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The Breakthrough Listen Targeted Search: GBT/L-band

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Abstract

We describe the search for narrow band radio signals between 1.1-1.9 GHz on a set of 692 stars within 50 pc of the Sun. We used the Robert C. Byrd Green Bank Telescope (GBT) for the observations these systems. These observations are part of the Breakthrough Listen Initiative, a 10 year SETI project. Observations were carried out with an strategy consisting on consecutive 5-minute observations of a targeted start an an off location. This strategy allowed us to use a detection pipeline to successful classifying most of the hits found as RFI. For the remainder potential candidates, we were able to classify them as terrestrial signals by visual inspection and the overall characteristics of the signals. No extraterrestrial signals with an EIRP of 10^{13} W or higher were detected. These results provide one of the most stringent constrains to date of the distribution of radio transmitters for nearby stars.

Keywords: (SETI; Breakthrough Listen;)

1. Introduction

The Search for Extraterrestrial Intelligence (SETI) is a field of Astrobiology which has focus mainly on the detection of artificial radio signals from a extraterrestrial civilization. It is difficult to quantify the probability of success, given the little is known about life in the universe. Results in the last couple of decades on the fields of exoplanets, and the solar system, give some hope, whatever small.

The search for electromagnetic signals may be the best change of finding life of any kind. In situ searches in the solar system for bacterial lifeforms, or studies of exoplanet atmospheres for the detection of bio-signatures, may prove not sufficiently far-reaching for the detection of simpler and possibly more common life types than the intelligent kind.

The *Breakthrough Listen Initiative* is a major new program for SETI was announced on 2015. This program will utilize, for a period of a decade, the major radio telescopes on the planet with the best available technology to try find any signature of extraterrestrial technology, or to a minimum, put strong constrains on their current existence our galaxy.

In this manuscript we outline the results of our project. We describe the observations in Section 2. In Section 3 we describe the analysis and present the results results. Section 4 presents the discussion and conclusions.

2. Observations

The *Breakthrough Listen Initiative* started the first observing campaign of nearby stars with the Robert C. Byrd Green Bank Telescope (GBT) on January 2016. The target selection for this first campaign comprises of a set of stars equally distributed on the sky, as well as a uniform distribution of stellar types. From that sample, a set of 1185 targets are observable from the GBT. The selection criterium is described in detail in Issacson et. al. (2017) [1]. In this work we preset the results from the analysis of a selection of 692 stars. This list of targets was selected based on their data completeness. Figure 1 shows their sky distribution.

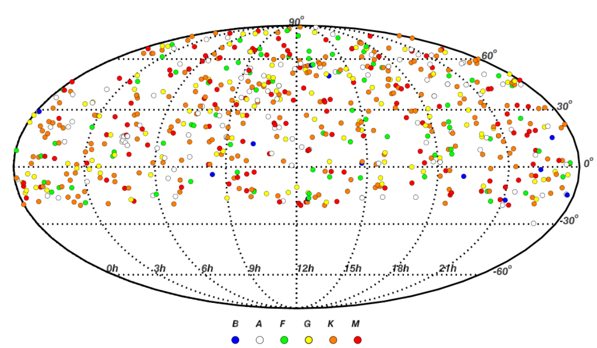

Fig. 1. Sky distribution of targets for this project. Targets are color coded depending on their spectral type.

We observed the sample of stars shown in Figure 1 with the L-band receiver of the GBT. This band covers the frequency region 1.1-1.9 GHz. We did not recorded in inner region 1.2-1.33 GHz, we use a notch filter to suppress the strong radio frequency interference (RFI) in this region of the band.

The observation followed an "on-off" strategy. Each target was observed for 5 minutes and immediately followed by a 5 minute observation of an off position, generally of another star selected from the *Hipparcos* catalogue. Each target was observed at least three times with this set-up.

The data was recorded using the *Breakthrough Listen* backend [2] as raw complex voltage data with 8-bit format, and then channelized to 3 Hz by 18 second, frequency and time resolutions respectively.

3. Analysis and Results

A putative extraterrestrial transmitter will be affected primarily by a Doppler acceleration caused by the rotation of the Earth and potentially the host exoplanet. This acceleration in a short observation causes a linear drift on the rest frequency of the signal.

We use the software *turbo*SETI [3] to search for narrow band signals suffering for Doppler acceleration to a value of +/- 2 Hz/s. This covers well the effect of the acceleration caused by the Earth rotation (about 0.16 at 1.4GHz). Also, a SNR threshold of 25 was used

The detection pipeline was used on approximately 4,800 files. This resulted in almost 29 million hits. A post-processing criteria rejected most . This criteria uses the fact that an extraterrestrial signal will only be detected in the set of 3 "on" observations, but not on a single "off" observation. Figure 2 shows the distribution of these hits with frequency, before and after post-processing. After post-processing, 11 targets were left having signals of interest. These were further rejected by human inspection of the data.

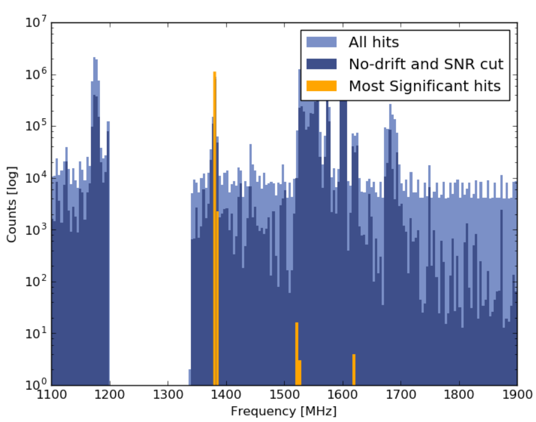

Fig. 2. Frequency distribution of the hits found by *turbo*SETI. The color usage is explain in the figure.

4. Discussion and Conclusions

We report the non-detection of narrow band signals of extraterrestrial origin. Based on the sensitivity of our GBT observations, we could detect an hypothetical transmitter, at the distance of 50pc, with the same equivalent isotropically radiated power (EIRP) as the Arecibo Planetary Radar (10^{13} W) or larger.

These results can put limits on the number of radio transmitters on the vicinity of the solar system to less than 0.1% of the stelar systems.

In order to compare our results with previous SETI efforts from the literature, we used several known figures-of-merit. Figure 3 compares our work with previous SETI efforts in terms of survey speed or the Drake Figure of Merit.

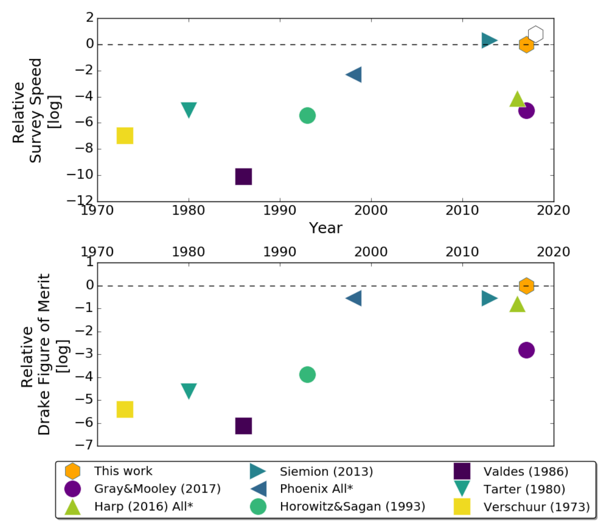

Fig. 3. Figures-of-merit for comparison to previous SETI campaigns.

We also devise a new figure-of-merit with the intent to provide an contextual reference to the number of transmitters in the galaxy for a given EIRP. We have named it the Continuous Waveform Transmitter Figure of Merit. It takes into account the number of stars observed, the fractional frequency searched, as well as the sensitivity of the observation based on the EIRP of putative transmitters. The CWTFM can be used to compare different types of projects (targeted stars, sky surveys, or other targets objects).

Using our results and those from Gray & Mooley (2017) [4], we can fit a power law describing the distribution of radio transmitters per given EIRP. We conclude by noting that these results provide the most stringent limits on powerful radio transmitters on nearby stars.

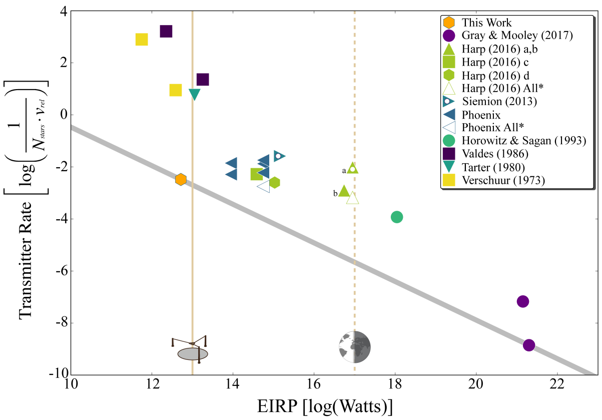

Fig. 4. Constrains on the

In the future, the use of next generation ratio telescopes such as MeerKAT, LOFAR, ASKAP, MWA, and other would allow the opportunity for observations of nearby stars at a large scale (10^6). This would let us archive statically significant constraints on the number of technologically advance civilizations in the galaxy.

Acknowledgements

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