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Search for Extraterrestrial Intelligence at 22 GHz with the Very Large Array

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Abstract. We have conducted a direct Search for Extraterrestrial Intelligence at the Water Maser frequency, 22.235 GHz, using the Very Large Array. The targets were 13 solar-type stars that were known to host exoplanetary systems. In all cases, the RMS limits of the flux density, 20 mJy (5σ), were sufficient to rule out any omnidirectional transmitters of the same power as terrestrial radars (5×10^{12} W). We discuss the significance of this non-detection.

1. Introduction

40 years ago, advances in radioastronomy made possible the first radio search for extraterrestrial intelligence (SETI), at the 1.420 GHz hyperfine line of neutral atomic hydrogen, which was suggested as a preferred (now sometimes called a "magic") transmission frequency. Oliver (1973) suggested that SETI programs should search the frequency range between the frequencies of the Hydrogen atom (1.4 GHz) and the OH molecule (1.7 GHz), which he called the "Water Hole". In this frequency range, the observational noise is a minimum. Since then, 99 SETI programs have been performed in the Water-Hole frequency range, mainly at the hydrogen frequency, but no reliable signal has yet been detected. It is important, however, not to restrict SETI searches to the water-hole. A number of other "magic" frequencies have also been proposed for SETI (e.g. formaldehyde, positronium, pi times the hydrogen frequency, etc.), and observations performed at those frequencies. Other programs have conducted searches over a broad

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range of frequencies, such as Project Phoenix (Tarter 2004), which has searched solar type stars within 60 pc from 1 to 3 GHz.

2. Search Frequency

For this SETI search, we chose the water maser emission frequency of 22.235GHz, for several reasons:

- The water maser frequency is a key one for radioastronomy, having contributed to studies of both star formation and extragalactic massive black holes.
- The maser mechanism may be important as a means of generating the high powers required for interstellar communications, and the strongest observed maser $0.15L_{\odot}$(distance 11.4 kpc) is a water maser (Liljestrom 1989). Although we do not yet have the technology to generate such luminosities using masers, it is possible that an advanced civilization may be able to construct such a maser.
- Water is even more significant than hydrogen for the formation of life as we know it.
- 22 GHz is relatively free from radio frequency interference (RFI) from ground and Earth-orbiting transmitters, partly because this frequency is protected for astronomy until 2007.

A disadvantage of 22 GHz is that the noise generated both by the atmosphere and by receivers is higher than at lower frequencies. Note that astrophysical water masers are not expected to be seen from our target stars, because such masers have been observed only from late-type stars and star formation regions.

Only two SETI observations have been made at this frequency (Nathaniel et al. 1980). These observations were performed with low sensitivity ($10^{-22}W/m^2$) and low frequency resolution (65 KHz), and did not take into account any universal reference frame. There are no current or planned major SETI projects which cover this frequency range (Ekers et al. 2002). Even the next generation SETI project, the Allen telescope array, will operate only up to 10 GHz.

When observing a spectral line, it is necessary to correct for Doppler shift, and this requires the use of a standard astronomical inertial frame. There exists a universal frame of reference, which is defined by the cosmic microwave background (CMB), and which is now widely used in SETI studies. In addition, we searched for lines shifted to the local standard of rest (LSR).

3. Target Stars

Within 100 light years of Earth are thousands of sun-like stars. However, to optimise the use of limited observing time, we conducted a SETI search of known exoplanetary systems.

Marcy (2004) has reported that planetary systems occur in about 10% of stars. Nearly all planets discovered so far are gas giant planets like Jupiter, because these are favoured by current detection methods. However, it is likely that these are accompanied by low mass planets whose masses are below the current detection limit. Furthermore, numerical simulations have shown that Rho CrB and 47 UMa may have terrestrial planets in the habitable zone (Jones et al. 2001). The probability that ETI exists on any particular planet may be very small. However, assuming that ETI has detected our solar system, including Earth, it is possible that ETI might choose us as transmit targets.

Within the limited observation time, we were able to observe northern 13 exoplanetary systems within 50 pc, listed in Table 1, including Rho CrB.

4. Observations

The observations were carried out in June 2001 using the Very Large Array (VLA)[1]. The VLA has only once before been used for a SETI experiment, in which it was used to search a region believed to contain the Ohio University "Wow" signal in 1995 and 1996 (Ekers et al. 2002).

Not only does the VLA have high sensitivity at 22 GHz, but the interferometers of the VLA have several advantages for SETI purposes over single-dish telescopes. One is that interference outside the direction of the source tends to be cancelled, and another is that the high spatial resolution allows radio source positions to be identified with optical objects.

We observed using two polarisations (left and right circular) with a bandwidth of 1.5 MHz, and 256 channels, giving us a frequency resolution of 6.104 KHz. This choice of bandwidth was dictated by the uncertainty in the Earths velocity relative to the CMB (369.5 ± 3.0 km/s) (Kogut et al. 1993) although a higher frequency resolution would be better matched to the narrow-band signals usually expected from ETI sources, and would be a better discriminant against natural water maser sources, since the narrowest interstellar water maser line has a width of about 10 KHz.

We observed each exoplanetary system for 20 minutes, spending 10 minutes observing at the frequency corresponding to the CMB rest frame and 10 minutes at the frequency corresponding to the LSR rest frame.

5. Results

Our results are shown in Table 1. We detected no signals in any of the target stars at either the CMB rest velocity or the LSR rest velocity above a typical 5σ limit of 20 mJy.

Given this upper limit on the radiated flux density S, the distance of target stars d and frequency resolution $\Delta\nu$, we can estimate the maximum emitted power of ETI omnidirectional transmitters L from each source using the simple equation,

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$$L = 1.2 \times 10^8 \frac{\mathrm{S}}{\mathrm{Jy}} \left(\frac{\mathrm{d}}{\mathrm{pc}}\right)^2 \frac{\Delta\nu}{\mathrm{Hz}} [\mathrm{W}]. \quad (1)$$

The strongest terrestrial Earth-level transmitters have a power of 5×10^{12} W, and so the final column of Table 1 shows the limit of detected power compared to this figure. It is remarkable that in many cases our search had enough sensitivity to detect an Earth-like civilization.

Table 1. 13 Target Exoplanetary Systems

Name	Distance (pc)	Spectral (Type)	Mag. (V)	Rad.Vel. (km/sec)	RMS (mJy)	L (5×10^{12} W)
HD 10697	30.0	G5IV	6.3	−43.5	3.0	2.0
HD 16141	35.9	G5IV	6.8	−53.0	5.2	4.9
HD 19994	22.4	F8V	5.1	+18.3	9.5	3.4
eps Eri	3.22	K2V	3.7	+15.5	7.1	0.1
HD 37124	33.0	G4IV-V	7.7	−12.0	8.9	7.0
HD 38529	42.4	G4	5.9	+28.9	2.2	2.8
HD 46375	33.4	K1IV	7.9	+1.0	2.4	2.0
rho CrB	16.7	G0V	5.4	+18.4	3.4	0.7
14 Her	17.0	K0V	6.7	−5.5	6.7	1.4
HD 195019	20.0	G3IV-V	6.9	−92.7	6.2	1.8
HD 210277	21.3	G0	6.6	−24.1	2.4	0.8
51 Peg	14.7	G2IV	5.5	−31.2	6.3	1.0
HD 217107	19.7	G8IV	6.2	−12.1	2.4	0.7

Note: L is normalized by 5×10^{12} W (power of the strongest terrestrial radars) to see their expected civilization levels easily.

6. Conclusions and Further Work

Our observations failed to detect any signal from the 13 stars searched at a typical 5σ limit of 20 mJy. However, this is only a small fraction of the roughly 100 planetary systems that have now been detected (Marcy et al. 2004). We plan an aggressive SETI program to search other exoplanetary systems not only at the water maser frequency but also at other magic frequencies. We also plan a continuous project at the water maser frequency along the galactic plane to search for ETI signals which have been amplified by naturally-occurring masers (Cordes 1993). Observations at these high frequencies are essential to complement the majority of SETI experiments that are carried out at lower frequencies.

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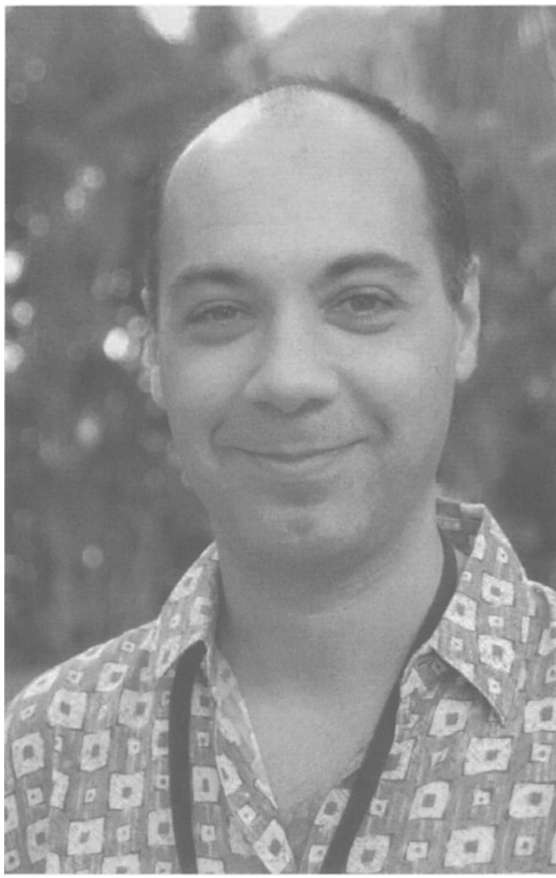

Guillermo Lemarchand (*photo: Seth Shostak*)