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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. 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 HI 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 angular resolution than previous single dish surveys and 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. 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) Figure 1 shows the path of the telescope beam. The upper figure show the path of the beam over the course of 15 hours. The lower figure shows the sky coverage for about 2 years of observations.

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 typically 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

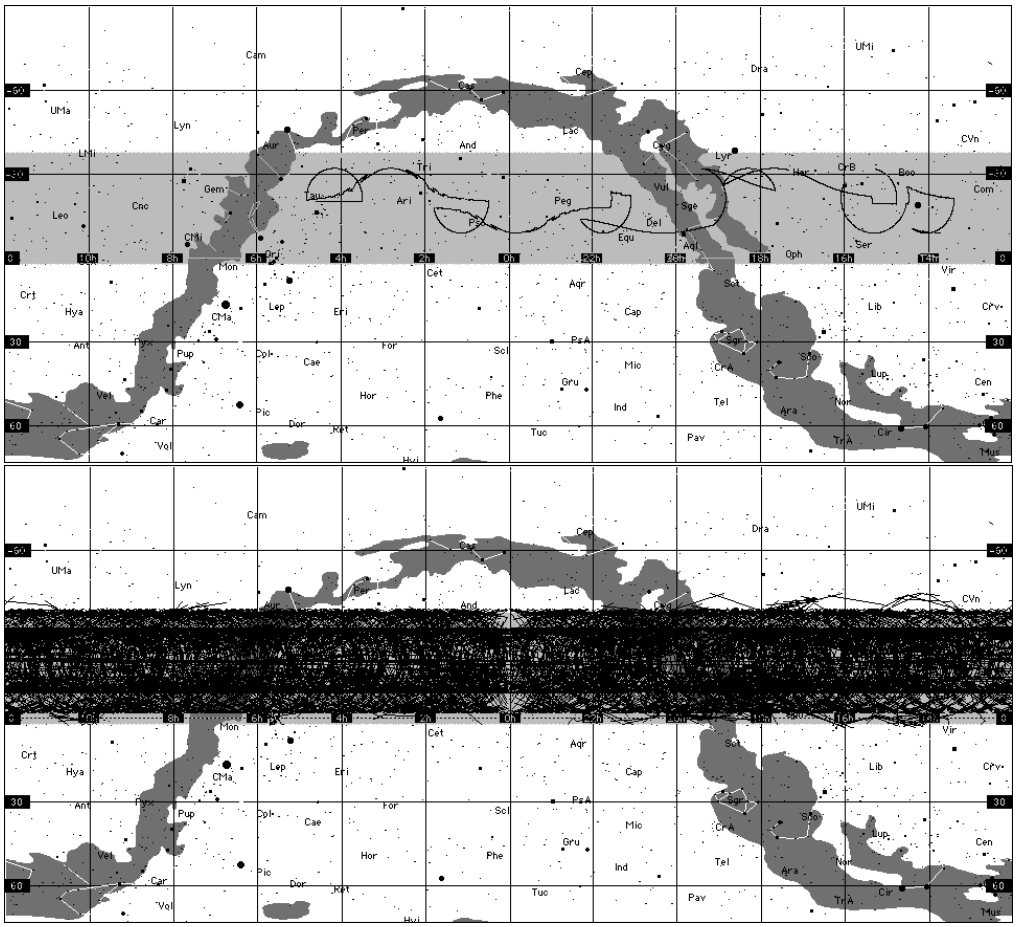

Figure 1. The upper figure shows the path of the telescope beam over 15 hours on August 5, 2001. The lower figure shows the sky coverage over 2 years of observations.

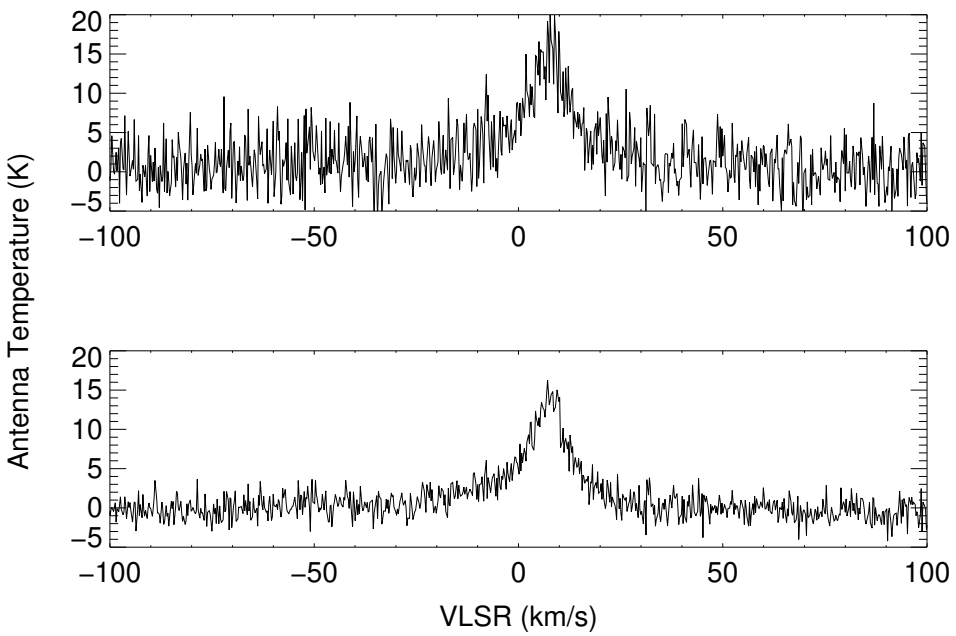

Figure 2. A 5 and 25 second integration along the same line of sight.

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

Figure 2 shows a spectrum 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} The upper plot shows a single raw 5 second integration spectrum with 1.22 kHz resolution. The lower plot represents the sum of 5 adjacent spectra, and shows the typical SNR that will be achieved in a 0.1 degree skymap pixel.

Figure 3 shows 27 spectra accumulated over 136 seconds. During the accumulation of these spectra the telescope beam was moving at more than twice the sidereal rate ($\sim$1.6 degrees over this duration). Significant changes are seen in the spectra are seen on scales approximating 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 $\sim$12 months.

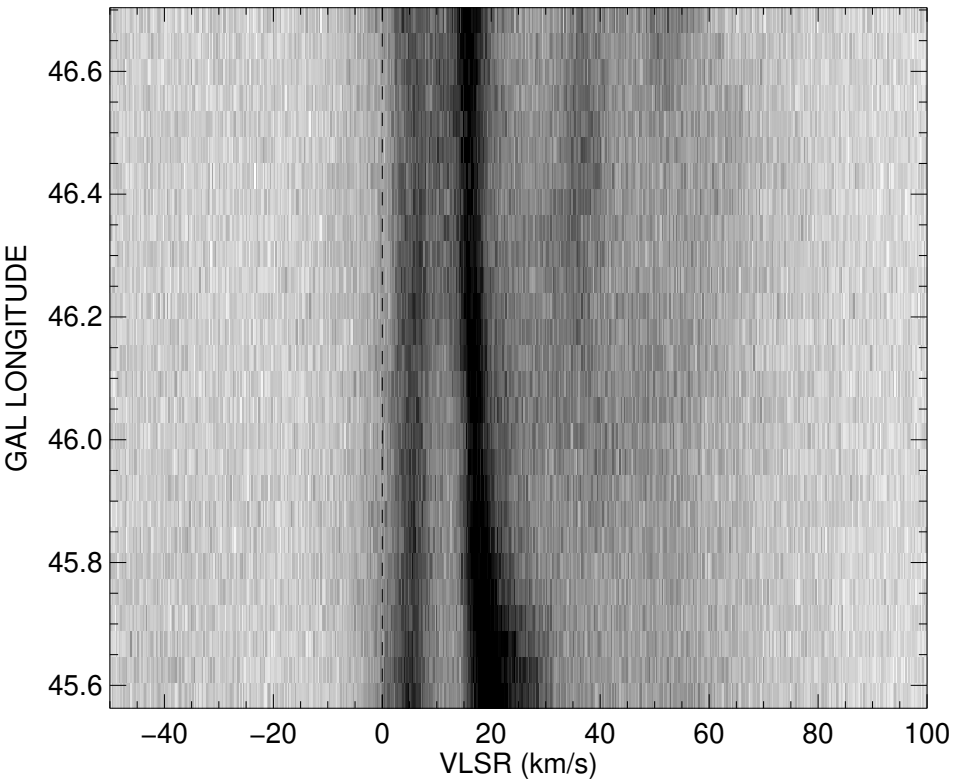

Figure 3. Spectra generated from 136 seconds of data. This sweep extends from (l,b)=(45.56,-4.60) to (l,b)=(46.70,-5.68). Each spectrum represents 5 seconds of data and transit of about 1/2 the beam width. Note the significant changes in line shape and velocity on scales $\sim$ the beam width.

Acknowledgements

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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, (Bologna: Editrice Compositori), 711