ON A COSMIC ALPHABET

D. Hoang-Binh
Département d'Astrophysique Fondamentale
Observatoire de Paris-Meudon
92195 Meudon Cedex
France

ABSTRACT. The choice of frequencies for SETI has been discussed by many authors. We wish to point out that the line spectrum provided by the hydrogen (H) atom is very rich, and covers a large spectral domain, from the ultraviolet to radio wavelengths. The frequencies of H lines present one remarkable feature, which in our opinion makes them more attractive than those of, e.g. the OH or H_2O lines, or those chosen arbitrarily in the water hole : they all relate to only one atom , the simplest and most abundant one in the universe. In terrestrial alphabets, one word is composed of one or several characters. We can always replace any set of characters by a set of H frequencies, and "write" messages with them. Since the H frequencies are universally known, a "cosmic alphabet" could be constructed with them. In a mono-frequency search for artificial radio signals, the frequency of the H166 alpha line, 1425 MHz, might be a good substitute for the frequency 1420 MHz of the H 21cm line. In a multi-frequency search, the frequencies of the prominent Hn alpha lines near H 21cm might be interesting. There are about ten of them in the water hole. Finally, owing to the physical link between them and the H 21cm frequency, those around this symbolic frequency appear most attractive .

1. INTRODUCTION

Since the pioneer work of Cocconi and Morrison (1959), there have been many discussions on the optimum ranges of frequencies to be used in the search for extraterrestrial intelligence (SETI). In the radio range, from 1 to 10 GHz, which has been preferred by most authors, the problem of knowing the "magic frequencies" which carry the interstellar messages, is still open. Naturally, many SETI programs have adopted frequencies near $f_\circ$= 1420 MHz, the frequency of the 21cm line of atomic hydrogen. However, the failure to detect artificial signals at $f_\circ$, and the discovery of interstellar molecular lines in the radio spectrum, have led many authors to favour other frequencies, in particular those in the water hole, a band between $f_\circ$ and the frequency of one OH line near 1720 MHz (Oliver 1977). Other ranges in the infrared and millime-

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tric spectra have also been considered to be attractive (Townes 1983, Kardashev 1979). Whatever the chosen range may be, it is highly desirable to narrow down the number of search frequencies. As pointed out by Beatty (1983), if the water hole is explored with a bandwidth of 1 Hz, it would take 570 years to monitor the 300 millions frequencies one at a time, for one minute each.

Now, there exists in nature a self consistent set of frequencies, ranging from the ultraviolet to radio wavelengths. Like f_o, they are given by hydrogen, the most abundant atom in the universe. Since they are universally known, they might be considered as "cosmic characters", and a "cosmic alphabet" could be constructed with them .

2. THE HYDROGEN LINE SPECTRUM

Neglecting the fine and hyperfine structures, the simplest atom provides us with a remarkably simple set of line frequencies, f(m,n), given accurately by

$$f(m,n) = R \left(1/m^2 - 1/n^2 \right)$$

where the Rydberg constant $R=3.288056 \times 10^{15}$ Hz, and m, n>m are the principal quantum numbers (m=1,2,3,....). One can see that these frequencies satisfy the usual criteria relevant to SETI :

(1) Derived from the laws of physics, they must be known to any advanced extraterrestrial civilization (ETC).
(2) They are universally observed, even in the radio spectrum (see e.g. Dupree & Goldberg 1970).
(3) One can find them in practically any spectral range longwards of 912 A; in particular, many of them are in the water hole .

In addition, the fact that they relate to only one atom confers them an unity, a property which plays an important role in physics and nature . However, it seems unlikely that an ETC will use all the radio H frequencies for interstellar communications (ICs). We will discuss the choice of frequencies below.

3. MONO-FREQUENCY COMMUNICATIONS

The question is : which frequency has the message ? The failure to detect signals at f_o has led some authors to suggest that a narrow band around f_o, say 1419-1421 MHz, might be protected (Verschuur 1973) or avoided by ETI because of natural interference (Goldsmith & Owen 1980). The "magic frequency" would then be close to f_o, but outside this 2 MHz band. Now, close to H 21cm, there do exist several prominent radio lines emitted by hydrogen in H^+ regions, the closest being H 166 alpha (due to the transition between levels n=166 and n+1) at 1425 MHz. We would suggest that f(166,167) might be a good substitute for f_o, if the latter was effectively avoided by ETI. The fact that both frequencies are given by the same atom is a further argument in its favour.

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Note that we have not discussed the beta and higher order lines. In nature, they are much weaker than alpha lines; hence, their frequencies appear less attractive.

4. MULTI-FREQUENCY COMMUNICATIONS

If an ETC preferred this mode, it could still use H frequencies. In this case, it might take advantage of the great number of available frequencies to construct a cosmic alphabet, in the sense that all of its characters are universally known. For illustration, Table 1 lists the frequencies of the H n alpha lines in the water hole. Most terrestrial alphabets are composed of a few dozens of characters. We could always replace one set of characters by one set of frequencies f(m,n), and thus transform any terrestrial alphabet into a cosmic one, in the sense given above. But an interstellar message, "written" with H frequencies, still needs to be decoded, and we still have to know the "magic frequencies". Since the problem is essentially the same as in the mono-frequency case, we will not discuss it further. However, we would like to point out some advantages of the multi-frequency mode. First, it is easier to recognize the artificial character of a signal. For example, if only 3 frequencies, namely those of the 164,165,166 alpha lines, are used, the conspicuous absence of features at the other nearby frequencies would point strongly to the artificial character of the signal, because this is not expected in natural sources. Second, the Doppler shift df is also easier to detect, because the relative shift df/f is the same for all frequencies. Once a frequency is suspected to be a message component, it is easy to calculate the shift of any other possible component.

TABLE 1

n	f(n,n+1)/MHz
166	1425
165	1451
164	1477
163	1505
162	1533
161	1561
160	1591
159	1621
158	1652
157	1683
156	1716

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5. DISCUSSION

We have suggested that besides the frequency of H 21cm, other H radio frequencies might possibly be "magic frequencies". Such a big choice does not seem to be a great disadvantage, because modern spectral analyzers under construction, such as the NASA 8 millions channels one (Beatty 1983), would be quite suited to a multi-frequency search. Since there is a physical (atomic) link between them and the H 21cm frequency, it is not unreasonable to expect "magic frequencies" around f_o, which has an outstanding symbolic value. Finally, the excited H frequencies might be preferred, because excited (high energy) states seem more reminiscent of life than the ground (low energy) state. ICs would then look like a lively cosmic symphony, in harmony with the monotonic song at 1420 MHz .

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