SETHI@Berkeley– A Piggyback 21-cm Sky Survey at Arecibo

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Abstract

SETI@home observes a 2.5 MHz bandwidth centered on 1420 MHz near the 21-cm line using a short line feed at Arecibo which provides a $6'$ beam. This feed sits on Carriage House 1, which means that during normal astronomical observations with the new Gregorian dome the feed scans across the sky at twice the sidereal rate. We are using the SETI@home receiver to obtain about 4.4×10^6 spectra per year with integration time of 5 seconds per spectrum. We have accumulated 2.6 years of data covering most of the sky observable from Arecibo. This survey has much better resolution than previous single disk surveys and much better sensitivity than existing or planned interferometric surveys.

Observing Methodology

The UCB SETI searches use the 1420 MHz line feed on Carriage House 1 at the National Astronomy and Ionospheric Center's 305 meter radio telescope in Arecibo, Puerto Rico. (See Figure 1) This unique arrangement allows observations to be conducted without interference with other uses of the telescope. This results in two main modes of observation. If the primary observers feed is stationary or stowed the beam scans across the sky at the sidereal rate. If the primary observer's feed is tracking a position on the sky, the beam scans the sky at twice the sidereal rate. At twice the sidereal rate, the beam width corresponds to a 12 second beam transit time. (Korpela et al. 2001) Figures 2 and 3 show the path of the telescope beam over the course of 1 day, and the entire program respectively

Figure 1. A photo of the NAIC 305 meter telescope at Arecibo. The inset at right shows the details of the "carriage house" structure. The feed used by this project is the line feed extending downward from the carriage house. (Photos courtesy of NAIC–Arecibo Observatory, a facility of the NSF.)

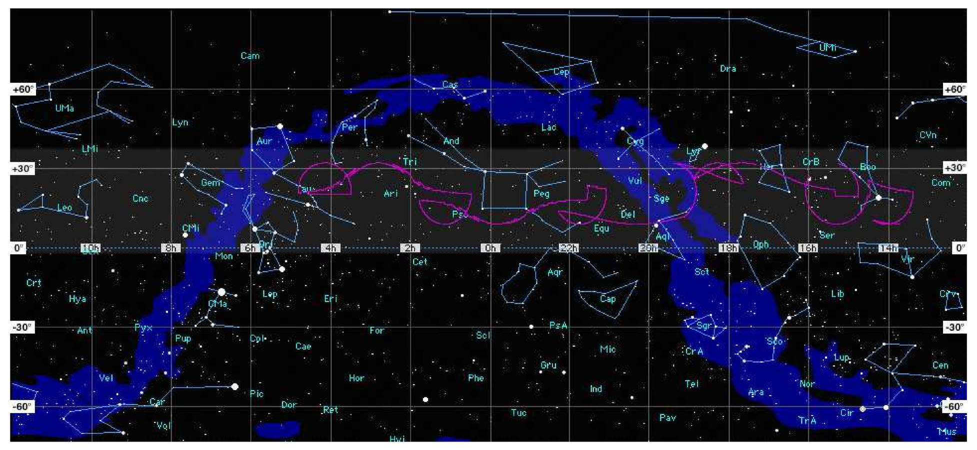

Figure 2. The path of the telescope beam on August 5, 2001.

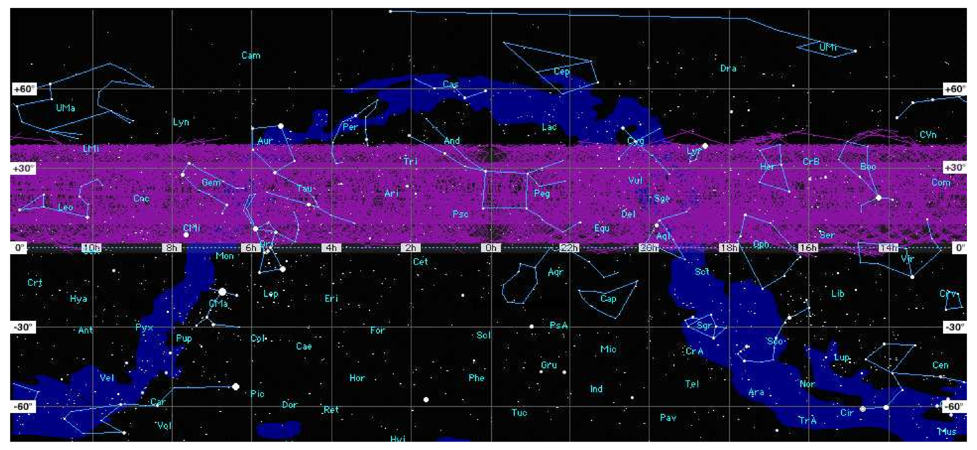

Figure 3. Sky coverage for entire project.

The time domain data for the sky survey is recorded as follows: first, a 30 MHz band from the receiver is converted to baseband using a pair of mixers and low pass filters. The resulting complex signal is digitized and then filtered to 2.5MHz using a pair of 192 tap FIR filters in the SERENDIP IV instrument. (Werthimer et al. 1997) One bit samples are recorded on 35 GByte DLT tapes (one bit real and one bit imaginary per complex sample). These tapes are shipped to Berkeley for use in the SETI@home program. T_{sys} for the system is 75K.

The SETHI@Berkeley program analyzes these tapes to extract hydrogen spectra. The 2.5 MHz time series data are converted to raw spectra using 2048 point FFTs ($\Delta\nu$=1220 Hz). 6144 FFTs are accumulated into a single power spectrum of 5.033 second integration time. The resulting power spectrum is corrected for 1 bit sampling effects by using the Van Vleck correction. The spectrum, its start and and end coordinates, and its time are stored in a database for future use. This database will be queried to develop spectral maps of the neutral hydrogen distribution.

Example Spectra

Below we present an individual spectrum. This spectrum was taken along a line of sight near 3C192 (l,b)=(197.7,24.4). The hydrogen column along this line of sight is $\sim 4.2 \times 10^{20}$ cm^{-2} Figure 4 shows a single raw 5 second integration spectrum with 1.22 kHz resolution. Figure 5 represents the sum of 5 adjacent spectra, and shows the typical SNR that will be achieved in a 0.1 degree skymap pixel.

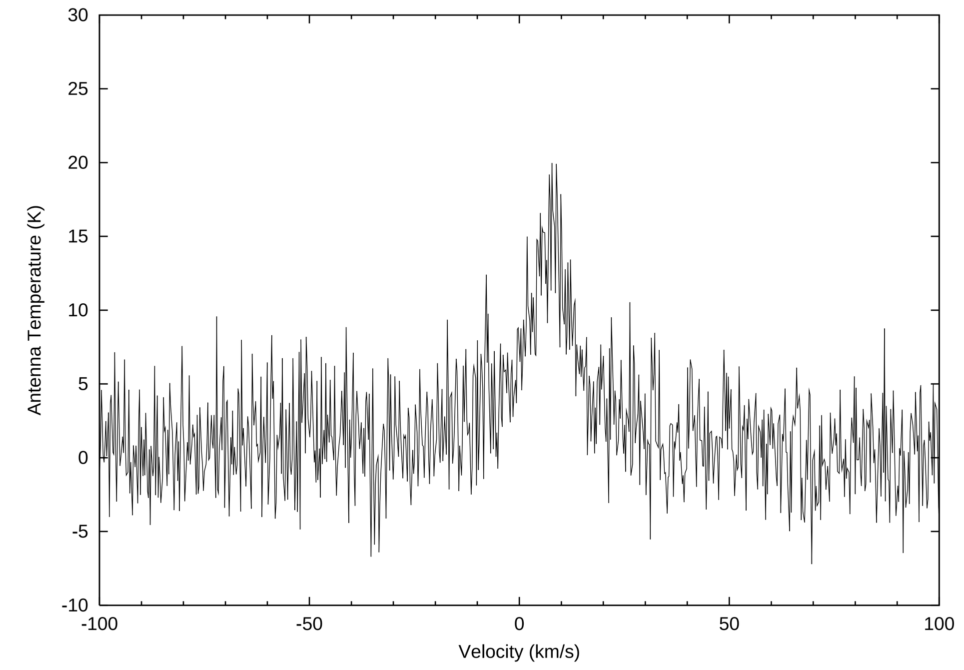

Figure 4. A 5 second integration spectrum

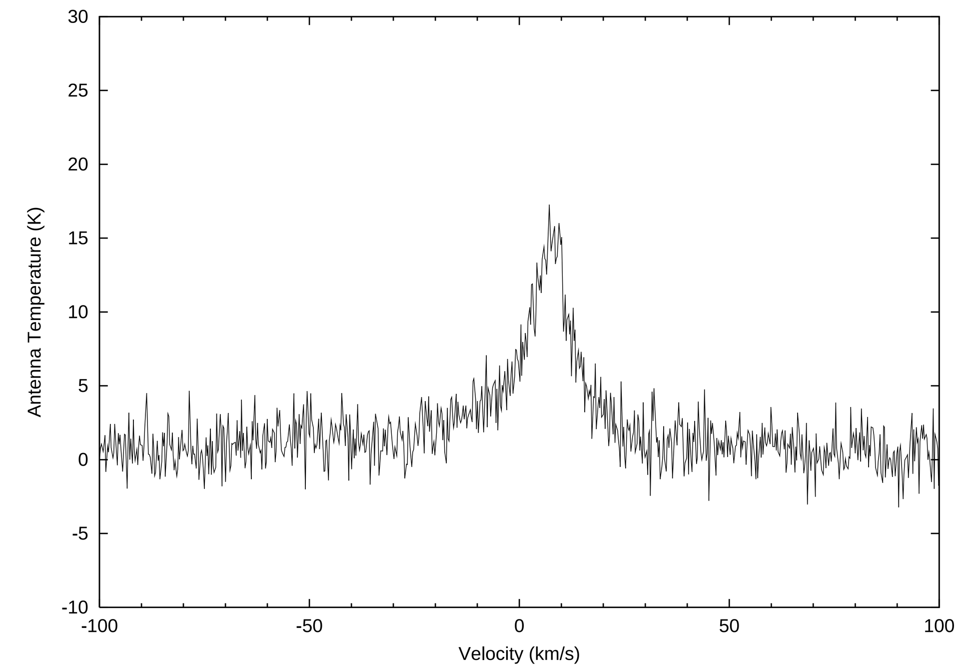

Figure 5. A 25 second integration along the same line of sight.

Figure 6 shows 54 spectra accumulated over 272 seconds. During the accumulation of these spectra the telescope beam was moving at nearly the sidereal rate ($\sim$1.1 degrees over this duration). Significant changes are seen in the spectra are seen on scales approximating the beam width.

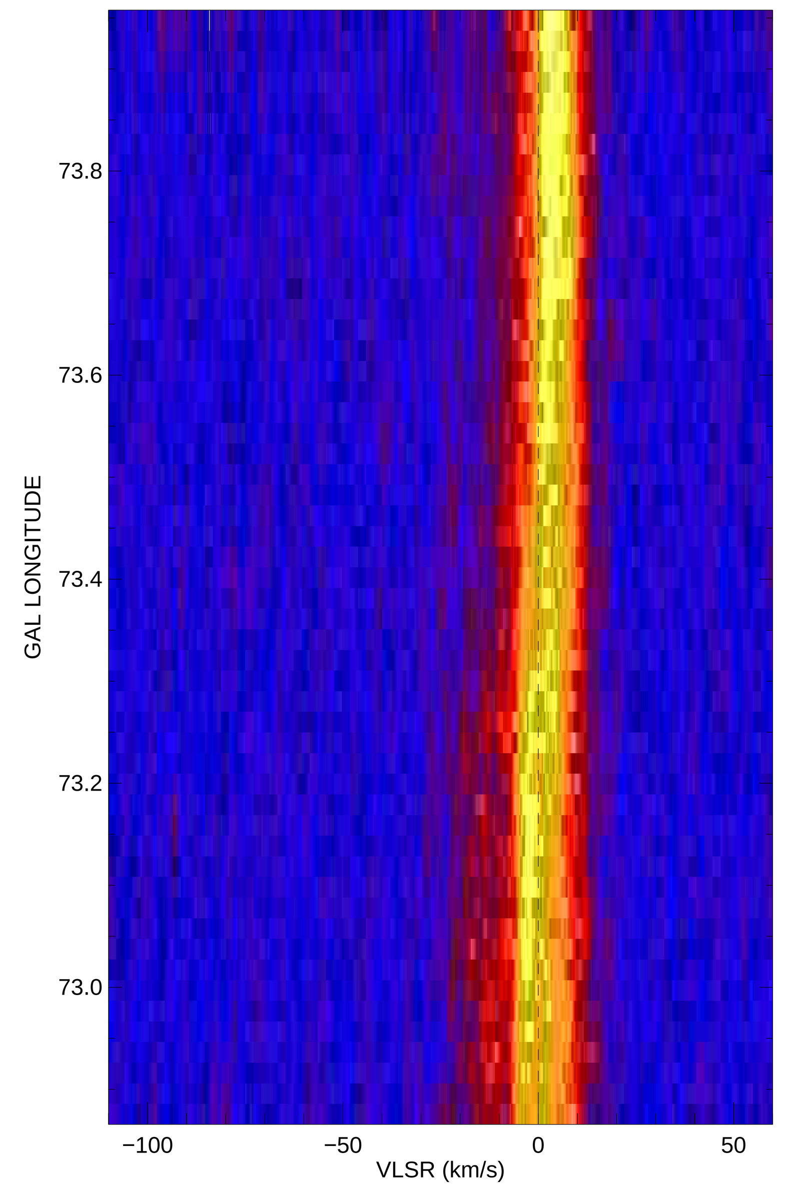

Figure 6. Spectra generated from 272 seconds of data. This sweep extends from (l,b)=(72.87,-22.99) to (l,b)=(73.96,-23.52). Each spectrum represents 5 seconds of data and transit of about 1/5 the beam width. Note the significant changes in line shape and velocity on scales $\sim$ the beam width.

Program Status

Data accumulation for SETI@home began in December 1998. We currently have accumulated about 58 Msec of observation time, which will translate into 11.5 million spectra. The survey has covered 79.4% of the accessible sky. If mapped into pixels 1 beam width in size, the median exposure per pixel is $\sim$20 seconds. We anticipate that data collection will continue for at least 1 additional year.

Generation of the spectral database is just beginning. We anticipate analysis of the existing data to be complete in 12 months.

REFERENCES

Korpela et al. 2001 *Computing in Science and Engineering*, **3**, 79.

Werthimer et al. 1997, in *Astronomical and Biochemical Origins and the Search for Life in the Universe*, eds: Cosmovici, Bowyer, & Werthimer, (Editrice Compositori: Bologna), 711.

This poster was prepared with Brian Wolven's Poster LaTeX macros v2.1.

What is SETI@home?

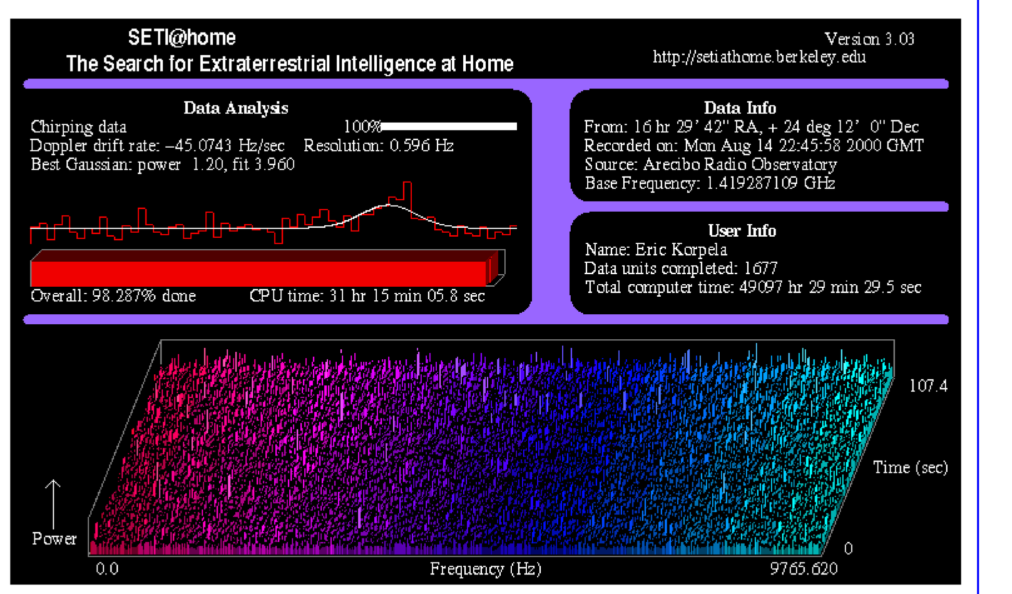

Figure 8. SETI@home screensaver client, version 3.03.

SETI@home is currently the worlds largest distributed computing project, involving over three million volunteers in 226 countries. Radio telescope data from the Arecibo radio observatory covering a 2.5 MHz wide band centered on 1420 MHz is divided into work units of 10 kHz bandwidth and 107 second duration. These work units are distributed over the Internet to the volunteers who run the SETI@home client program. On Windows and Macintosh platforms this client presents itself as a screensaver (see above) which analyzes the data when the computer is not otherwise in use. A text based version is available for most UNIX based platforms. This client can be run in the background at low priority.

The client searches for narrow band signals over 14 octaves of bandwidth between 0.075 and 1221 Hz. It performs this search at 24291 Doppler drift rates between -50 Hz/s and +50 Hz/s. It performs Gaussian fitting to detect faint signals that match the profile expected as the telescope beam moves past an object on the sky. And it searches for pulsed signals of the type described here. The entire process typically requires 4 trillion floating point operations to fully examine a single work unit.

SETI@home volunteers have collectively donated 762,000 CPU years for a total of 10^{21} floating point operations. The results returned include 2.7 billion potential signals which are being processed through data quality checkers and RFI removal algorithms.

For more information about SETI@home see Korpela et al. (2001, *Computing in Science & Engineering*, **v3n1**, Scientific Programming) or visit *http://setiathome.ssl.berkeley.edu/*.