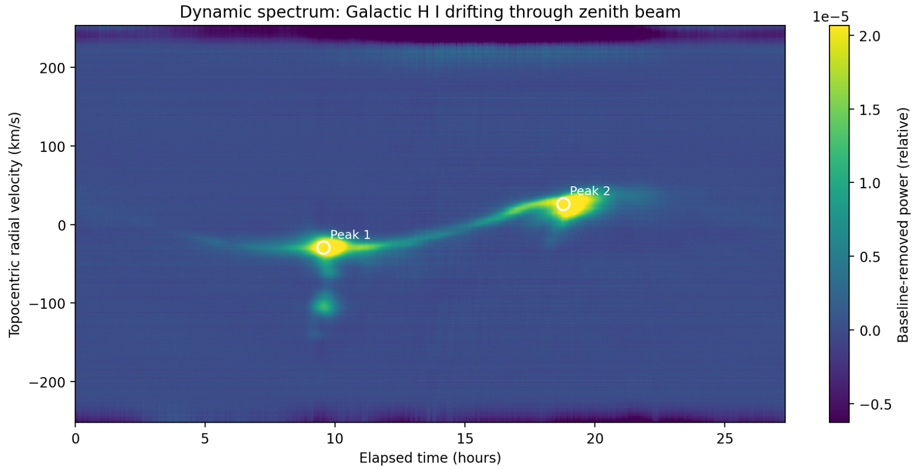
Scientific report: 21 cm H I zenith drift scan

Glendora, California - 2.1 m dish - relative-power spectroscopy

Abstract

A zenith-pointed 2.1 m radio telescope in Glendora, California recorded 1,000 spectra across 1419.205-1421.600 MHz, covering the neutral-hydrogen 21 cm transition at nu0 = 1420.405752 MHz. After smooth bandpass removal, the residual dynamic spectrum shows Galactic H I emission in two prominent time windows. The analysis uses a topocentric radio velocity convention and intentionally avoids absolute brightness calibration because no hot/cold, noise diode, or standard source calibration is available.

Input file	MLO-Lewin_20260429_451000_1000.zip
Spectra x channels	1,000 x 512
Start/end file time	2026-04-29 20:55:42 to 2026-05-01 00:14:52
Duration/cadence	27.319 h / median 97 s
Rest frequency used	1420.40575177 MHz
Frequency span	1419.205000 to 1421.600312 MHz
Velocity span	-252.1 to 253.4 km/s
Line-integration range	-160 to +160 km/s
Sky path assumption	PDT/UTC-7 for approximate RA/l,b only



Residual dynamic spectrum used as the primary science diagnostic.

1. Aperture, wavelength, and beam

For a circular aperture, a first-order diffraction estimate gives a beam scale proportional to lambda/D. A real amateur dish includes feed illumination, blockage/scattering, spillover, surface errors, and ground pickup; therefore the value below should be treated as an order-of-magnitude FWHM-like beam estimate rather than a measured beam pattern.

Angular response estimate

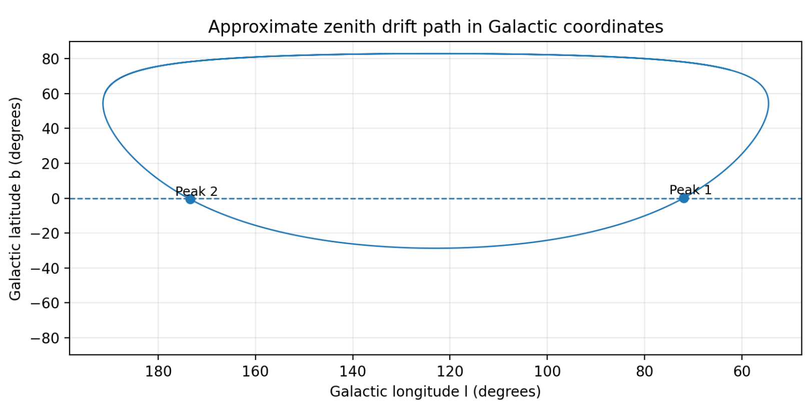
```
lambda0 = c / nu0
= 299792458 m s^-1 / (1420.40575177e6 s^-1)
= 0.21106 m

theta approx 1.22 lambda0 / D
= 1.22 * 0.21106 / 2.1 = 0.1226 rad
= 7.03 deg
```

Zenith drift geometry

For a zenith-pointed instrument at geographic latitude phi, the instantaneous beam center has declination approximately delta = phi. The right ascension of the zenith equals the local sidereal time. The Galactic longitude and latitude used in the figures were computed from this RA/Dec path assuming the file timestamps are PDT.

Coordinate model

```
delta_zenith approx phi_site
RA_zenith(t) = LST(t)
(l,b) = EquatorialToGalactic(RA_zenith, delta_zenith)
```



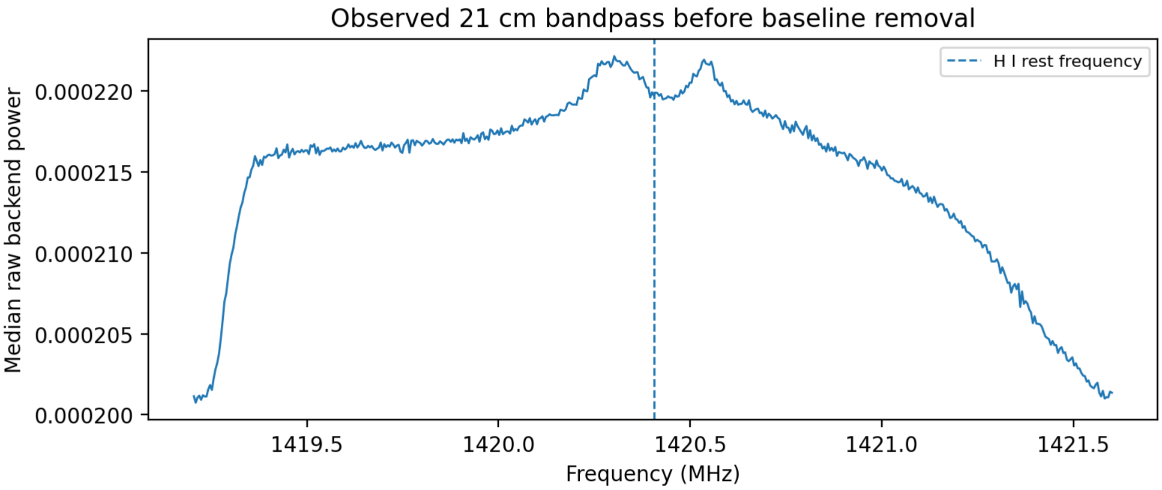
Approximate Galactic coordinates of the zenith track. Times affect coordinates, not the spectral detection.

2. Spectral sampling

The spectrometer returned 512 frequency channels with spacing 4.6875 kHz. At 1420 MHz, this corresponds to a velocity spacing of 0.989 km/s. This is finer than the broad features seen by the 7 degree beam, so spectral resolution is not the limiting factor in this observation.

Channel-to-velocity conversion

```
Delta_v = c * Delta_nu / nu0
= 299792.458 km/s * 0.0046875 MHz / 1420.40575177 MHz
= 0.989 km/s per channel
```



Median raw power spectrum. Baseline structure dominates the line amplitude, so bandpass subtraction is essential.

Measurement model

A compact model for each observed spectrum is the sum of a smooth instrumental/continuum term, a line term, and noise. Because this report does not have an independent calibration, the units are backend-relative.

Relative-power spectrum model

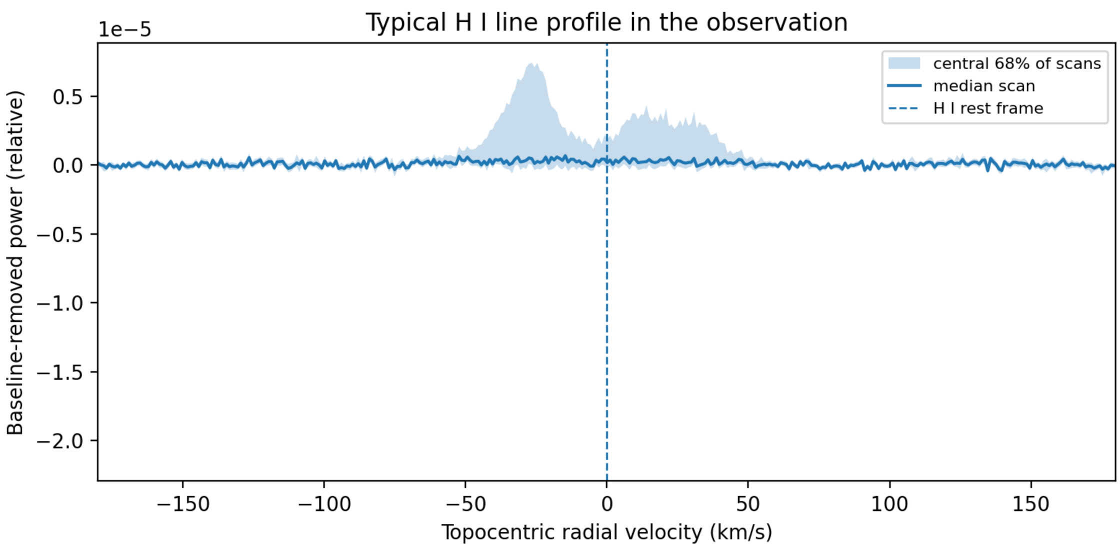
```
P_i(nu) = G_i(nu) [T_rx + T_sky(nu,t_i) + T_HI(nu,t_i)] + epsilon_i(nu)
B_i(nu) approx smooth bandpass/continuum model
R_i(nu) = P_i(nu) - B_i(nu)
```

3. Topocentric radio velocity

The figures use the radio definition of radial velocity. In this convention, emission observed below the rest frequency has positive velocity and emission observed above the rest frequency has negative velocity. No heliocentric, barycentric, or Local Standard of Rest correction has been applied.

Velocity convention

```
v_topo = c * (nu0 - nu_obs) / nu0
nu_obs = nu0 * (1 - v_topo/c)
v_LSR = v_topo + v_corr(t, RA, Dec) [not applied here]
```



Median residual profile plotted against topocentric radio velocity.

Practical implication

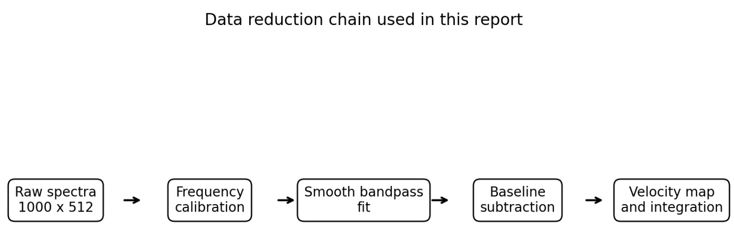
- Topocentric velocities are acceptable for internal detection plots and repeatability checks.
- For comparison to professional H I surveys, recompute the velocity axis in the same frame used by the survey, usually LSR.
- Because the observation spans more than a day, the barycentric/LSR correction is not exactly constant across all spectra.

4. Smooth baseline removal

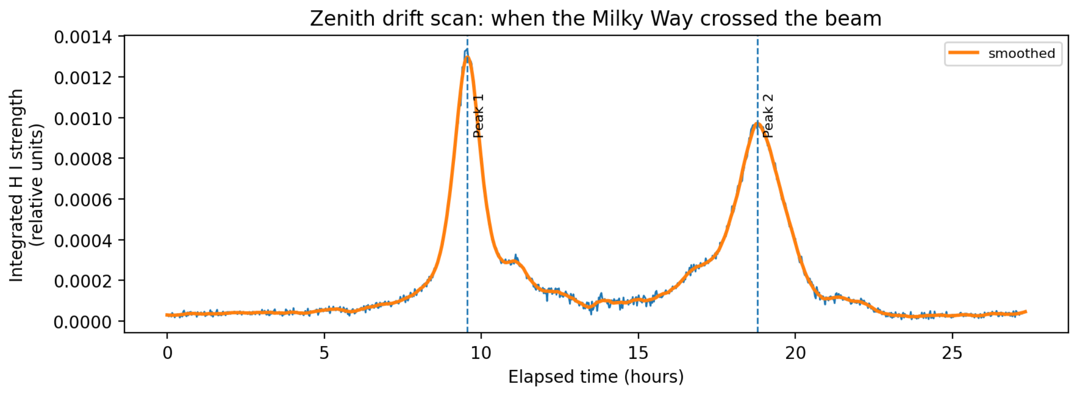
Single-dish H I spectra usually require bandpass correction because the receiver and analog/digital signal chain imprint a smooth spectral shape. The approach used here subtracts a smooth baseline from each spectrum and analyzes the residual line window. This preserves line-like structure while suppressing broad instrumental curvature.

Line extraction definitions

```
Fit or estimate B_i(nu) using line-free or smoothly varying channels.
Residual: R_i(v_j) = P_i(v_j) - B_i(v_j)
Integrated line proxy: S_i = sum_{v1 < v_j < v2} R_i(v_j) * Delta_v
Here: v1 = -160 km/s, v2 = +160 km/s.
```



Reduction chain. The product is a relative line-strength and velocity data set, not a flux-calibrated cube.



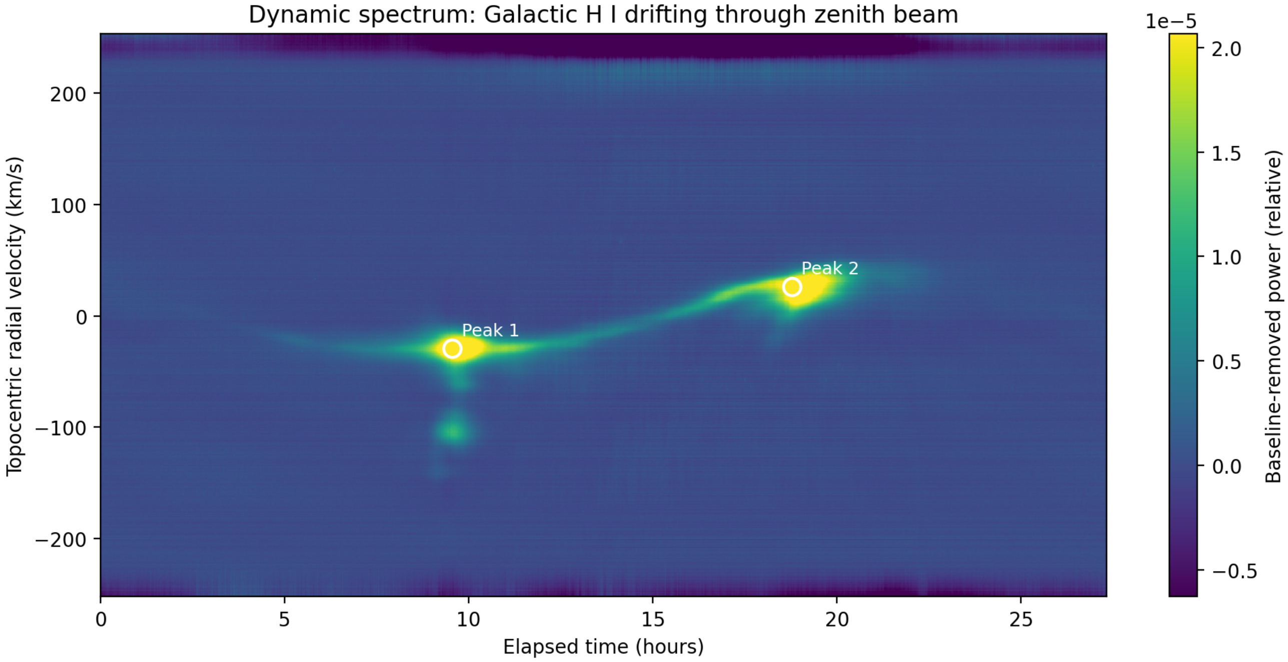
Integrated residual line proxy S_i versus time. Vertical markers show the strongest windows.

Baseline systematic

Caution: excessive baseline flexibility can remove broad real H I emission; insufficient flexibility leaves bandpass residuals. A future reduction should test polynomial order, masked velocity windows, and reference spectra.

5. Drift-scan H I detections

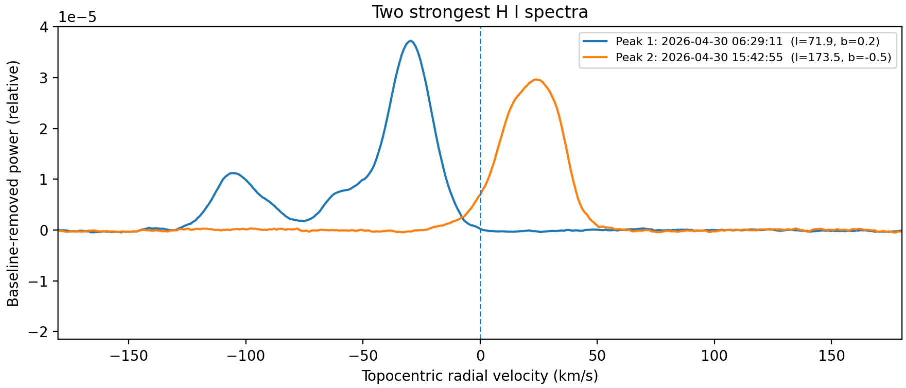
The dynamic spectrum displays residual power as a function of elapsed time and velocity. The two brightest windows are not isolated one-channel spikes; they extend across time and velocity, a morphology expected from Galactic H I entering and leaving a broad beam.



Dynamic spectrum with strongest windows marked. These are the primary detection products.

Peak-window measurements

Window 1	t=2026-04-30 06:29:11, l=71.9, b=0.2, v_peak=-29.5 km/s
Window 2	t=2026-04-30 15:42:55, l=173.5, b=-0.5, v_peak=25.9 km/s



Strongest spectra. Velocity differences reflect Galactic kinematics and beam direction, not instrumental retuning.

6. Radiometer sensitivity

The ideal radiometer equation states that random noise decreases as the square root of bandwidth times integration time. This is the reason averaging spectra or stacking repeated sidereal scans improves detectability. In practice, gain drift, RFI, standing waves, and imperfect baseline subtraction often dominate over the ideal thermal noise floor.

Ideal total-power radiometer scaling

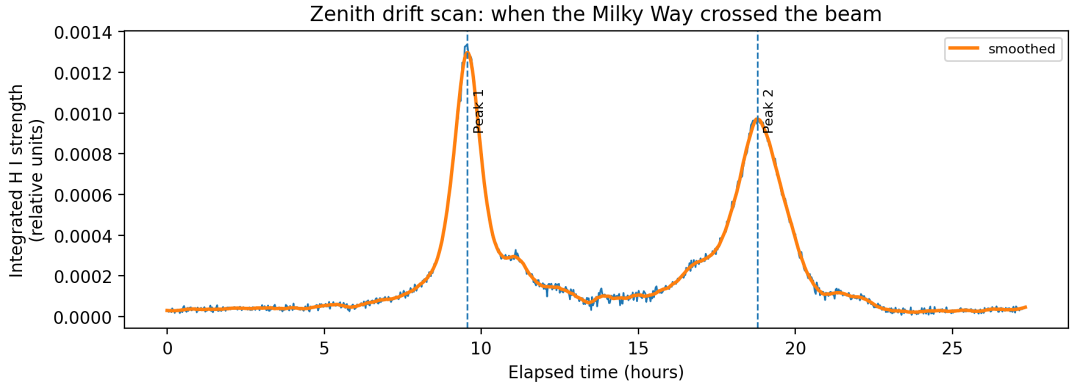
```
sigma_T = T_sys / sqrt(Delta_nu * tau)
SNR approx T_line / sigma_T
For N independent spectra stacked at the same sky position:
sigma_stack approx sigma_single / sqrt(N)
```

Calibration path

To convert the relative residual power into antenna temperature, measure the receiver response to two known loads or inject a calibrated noise source. A simple Y-factor estimate of receiver temperature is:

Hot/cold calibration sketch

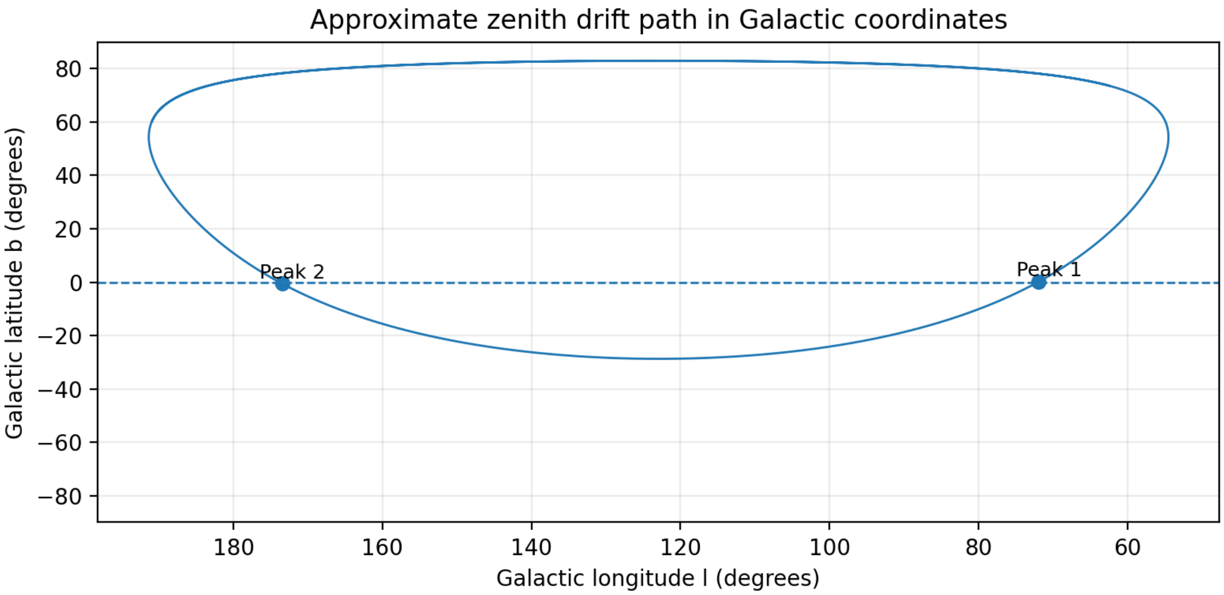
```
Y = V_hot / V_cold
T_rx = (T_hot - Y*T_cold) / (Y - 1)
T_A,line approx (V_line/GkDelta_nu) after gain calibration
```



Signal repeatability and stacking should be evaluated in local sidereal time.

7. Sky path and Galactic interpretation

The strongest windows occur close to the Galactic plane in the approximate coordinate solution. This is physically sensible: neutral hydrogen is concentrated in the Galactic disk, and a broad beam crossing the plane should show enhanced 21 cm emission.



The zenith path crosses the Galactic plane near the two strongest H I windows.

Comparison to professional surveys

- Convert each spectrum from topocentric velocity to LSR velocity.
- Convolve or smooth reference survey spectra to the approximate 7 degree beam, or at minimum average nearby survey pixels.
- Compare line centroids, broad velocity extent, and relative intensity as a function of Galactic longitude.
- Do not compare absolute brightness until calibration is added.

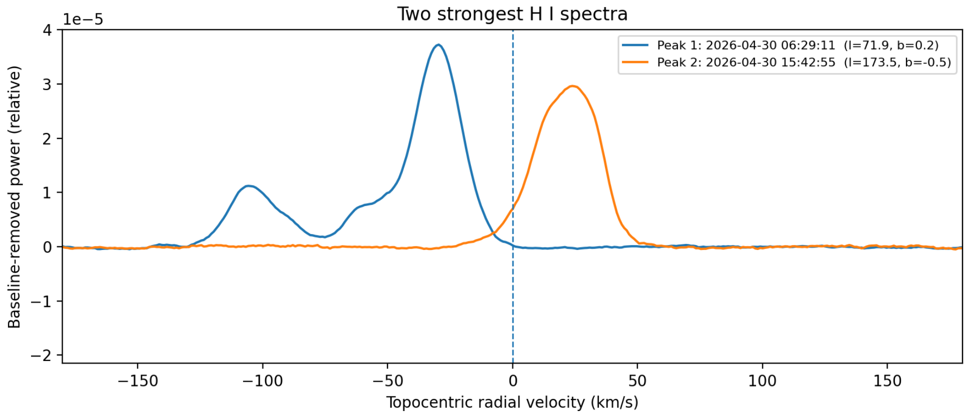
Future column-density formula

```
For an optically thin, calibrated H I line:
N_HI [cm^-2] = 1.823e18 * integral T_B(v) dv [K km/s]
This report does not compute N_HI because T_B calibration is unavailable.
```

8. What can bias the result?

The data contain a clear line detection, but scientific interpretation is limited by calibration and by the known difficulties of total-power single-dish measurements. The most important uncertainties are listed below.

- Bandpass and gain drift: slow changes can mimic broad changes in integrated residual power.
- Standing waves: cable or dish-feed reflections can create sinusoidal spectral ripples.
- Radio-frequency interference: narrowband transmitters can masquerade as spectral lines if they are persistent or drift.
- Beam uncertainty: the 7 degree beam is a diffraction estimate, not a measured beam map.
- Velocity frame: topocentric velocities should not be mixed with LSR survey velocities.
- Absolute scale: without calibration, the residual power cannot be converted to Kelvin or Jansky.



Line morphology helps distinguish broad Galactic emission from single-channel RFI, but repeat observations are still needed.

Key validation test

The best validation is sidereal repeatability: the same H I structures should return at the same local sidereal time on different observing dates.

9. Conclusions

- The data show a strong detection of Galactic neutral hydrogen in the 21 cm band.
- The observation spans 27.319 hours with 1,000 spectra and a velocity coverage of roughly +/- 253 km/s.
- The strongest residual windows occur near 2026-04-30 06:29:11 and 2026-04-30 15:42:55.
- The most valuable upgrade is calibration, followed by multi-night sidereal stacking and LSR-corrected survey comparison.

Recommended analysis extensions

- Re-reduce with several baseline models and quantify how peak velocities and integrated line strengths change.
- Compute an RFI mask using time-frequency outlier detection and compare masked/unmasked products.
- Make a sidereal-time waterfall from multiple nights.
- Measure the beam empirically by drifting across the Sun at a suitable frequency or across strong continuum sources if possible.
- Add hot/cold or noise-diode calibration and derive T_A(v), then estimate optically thin H I column density along the drift path.

References and source material

- User observation data: MLO-Lewin_20260429_451000_1000.zip; supplied timelapse MPEG.
- G. Verschuur, The Invisible Universe, Springer, 2015 - 21 cm line background.
- J. J. Condon and S. M. Ransom, Essential Radio Astronomy, Princeton University Press, 2016 - radiometers, radiometer equation, atmospheric windows.
- ITU-R Handbook on Radio Astronomy, 3rd ed., 2013 - characteristics of radio astronomy observations and H I line context.
- B. F. Burke, F. Graham-Smith, and P. N. Wilkinson, An Introduction to Radio Astronomy, 4th ed., Cambridge University Press, 2019 - single-dish and spectral-line context.

Final assessment

Scientific bottom line: this is a credible H I detection data set. With calibration and repeat scans, it can become a quantitative amateur radio astronomy survey product.