a beacon instead of transmitting across interstellar distances. The ETI source also faces the problem of transmitting to all other potential receivers within 1,000 light years, also during a galactic timespan. If some way could be found to reduce this formidable broadcasting load, then the total power requirement could be dramatically reduced, or the strength or information content of the signal could be increased.

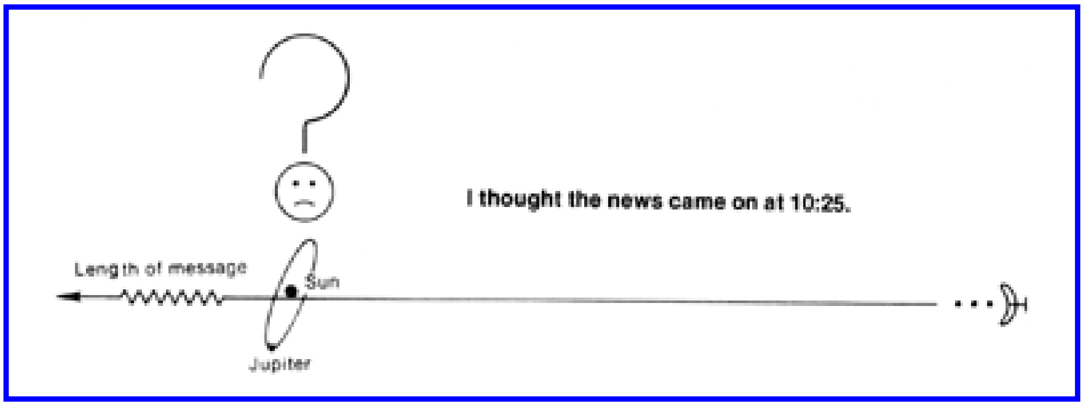
Part of the solution to reduce transmission requirements is to broadcast a narrow beam to each potential receiver. This requires only that ETI maintain a modest astrometry program so that they know where each target will be when the signal arrives. Narrow beam transmission has the great advantage that it can reduce the power transmission required by orders-of-magnitude at the cost of a very modest improvement in the quality of the transmitter.

This still leaves the ETI source with the problem of broadcasting continually to all potential receivers over a galactic evolution timescale. This conclusion is not altered if one makes the more common assumption that there were a large number of ETI in our search volume but they each broadcast for only a fraction of a billion years. Evidently, there is much to be gained in terms of power requirements or signal quality if the ETI could spend only a short time broadcasting to each possible receiver and still be fairly certain that we would be listening.

The Sun's Proper Motion

Fortunately, there is a clock which we can use to define preferred times to listen to stars in a given direction. The orbital motion of the planets around the Sun produces periodic slight displacements in the Sun's position as viewed from the distant stars. The change in position of a star in the sky, including these slight displacements, is called proper motion.

Remembering that the ETI we detect must keep broadcasting over a galactic timescale, it is easy to see how they could measure the Sun's proper motion to this accuracy. Such a measurement requires a good optical interferometer or the equivalent. There are at present serious proposals to build such an instrument in Earth orbit. This instrument would have a resolution of around one microarcsecond, which is probably limited by thermal expansion in the connection of the relatively modest baseline of ten meters. Now the maximum displacement of the Sun due to Jupiter's orbital motion is about 1 percent of the distance from the Sun to the Earth. For ETI to determine this displacement to an accuracy of one part in 100,000 from 1,000 light years away would require about ten measurements with a resolution of one nanoarcsecond. There is every reason to believe that the step from microarcsecond resolution instruments now being proposed to nanoarcsecond resolution would not be a major requirement for a mature technological civilization. The required ten kilometer baseline could probably be achieved by shielding the instrument from stellar heating and/or by careful laser ranging between the photon collectors. Alternately, more patient ETI could use an instrument with lower resolution and average data taken over a longer interval.



In addition to making an accurate measurement of the Sun's proper motion across their sky so we can "synchronize our watches," the ETI must also know the distance to the Sun with comparable accuracy. Otherwise, their signals will not arrive at the preferred times. For example, if they underestimate the distance to the Sun by 0.1 light years and transmit to us only for a day every five years, then we may tune in a month after their signal passes through the solar system. (see sketch). Fortunately, the instrument they use to measure the Sun's proper motion can also find the distance to the Sun, by parallax. For example, if the instrument has an orbit around its star with a diameter 3 times that of the Earth around the Sun, then with nanoarcsecond resolution it could measure a 1,000 light-year distance to the Sun to within 1/10,000 light-year in one set of measurements. *This accuracy would allow ETI to time their transmissions to arrive within 1/100,000 Jovian orbital periods of the preferred times for us to receive them.*

In principle then, the orbital displacement of the Sun during its proper motion across the transmitter's sky defines a preferred time for ETI to send signals to us. In practice, there may be some ambiguity due to the minor influence of Saturn and other planets superimposed on the dominant ten year period defined by Jupiter. There is also the question of whether to listen at times of maximum displacement, or whether to prefer minimum displacement (i.e., conjunctions of Jupiter with the Sun as viewed from the search target). As with frequency selection, the solution to this ambiguity must be to define a set of preferred search times and to devote the most observing time to those that seem most likely. Since the frequency spectrum of the Sun's displacement from its mean proper motion has only a few prominent peaks and valleys, this ambiguity should not decrease the usefulness of the synchronization technique by even an order of magnitude. And if some ETI adopt a strategy of broadcasting at a few preferred times rather than a single preferred time, the chances of having overlapping timing strategies rapidly approaches unity.

Another potential ambiguity in guessing common broadcast timing strategies is the possible use of other mutual observables. An example would be using supernovae explosions as a timing synchronizer. However, such strategies require us as well ETI to make an extremely accurate distance measurement, for reasons similar to those discussed above. It should be clear that this is likely to be beyond the capability of the most recently emerging listeners. Perhaps such possibilities should be investigated further, but for the moment the regular motion of solar planets is the only method for accurate synchronization known to be available to us and to potential sources of communication from extraterrestrial intelligence.

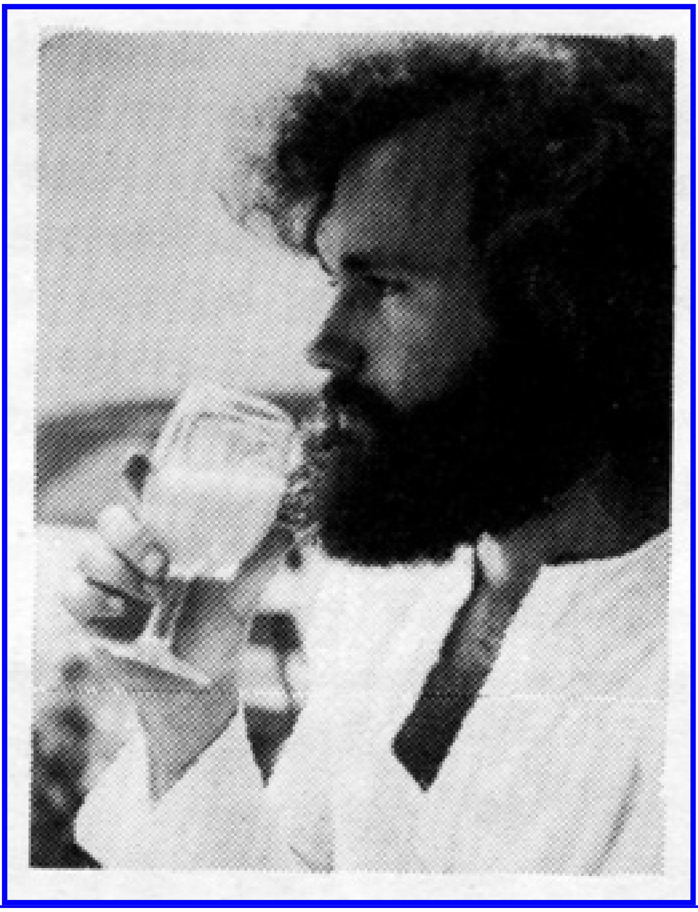
The advantage of having such a synchronization method is quite clear. The advantage is directly analogous to that of transmitting at preferred frequencies. In the case of frequency selection, ETI have the choice of using a large number of transmitters or enormous power to transmit at all frequencies, or they can effect a large reduction in transmission requirements using preferred frequencies defined by common astrophysical knowledge. In the case of broadcast timing, ETI have the choice of transmitting simultaneously to all possible listeners, or they can build a single interferometer to acquire the common astrophysical knowledge which allows broadcasting to all potential listeners at preferred times with a single transmitter of modest power.

Conclusion

The merits of adopting the search strategy proposed here have been clearly outlined above — an increase by four or five orders-of-magnitude in the probability of discovering an ETI would be worth a great deal in terms of observing time. Moreover, it is not necessary to make the dangerous assumption that all ETI will assume the broadcast strategy proposed here. Even if only a few ETI adopt a synchronized broadcast strategy, they will still have orders-of-magnitude advantage in broadcast power or bandwidth and therefore be the easiest to detect if the appropriate search strategy is chosen. It only remains to make two closing comments about implementing this proposal.

First, despite a thirty year history as a modern discipline, the field called "interstellar studies" has the equivalent of only a handful of full time workers. The discipline is therefore still in the early stages of development, and it may well be that some essential ideas have been overlooked. A search strategy synchronized with the Sun's motion is an example of such an idea.

The final comment, and the most compelling reason that a synchronized search strategy should be adopted if one wishes to maximize the chance of detecting communication from extraterrestrial intelligence, is very simple. If one intends to observe a large number of stars, then it hardly matters in what order the stars are searched. Reordering the observing targets to look at certain stars at preferred times is a minor inconvenience. It therefore seems obvious to take at least half of the observing time devoted to serial searching and attempt to gain the orders-of-magnitude improvement which should result from the synchronized search strategy.



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Designed by Jerry Ehman.
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