

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886
March 24, 2026**

Telephone: 617-715-5533

To: EDGES group

From: Alan E.E. Rogers

Subject: Simulations of EDGES-3 observations of the change in 21-cm center frequency

The analysis of EDGES-3 data from the WA vs GHA performed in memo 502 shows changes in the center frequency of the best fit global 21-cm absorption spectra that could be the result of a significant motion.

Figure 1 shows the extent of the EDGES-3 beam at 45 degrees elevation for GHA 0,6,12 and 18 hours made by plotting the locations of the beam at 45 degrees elevation around a circle in steps of 10 degrees of azimuth. This figure shows the potential measuring motion in the direction from galactic latitude, longitude (0,0) to (60,300) degrees which is in the direction of the center of the circle of GHA equal to 18 hours.

Figure 2 shows the coverage of the beams for an elevation range of 45 degrees to the zenith for data taken at GHA 0,6,12 and 18 hours. Table 1 shows the simulated best fit to the global 21-cm absorption based on the Doppler shift of a velocity of 2000 km/s in a direction 45 degrees galactic plane which is labeled GHA=18 in figures 1 and 2.

The global 21-cm spectrum without Doppler shift is assumed to have a center frequency of 78 MHz, width of 19 MHz, depth of 0.5 K and flattening of $\tau = 4$.

To simulate the effect of the velocity each simulated measurement in frequency and location in the galactic plane is weighted in proportion to the antenna beam gain. The 21-cm spectrum at each point is Doppler shifted by a velocity of 2000 km/s times the cosine of the angle between the vector direction of the dipole and the direction of the galactic center to the sampled point. The results of these simulations are listed in Table 1 below:

Center freq MHz	GHA hrs	Range of GHA	Center freq MHz	GHA hrs	Range of GHA
77.98	00	1	77.98	00	6
77.67	06	1	77.67	06	6
78.22	12	1	78.14	12	6
78.45	18	1	78.45	18	6

Table 1. Results of simulations using 1900 km/s 58-100 MHz

Several tests of these results were made which did change the SNR made small changes to the absorption amplitude at the level of 0.01 K but did not change center frequency results in table 2. The largest change made was to change the motion direction from (0,0) - (60,-60) to (0,0) - (48,-96) did not change the frequencies in table 1. These simulations have been done without added noise, beam correction or calibration errors.

The Doppler simulated shifted center frequency at GHA=18 of 78.45 MHz is only slightly lower than the measured center frequency in table 2 of memo 502 of 78.5 MHz the measured center frequency at GHA=0 of 79.3 MHz with a frequency shift which implies about 4000 km/s is almost certainly a systematic due to the low SNR and given the strong foreground at this GHA. In addition the data at this GHA is more effected by beam correction and calibration errors. Accurate calibration was only available from day 54 up to day 308 of 2023 when the VNA failed.

In summary the results of the measurements and simulations show that the EDGES-3 at the WA may be able to get a significant result for the velocity with more study and restoration of the built-in calibration. Further analysis of the available data will be made to estimate the errors in the center frequency of the 21-cm absorption measurement.

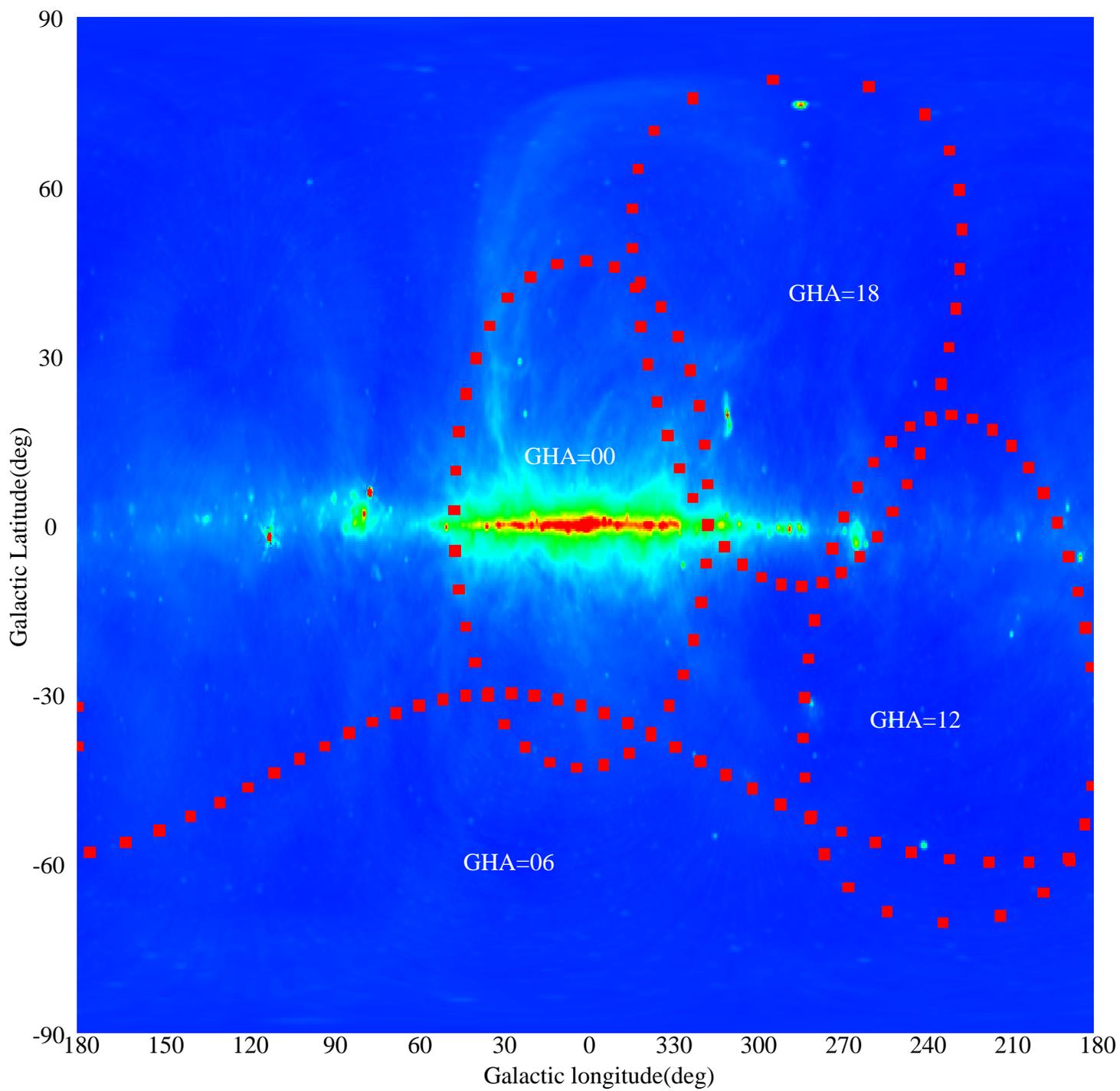


Figure 1. The location of EDGES beam at the WA 45 degrees elevation in steps of 10 degrees azimuth.

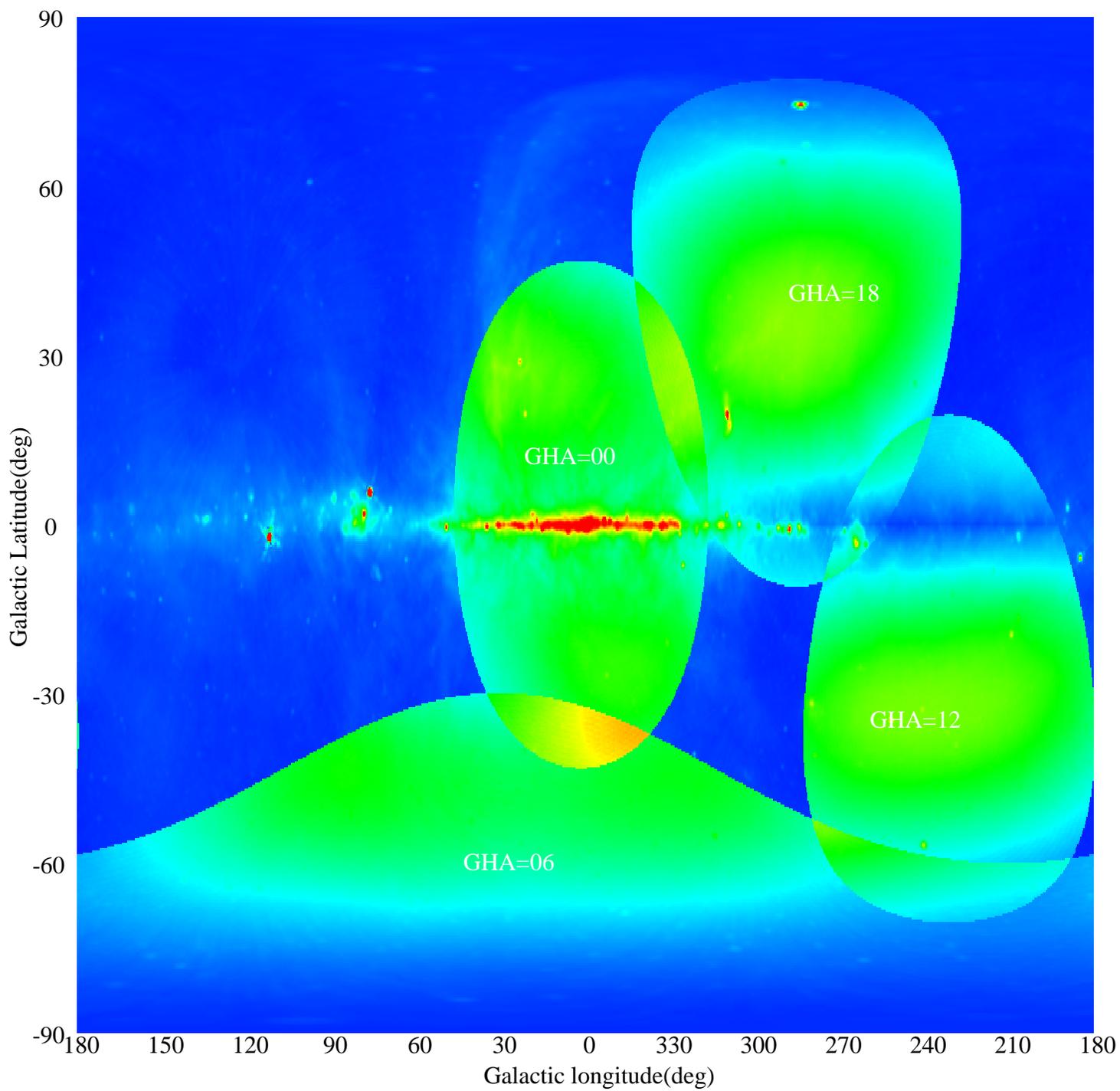


Figure 2. Coverage of the EDGES beam from 45 degrees to the zenith for GHA 0,6,12 and 18 hours.