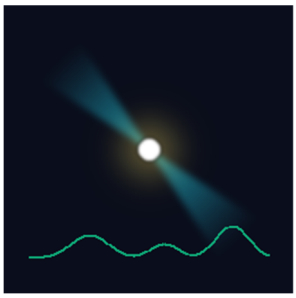
August 2026 Hydrogen Drift-Scan Campaign

DSES Haswell 60-foot dish — Report 2, superseding the August 19 report



Rev A

Richard M Hambly (K0GD)

DSES

August 2026

Contents

August 2026 Hydrogen Drift-Scan Campaign

Through most of August 2026 the DSES 60-foot dish at Haswell sat motionless while the sky drifted through its beam, recording a hydrogen-line spectrum around the clock. This report presents the two science datasets from that campaign — a wide-band survey (August 14–19) and a deeper, higher-resolution survey with an upgraded receiver configuration (August 24–31) — together with a precise measurement of where the telescope is actually pointing, made from the sky itself and tied to the mount's position encoders. It supersedes the August 19 report; every result here is computed from the corrected telescope pointing and improved analysis, and the earlier report's recommendations have been acted on or revised by what we have since learned.

What the campaign shows:

- **Neutral hydrogen detected twice per sidereal day, every day, in both datasets** — the Milky Way's plane crossing the fixed beam in Cygnus and toward the anticentre, with spiral-arm gas components resolved out to −100 km/s. The deep dataset samples the line at **0.10 km/s resolution with the receiver's own artefacts entirely outside the band** — the cleanest hydrogen spectra this instrument has produced.
- **Cygnus A transited the beam on all seventeen observing days**, and after correcting a bookkeeping subtlety its transit time agrees across every segment to a few seconds. The measured transit is **48 ± 2 seconds later than the precise astronomical prediction** — a fixed east-west boresight offset of **0.15°**, now the telescope's one remaining pointing unknown.
- **The mount's encoders check out.** A System 1 team visit on August 26 provided exact encoder readouts of the park position; with those numbers the elevation encoder is consistent with the sky, and the dish returned from the mount exercise to within **20 arcseconds** — confirmed independently by the transit data, which never moved.
- **On-axis sensitivity is about 1,700 Jy** (system equivalent flux density), a factor ~3.4 better than the August 19 report's off-axis upper bound, thanks to the corrected pointing.
- **Data integrity remained perfect**: 9,791 spectra in the new dataset with zero gaps, on top of segment 1's 16,205 — a month of unattended operation without a lost row.

1. The observations

Both datasets were taken with the dish parked and the sky drifting through the beam. The park position — from the mount encoders, read out by the System 1 team on August 26 — is

azimuth 359.978°, elevation 87.177°, which points the beam at declination **+41.20°**. (The August 19 report used the nominal az 0°/el 87° from the observing log; the encoder readouts correct that, and every coordinate in this report uses the true position.)

Parameter	Segment 1 (wide)	Segment 4 (deep)
Dates (UTC)	Aug 14 21:19 – Aug 19 15:38	Aug 24 16:52 – Aug 31 20:39 (continuing)
Band	1418.4 – 1422.4 MHz (4 MHz)	1419.61 – 1421.21 MHz (1.6 MHz)
Channels	3276 × 1.221 kHz (0.26 km/s)	3276 × 0.488 kHz (**0.10 km/s**)
One spectrum every	25.4 s	64 s
Receiver artefact (DC)	in band, on the line (blanked)	**out of band entirely**
Spectra recorded	16,205	9,791
Data gaps	none	none
Software	Spectrum Analyzer 1.3.1	Spectrum Analyzer 1.3.3, LO-offset preset

Between the two science segments, a receiver-configuration fault was found, diagnosed from the sky, fixed in software, and verified — section 8 gives the one-paragraph account. The interlude data (Aug 19–24) contribute continuum timing to section 4 but no line science.

The receiver upgrade that defines segment 4 parks the radio's local oscillator 1.5 MHz away from the displayed centre and lets the digital downconverter bring the band back. The hydrogen line sits dead-centre in the recorded band while the receiver's self-generated DC artefact — which in segment 1 landed 1.3 km/s from the line's rest frequency, inside the science — falls outside the band altogether.

2. Hydrogen

Hydrogen atoms throughout the Galaxy radiate at 1420.4058 MHz. The gas orbits the galactic centre, so the line arrives Doppler-shifted, and the shift maps each cloud's motion — and through the geometry of galactic rotation, its rough location. Each spectrum was corrected to the local standard of rest and the instrument bandpass divided out.

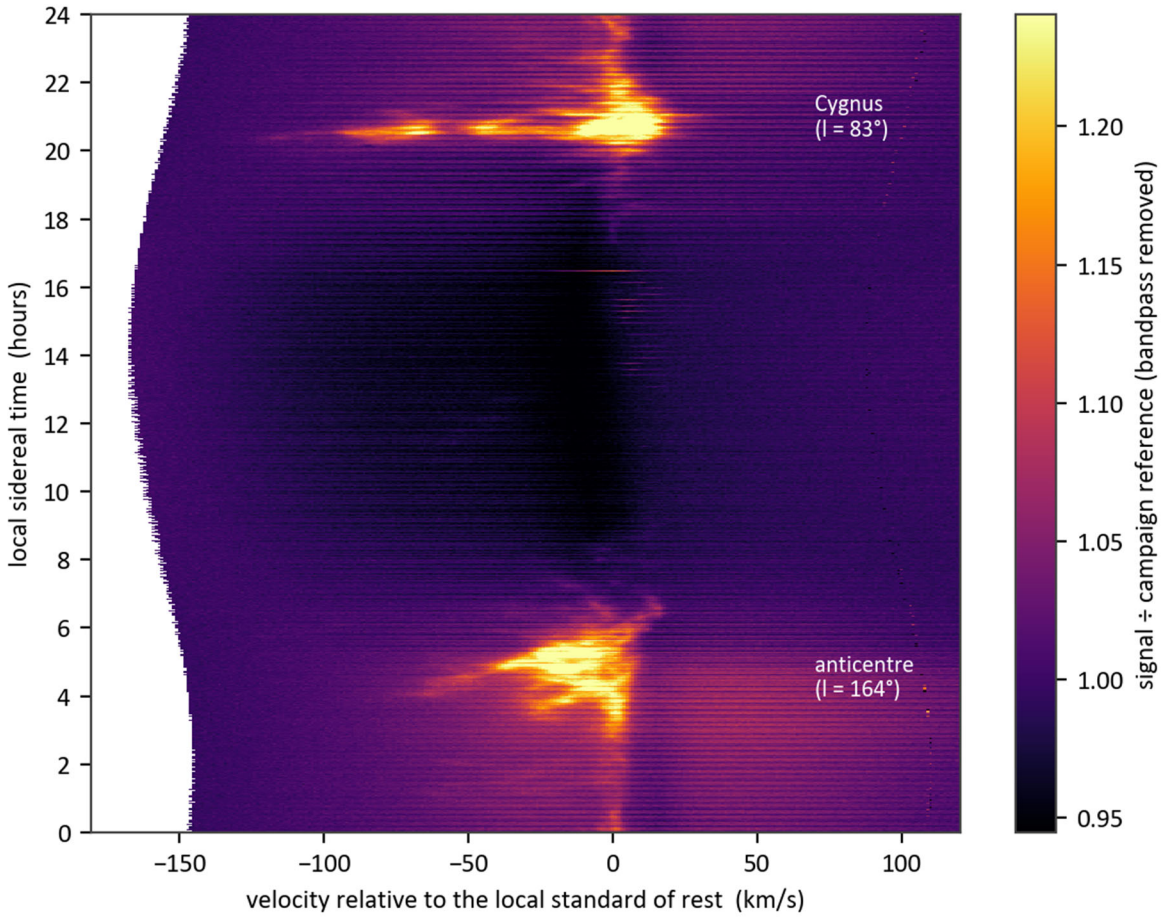


Figure 1 — Seven days of hydrogen spectra from the deep dataset, stacked by sidereal time. The two bright bands are the Milky Way's plane drifting through the beam — Cygnus at LST 20–22 h, the anticentre at LST 4–6 h — repeating identically every sidereal day.

The plane crossings repeat every sidereal day at the same strength in both datasets:

Crossing	Galactic longitude	Peak line strength	Velocity of peak
Cygnus, LST 20–22 h	83°	1.240 × quiet sky	+3 km/s
Anticentre, LST 4–6 h	164°	1.231 × quiet sky	−9 km/s
LST 22–24 h	101°	1.111 × quiet sky	0 km/s
LST 18–20 h	72°	1.041 × quiet sky	+3 km/s

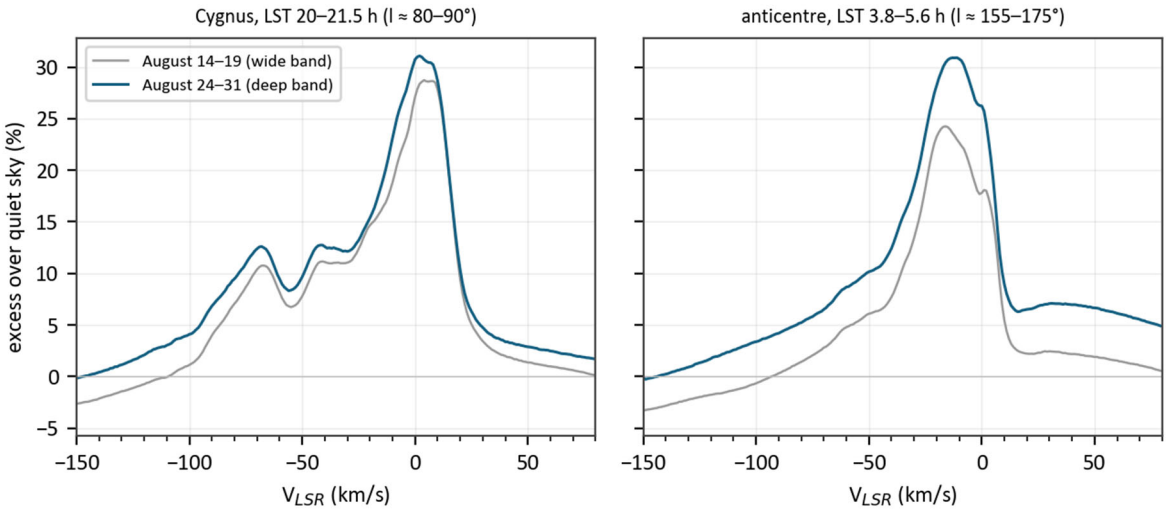


Figure 2 — Hydrogen profiles at the two plane crossings, wide dataset (gray) and deep dataset (teal). The Cygnus direction resolves local gas near 0 km/s plus outer-arm components near −45 and −70 km/s. The deep dataset traces the same physics with half the channel width and about a third the channel noise.

The two datasets are complementary. The wide band covers ±420 km/s and feeds the classic longitude–velocity diagram (Figure 3); the deep band covers ±170 km/s — comfortably containing all the galactic hydrogen at this declination — with twice the velocity resolution and markedly lower noise.

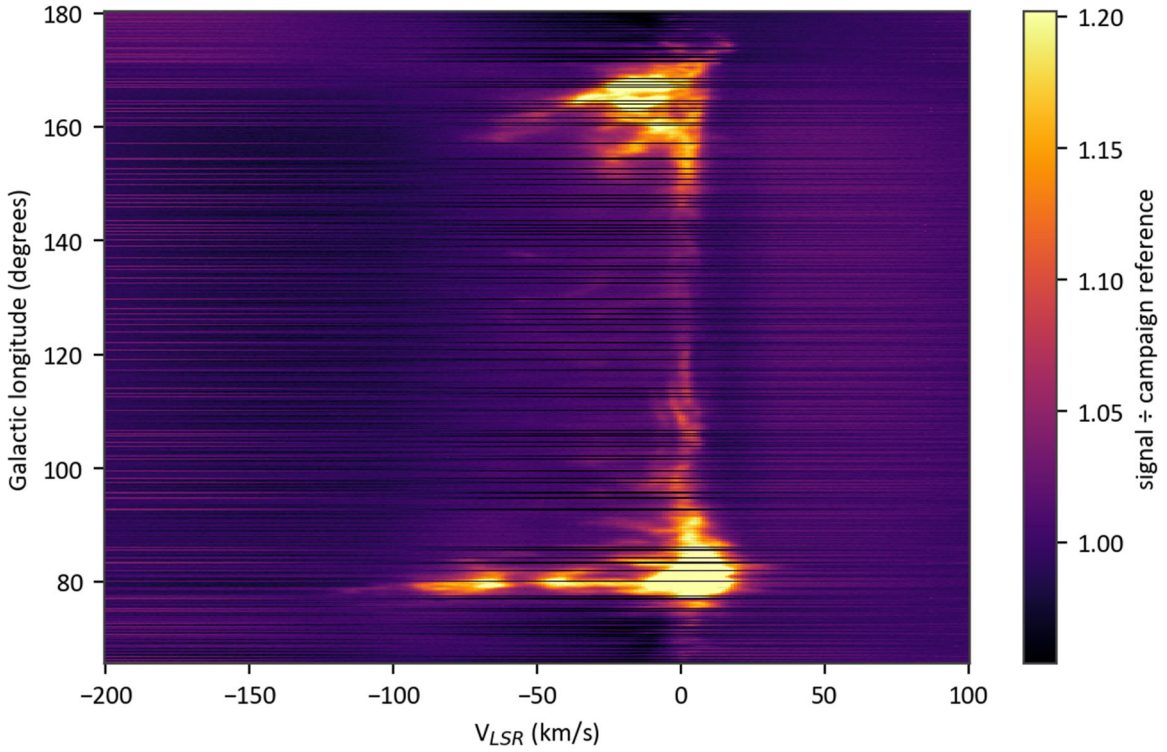


Figure 3 — Longitude–velocity diagram along the Dec +41.2° track, from the wide dataset. A fixed-declination drift scan samples the plane only where its track crosses it — the two populated strips near l = 85° and l = 165° are the honest limit of the observing mode.

The receiver upgrade matters most exactly where the local gas lives. In segment 1 the receiver's DC artefact sat 1.3 km/s from the line's rest frequency and the affected channels had to be blanked; in segment 4 that velocity range is a clean measurement:

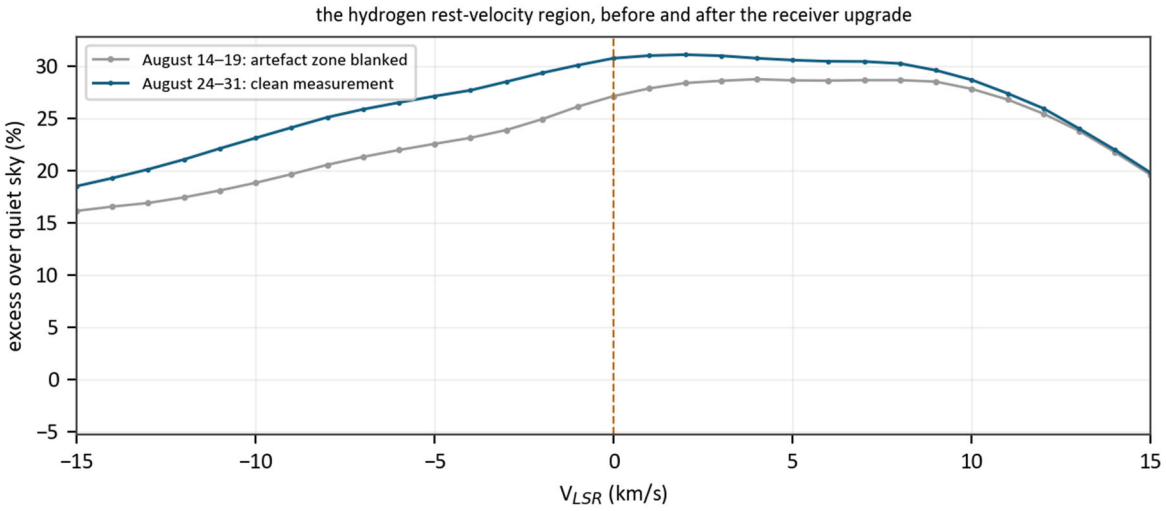


Figure 4 — The hydrogen rest-velocity region before (gray) and after (teal) the receiver upgrade. What was a repaired hole in the science band is now well-sampled data at 0.10 km/s per channel.

3. Cygnus A: seventeen days of transits

Cygnus A — a radio galaxy 600 million light-years away and one of the strongest sources in the sky — passed through the beam every observing day of the campaign. Because it is effectively a point source, its daily transit measures the telescope rather than the sky.

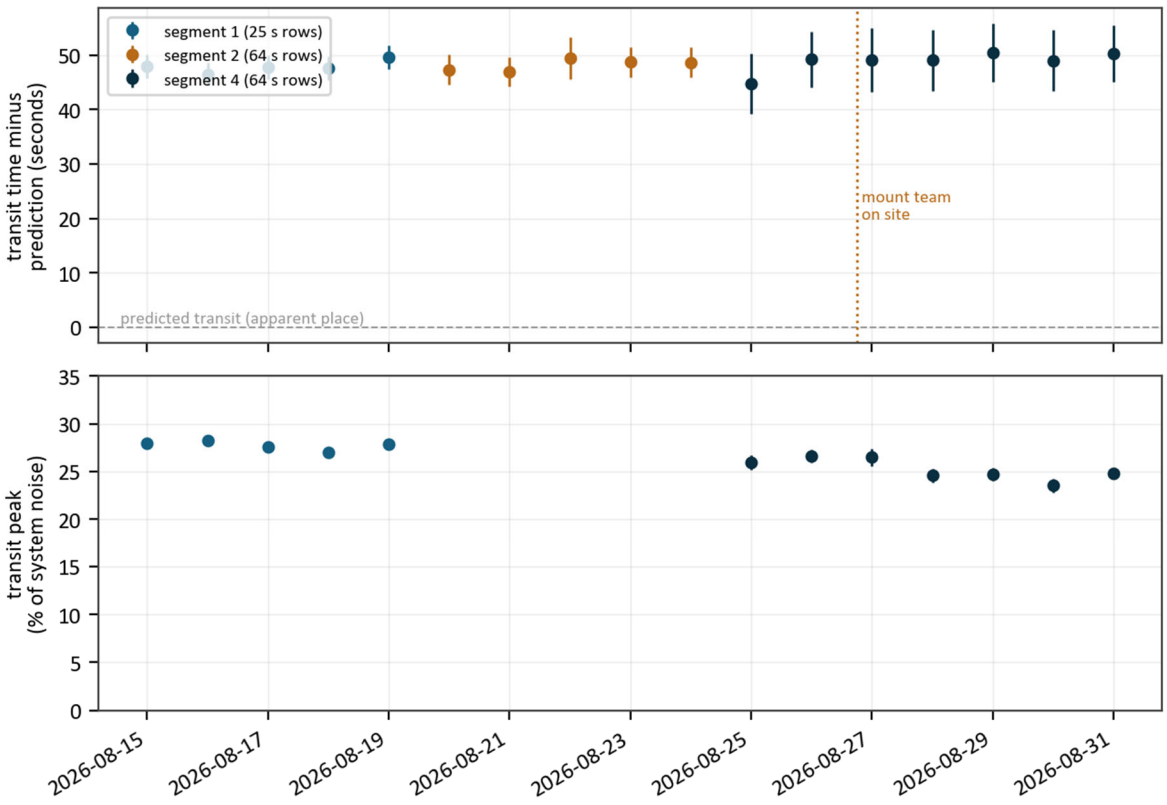


Figure 5 — Top: transit time versus the precise astronomical prediction, all seventeen days, after correcting each segment's integration-time stamp offset. The +48 s offset is constant across three receiver configurations and straight through the August 26 mount-team visit (dotted line). Bottom: transit amplitude by day (line-free continuum estimator; the interlude segment is omitted where its band lacks line-free channels).

Timing, and the one remaining pointing term. After accounting for the row-timestamp convention (spectra are stamped at the end of each integration, so fitted transit times read half an integration late — 13 s in segment 1, 32 s in segments 2 and 4), all seventeen days agree on the transit time to ±2 seconds. Against a rigorous prediction for Cygnus A's apparent position (precession and nutation included), the measured transit is

+48 ± 2 seconds late, i.e. the beam points **0.152° west** of where the mount's axes say. At this near-zenith elevation the azimuth encoder can contribute only arcseconds to that, so this is a fixed **boresight or mount-tilt term** — the single remaining pointing unknown, and the target of the calibration campaign in Appendix A.

The mount visit as a controlled experiment. The System 1 team exercised the mount on August 26 and returned it to within 0.006° per axis by the encoders. The transit series brackets their visit: timing and amplitude are statistically identical before and after. Two independent methods — encoders and sky — agree that the mount repositions to ~20 arcseconds, a genuinely encouraging result for the mount-control work.

Sensitivity. With the corrected pointing, Cygnus A passes 0.470° from the beam centre, where a 0.70° beam passes 28% of its on-axis response. The measured transit amplitudes then imply an on-axis system equivalent flux density of roughly **1,600–1,800 Jy** — a respectable figure for a 60-foot dish and a ×3.4 revision of the August 19 report's off-axis bound. (The residual spread, including a mild ~7% amplitude decline across segment 4's week that timing and beam width say is not pointing, is honestly unexplained — weather and gain are the leading candidates; the calibration night in Appendix A measures the sensitivity on-axis and settles it.) The transit width gives a beam of **0.69–0.70°** FWHM, consistent every day of the campaign. The Gamma Cygni supernova remnant and the DR 21/Cygnus X region follow Cygnus A across the beam each day at flux ratios consistent with the catalogs — the whole chain, feed to file, behaving linearly.

4. Data quality

- **Zero gaps in either dataset** — 26,000 spectra across the campaign, every interval at its nominal cadence, every UTC-midnight file rollover seamless.
- Total received power stable to ±0.06 dB day-to-day within each segment.
- The band is exceptionally clean. One weak external carrier (near 1420.00 MHz, a single channel wide, ~1 dB) is the only interference in a month of data, and it sits outside the velocity range of the galactic hydrogen studied here. Its single-channel sharpness, verified daily, doubles as a running proof of the receiver's spectral integrity.
- The deep dataset's receiver artefact status, checked daily: absent (≤0.006 dB at the band centre).

5. Recommendations

1. **Run the pointing-calibration campaign (Appendix A), now anchored to encoder truth.**

   The next site visit should park the dish at **azimuth 359.978° (unchanged), elevation 87.647°** — a single-axis move of +0.47° that places the beam directly on Cygnus A if the elevation encoder is truthful. One night of ordinary drift-scan there measures the on-axis sensitivity directly and closes the elevation question; subsequent one-night grid points, and daytime checks on Cassiopeia A and the Sun, separate boresight from mount tilt and turn the 0.15° east-west term into a calibrated correction. Until that campaign completes, narrow-beam pointed work (the hydrogen line and above, and especially EVE) should treat encoder pointing as uncertain at the 0.15° level east-west.

2. **Adopt the LO-offset drift-scan preset as the standard hydrogen configuration.** It is

now the proven best mode: line centred, artefacts out of band, full spectral resolution, honest headers — the software verifies the radio actually applied the offset rather than trusting it.

3. **Timestamp refinement for a future software release:** stamping each spectrum at the middle of its integration rather than the end would remove the half-integration timing correction applied in this analysis. Until then the correction is documented here and in the analysis notes.

6. Where the data and analysis live

```
Documents\DSES\Science\HI_and_Drift_Scan\

  DSES_SA_Recordings\       the daily .txt files from the site Pi (all segments)

  analysis_2026-08\         segment-1 analysis + the superseded Aug 19 report

  analysis_2026-08_seg2\    the receiver-fault investigation record (segments 2-3)

  analysis_2026-09\         THIS report: campaign analysis, transit series,
figures
```

Everything is scripted and re-runnable; the drift scan was still recording as this report was written, and extending any result with the later days is a single command.

7. Methods and caveats

Each dataset was reduced with an independent pipeline (channel-level bandpass removal against quiet-sky references, per-sample Doppler correction to the local standard of rest, Gaussian fits to the continuum transits using line-free channels), cross-checked against the ezRA community toolchain on segment 1. Between the science segments, a receiver-configuration fault — two interacting tuning bugs that mislabeled the recorded band and, on the site hardware, degraded spectral resolution — was found from the sky, reproduced on the bench, fixed in Spectrum Analyzer 1.3.3, and verified on-site within minutes of deployment. The interlude data (Aug 19–24) are used only for continuum transit timing, where they are fully valid; the investigation record lives in the analysis folders.

Caveats stated plainly:

- Brightnesses are relative to system noise or quiet sky, not calibrated kelvins or janskys; the sensitivity figure assumes Cygnus A's catalog flux (1,590 Jy at this band).

- The on-axis sensitivity and any residual elevation-encoder error are degenerate in these data; the Appendix A night on Cygnus A breaks the degeneracy by design.
- The ~7% amplitude decline across segment 4's week is unexplained (timing and beam width exclude pointing drift; weather and receiver gain are candidates). It does not affect the line results, which are ratios against same-day references.
- Source identifications rest on positional matches and internally consistent flux ratios, not pointed confirmations.

Appendix A. The pointing-calibration campaign

The campaign's one open pointing term is the fixed 0.152° east-west boresight/tilt offset measured in section 3. The plan below turns it — and the sensitivity degeneracy — into calibrated numbers using the same unattended drift-scan technique as this report, one telescope move per site visit.

Visit 1 (committed): park at azimuth 359.978°, elevation 87.647° — beam on Cygnus A if the elevation encoder is truthful. Record the encoder readouts (photograph the display) before and after the move, and notify when done. One night of drift scan then yields the on-axis sensitivity directly, the residual elevation-encoder error with sign, and a stronger daily calibrator for the rest of the campaign. The hydrogen survey continues almost unchanged at the new declination.

Subsequent visits, half-degree elevation steps bracketing Cygnus A:

Visit	Azimuth	Elevation	Commanded Dec	Offset from Cyg A
1	359.978	87.647	+40.73	0 (on-source)
2	359.978	88.147	+40.23	0.5° south
3	359.978	87.147	+41.23	0.5° north

Fitting transit amplitude against commanded elevation maps the beam and pins the elevation scale; each night's transit time re-measures the east-west term for free.

Separating boresight from tilt requires the same measurement at other elevations and on both sides of the zenith: one night with the dish at az 359.978°, el 69.6° (Cassiopeia A, ~1,700 Jy, transits ~2:20 am local) and one daytime pass on the Sun (az 180°, elevation computed for the date, ~64° and falling; reduce the gain — the Sun is ~100× system noise). Same-sign elevation errors on both sides of zenith indicate an encoder zero offset; opposite signs indicate mount tilt. Three sources at three elevations on both sides of the zenith are the minimal set — and the measurements are all unattended drift scans once the dish is parked.