MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 617-715-5533

To: EDGES group

From: Alan E.E. Rogers

Subject: Analysis of EDGES-3 at the WA vs GHA 2023 day 54 to 2026 day 15

This memo extends the analysis of the EDGES-3 at the WA to cover more data to determine if there is any significant change in the global 21-cm absorption with Galactic Hour Angle (GHA).

The results of the 21-cm absorption obtained from 4-hour blocks of data from each day to obtain 6 cases with a GHA range of 00-04, 04-08, 08-12, 12-16, 16-20, 20-24 are listed in table 1 of memo 480.

In this memo the averaging is reduced from 4-hour to 1-hour blocks and the range of data is extended from 2023 day 54 to 2026 day 15. These results are shown in table 1 below.

center MHz	SNR	amp K	width MHz	rms1 mK	rms2 mK	Range MHz	Sky K	Spectral index	Ion abs.	rms threshold K	GHA
78.5	10.4	0.68	22.9	69	61	60-102	4011	-2.85	1.66	1.0	00-04
77.7	14.7	0.44	22.9	47	30	60-102	1931	-2.89	0.91	0.3	04-08
77.3	41.1	0.62	22.9	53	15	60-102	1651	-2.90	1.08	0.3	08-12
77.7	34.9	0.66	22.9	69	19	60-102	1894	-2.89	1.49	0.3	12-16
80.1	29.8	0.46	19.0	75	19	60-102	2304	-2.88	1.36	0.3	16-20
79.7	21.8	0.62	22.7	88	27	60-102	3850	-2.85	1.86	0.5	20-24

Table 1. Results of 21-cm grid search using 1 hour blocks of GHA 2023 day 54 to 2026 day 15

These results used a value of dgha of 0.5 instead of the value of 2.0 used in memo 480. The rms thresholds were set to the values in table 1 instead of the fixed value of 0.35 K used in memo 480. Otherwise the same parameters as used in memo 480 were used. The Sky noise temperature, spectral index and ionosphere absorption are the values at 75 MHz.

In order to account for a change in beam chromaticity on a scale of 30 minutes and averaging over 6 hours a test is made using 4 blocks over all GHA which don't overlap is made to avoid the 1 hour overlaps in table 1.

center MHz	SNR	amp K	width MHz	rms1 mK	rms2 mK	Range MHz	Sky K	Spectral index	Ion abs.	rms threshold K	GHA
79.3	15	0.68	22.9	64	41	60-102	4424	-2.85	1.89	0.8	00
77.7	27	0.53	22.9	46	20	60-102	1733	-2.89	0.89	0.3	06
77.7	38	0.63	22.9	59	17	60-102	1741	-2.89	1.26	0.3	12
78.5	22	0.48	21.8	53	22	60-102	2057	-2.89	1.38	0.3	18

Table 2. Results using 0.5 hour blocks covering a range of 6 hours centered at 00, 06, 12 and 18 hours

Table 3 shows the results with and without beam correction but using only data from every tenth day in order to reduce the time needed to get the results in a few hours instead of needing a couple of days. This test shows that beam correction is needed for the 6 hour ranges centered at 00 and 06 hours.

The 21-cm absorption results from data centered at 00 hours GHA may be centered higher than 78 MHz and this could due to the effects of the temperature anisotropy of the CMB dipole reported in the ARCADE 2 data and thought to be due to the motion of the solar system. Recent results report a velocity as high as 630 km/s which would shift the center of the 21-cm absorption by about +0.16 MHz when the GHA of the antenna beam is pointed in the direction of dipole and -0.16 MHz when pointed in the opposite direction. Given the broad beam an average weighted by the antenna gain is needed. For the EDGES-3 this reduces the Doppler shift by a factor of about 0.7 so that a velocity of about 2700 km/s for a Doppler shift of 0.5 MHz.

center MHz	SNR	amp K	width MHz	rms1 mK	rms2 mK	Range MHz	Sky K	Spectral index	Ion abs.	rms threshold K	GHA
78.5	28	1.51	22.1	67	49	60-102	4434	-2.86	3.34	0.8 no beam	00
77.3	7	0.22	20.5	39	30	60-102	1724	-2.89	0.06	0.3 no beam	06
78.5	17	0.41	21.7	64	25	60-102	1741	-2.89	0.45	0.3 no beam	12
78.1	8	0.40	22.9	79	52	60-102	2066	-2.88	1.01	0.3 no beam	18
78.9	10	0.57	22.9	72	54	60-102	4420	-2.85	1.91	0.8 with beam	00
77.3	24	0.57	22.9	49	23	60-102	1726	-2.89	0.91	0.3 with beam	06
78.3	27	0.61	22.3	64	23	60-102	1739	-2.89	1.27	0.3 with beam	12
77.0	10	0.53	22.9	75	48	60-102	2055	-2.89	1.41	0.3 with beam	18

Table 3. Results using every tenth day without and with beam correction

The excess radio dipole at radec(168,-7) deg discussed in Böhme et al. has an effective velocity as high as 1400 km/s which would doppler shift 78 MHz up to 78.36 at GHA 0 - 4 and down to 77.64 MHz at GHA 12 -16. This shift is similar, although smaller than the shifts in the results in the tables above.

The quasar dipole at radec(277,29) discussed by Singal with an effective velocity of 1500 km/s would doppler shift 78 MHz by about up by about 0.39 MHz at GHA 10 and down at GHA 22 - 0 which is in the opposite direction of the radio dipole and inconsistent with the EDGES 3 21-cm data.

However the quasar dipole radec discussed by Singal is now found to be consistent with the direction of the excess radio dipole and CMB dipole when Bayesian analysis along with an accounting for galactic plane contamination is used as reported by Mittal et al.

The Doppler shift in the results shown in Table 2 covers a range of about +/- 0.6 from 78.3 MHz and a dipole velocity of 1500 +/- 500 km/sec if the frequency shift is due to motion.

The radio source RACS-low survey and VLASS data have indicated a dipole 3–8 times larger than predicted by the CMB corresponding to a range of about 1000 to 3000 km/sec.

The coverage of the direction of the zenith, which is the maximum of the antenna gain, is shown in Galactic coordinates for the antenna in Western Australia and Adak in figures 1 and 2. The zenith direction follows a curve which depends on the earth's rotation and while the location on the curve depends on the time of day and the day of the year the curves depend only on the latitude of the site. This is shown that for a fixed zenith pointing antenna the overall coverage needed to cover the full sky for the best measurement of the dipole requires sites over a range of the earth's latitude. Multiple sites over a

range of lunar latitude is also needed for the best measurement of the dipole since the moon's rotation is "locked to the earth".

Figure 3 shows the antenna zenith curves for the sites for which EDGES data has been collected with the coordinates listed in table 4. The EDGES antenna has abroad beam with a 3-dB width of about 100 degrees so antenna is sensitive the sky noise from regions of the galactic plane at least 45 degrees away from the "red" squares in the figures which correspond to the antenna zenith. A full analysis is done in the analysis of the EDGES data with is needed to apply a "beam correction" of the data. The limits of the site latitude on the available data for fixed zenith pointed antenna are shown in this memo.

site	Latitude (deg)	Longitude (deg)	gal_lat(deg)	gal_lon(deg)
Boolardy WA	-26.7	116.5	-89 to 34	47 to -146(214)
Oregon	42.417	-119.05	-20 to 74	67 to 78
Devon Island	75.432	-89.811	12 to 42	106 to 139
Adak Island	51.94	-176.598	-11 to 65	79 to 166

Table 4. List of EDGES sites with the range galactic coordinates of curves in Figure 3

It is noted all the zenith curves make a closed path including the curve for Boolardy which makes the connection from gal_latlon(-89,47) to gal_latlon(-89,214) in a few minutes to complete a closed path in figures 1 and 3.

In summary the best fit 21-cm absorption spectra from EDGES-3 data from the WA shows a change in center frequency which is consistent with a CMB with increased strength in the direction of the hydra discussed in Secrest et al. 2025 but a more detailed analysis which includes antenna orientation and gain using the EDGES beam model whose details are given in Mahesh et al. 2021.

References:

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Mahesh, N., Bowman, J.D., Mozdzen, T.J., Rogers, A.E., Monsalve, R.A., Murray, S.G. and Lewis, D., 2021. Validation of the EDGES low-band antenna beam model. *The Astronomical Journal*, *162*(2), p.38.

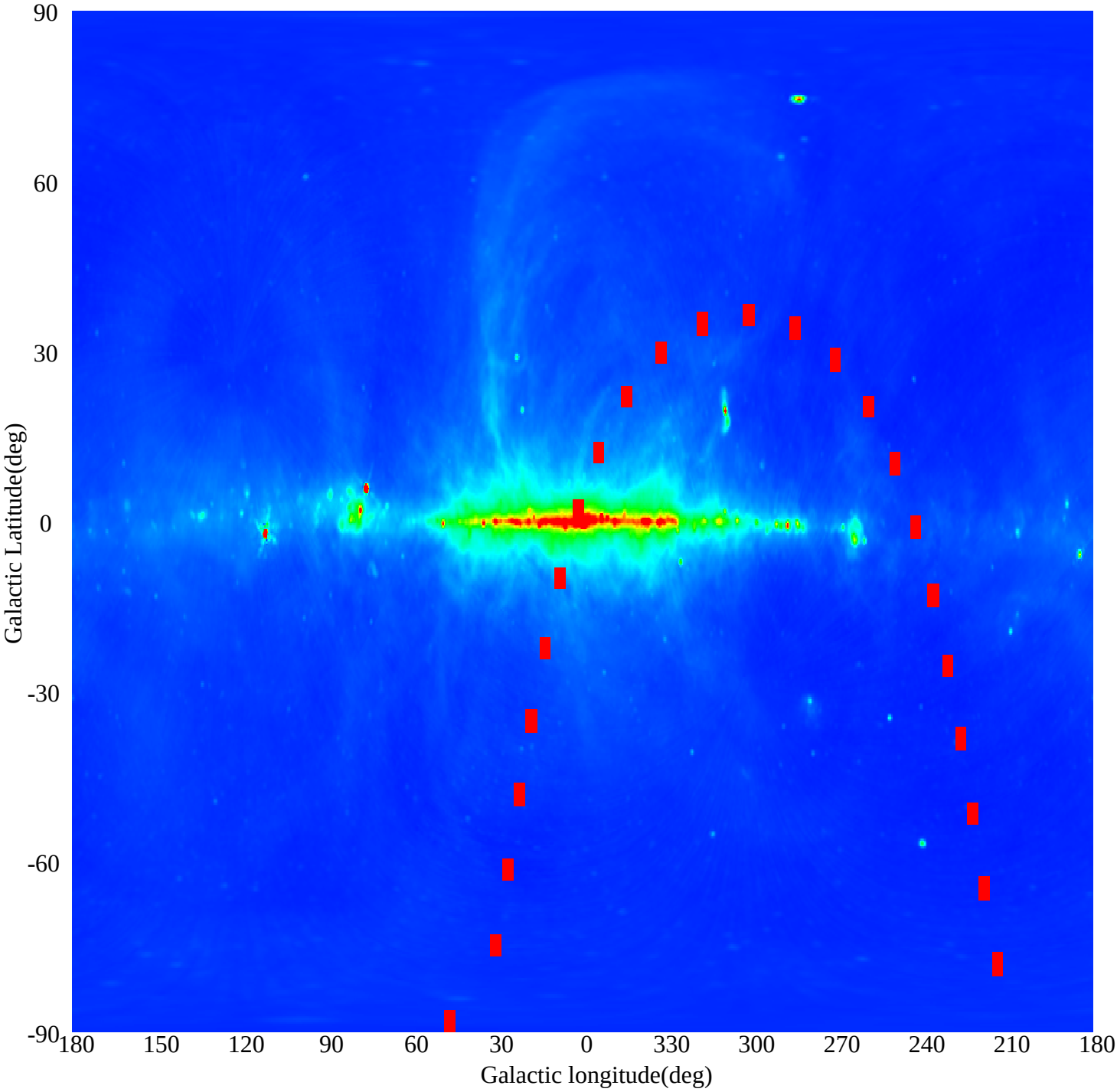

Figure 1. Location of the WA EDGES antenna beam zenith at each UT 00 - 23 on 2025 day 50

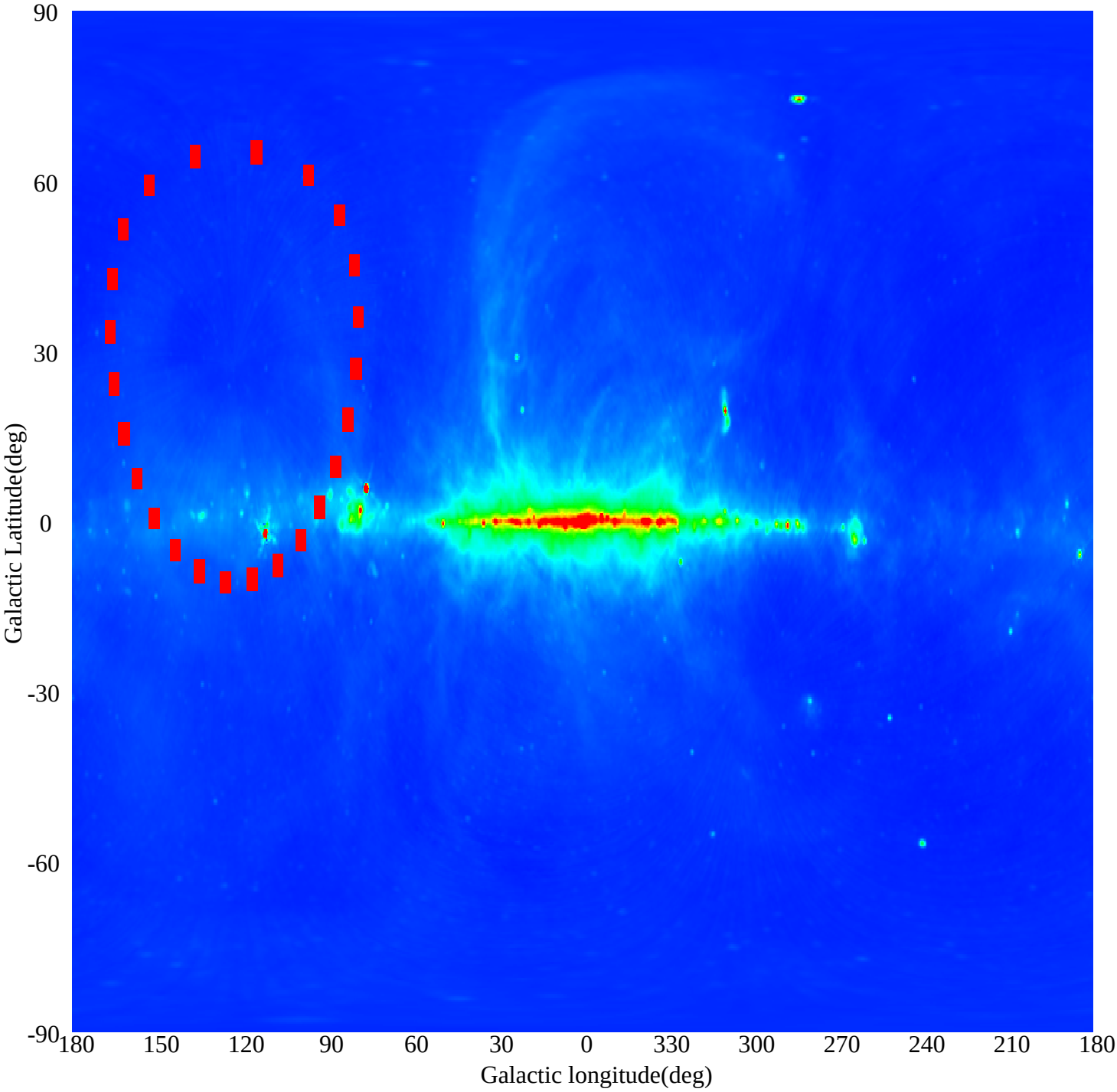

Figure 2. Location of the AdaK EDGES antenna beam zenith at each UT 00 - 23 on 2025 day 50

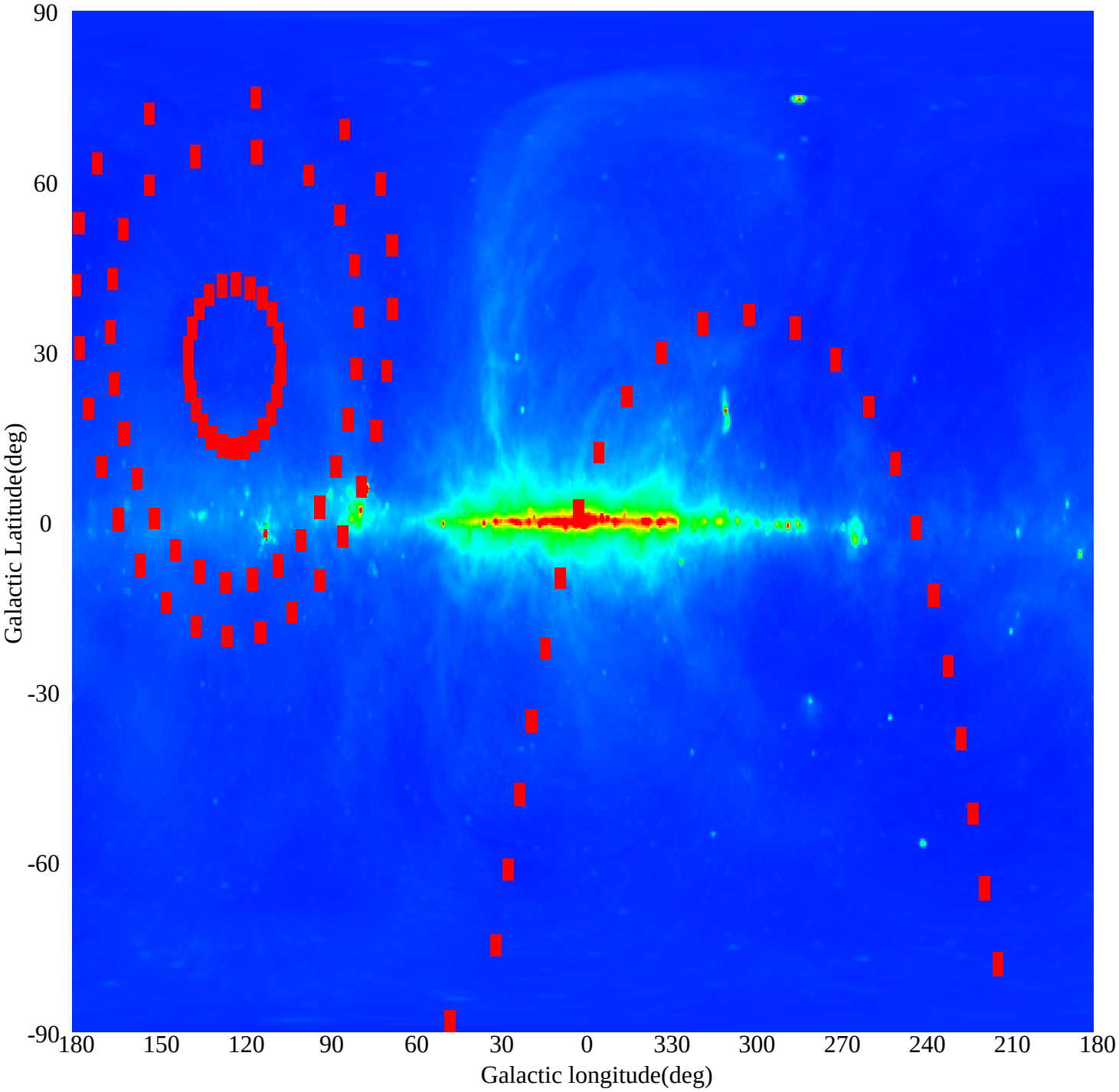

Figure 3. Zenith curves for sites listed in Table 4 using UT 00 - 23 on 2025 day 50