EDGES / Dawn

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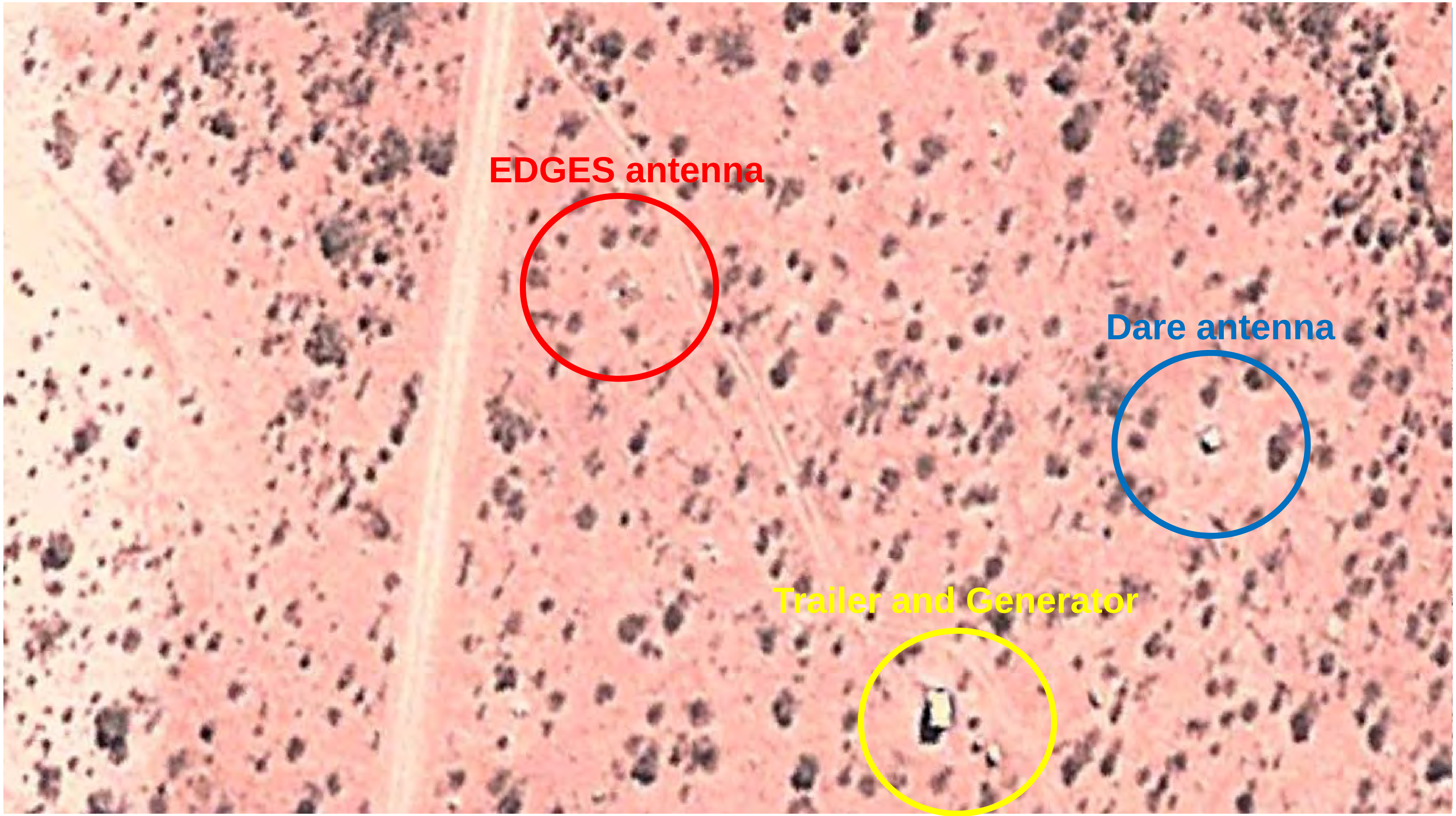
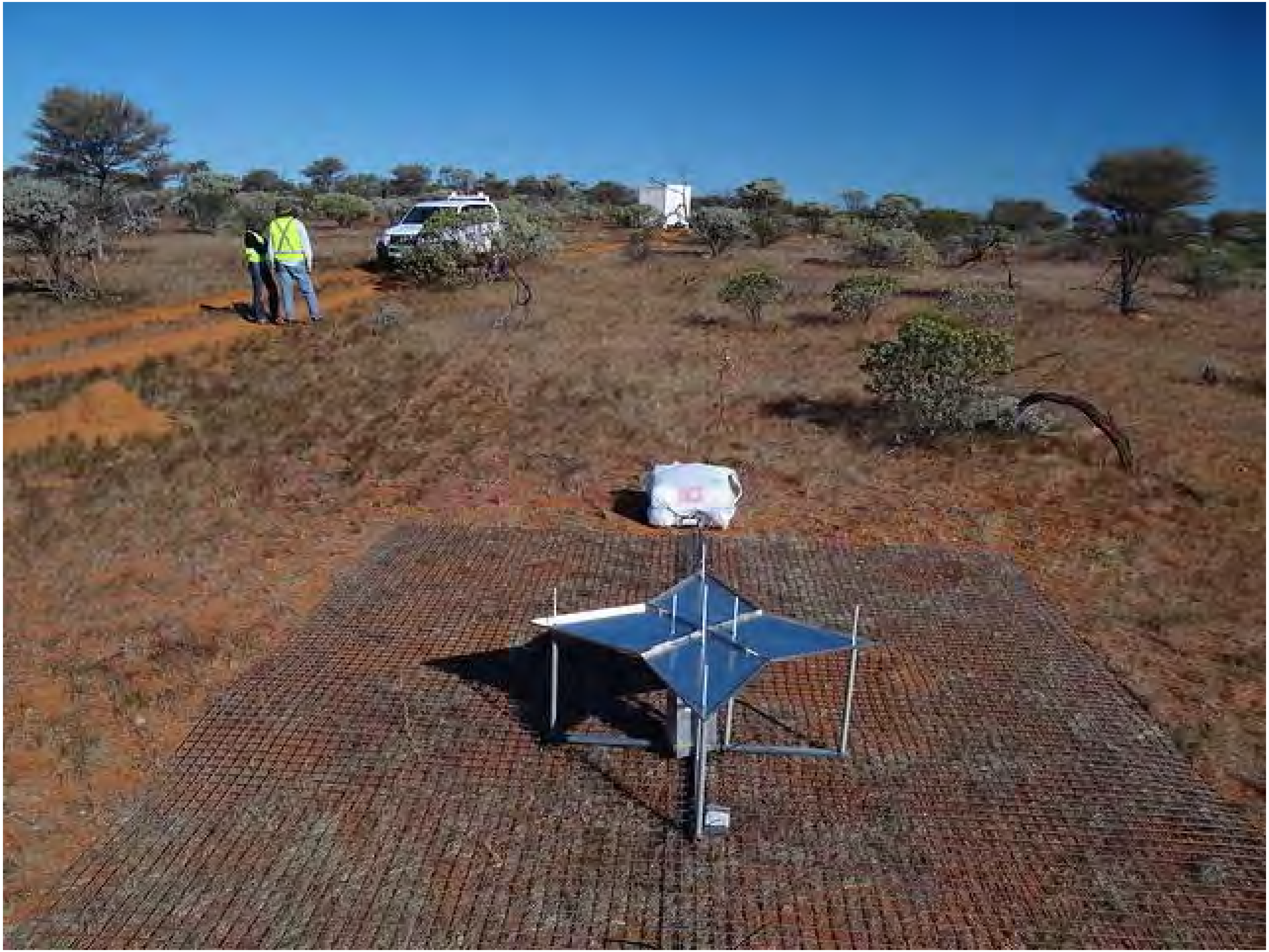
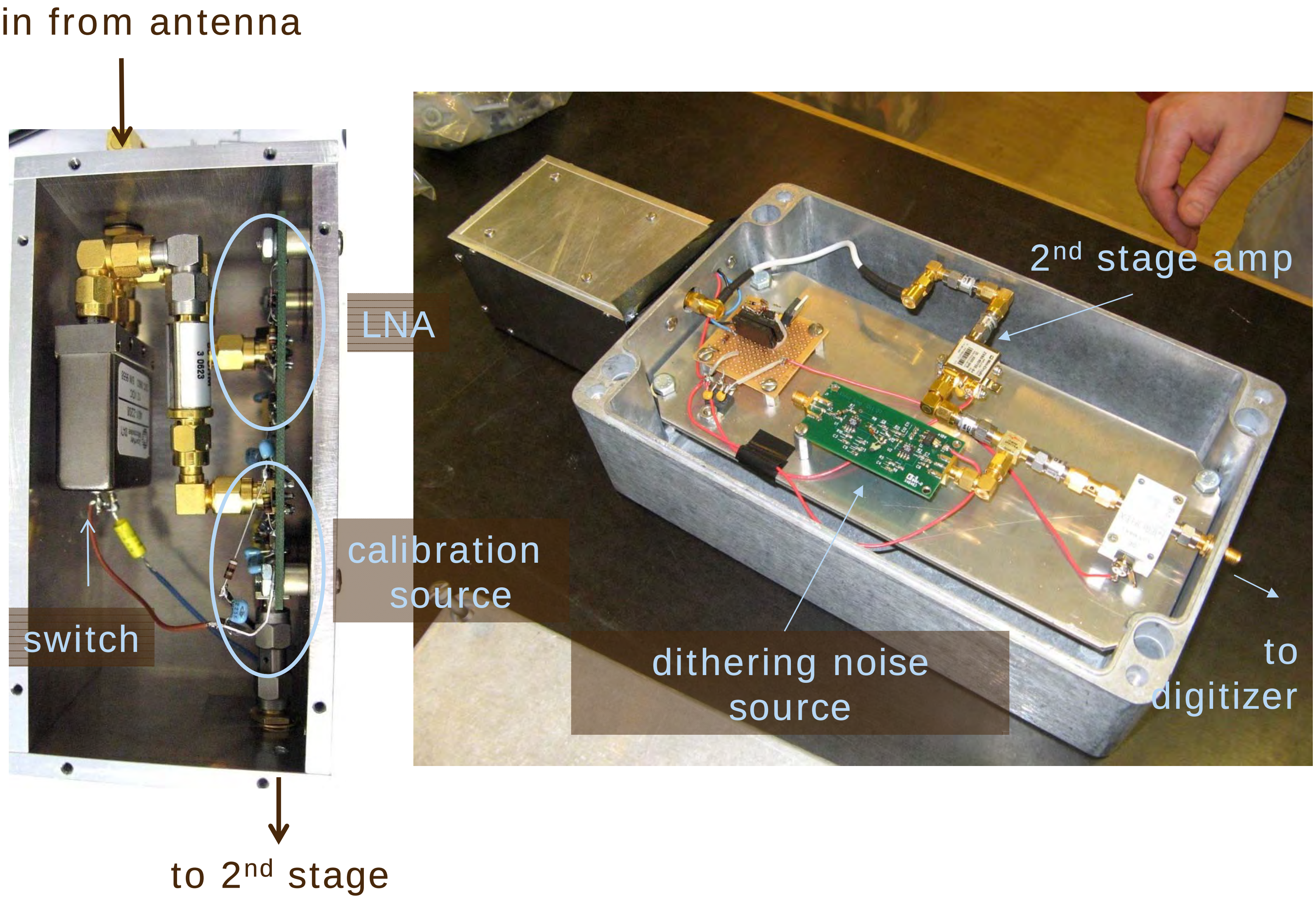
EDGES (and DARE) at MRO



26º 42’ 31 S,   116º 38’ 02 E

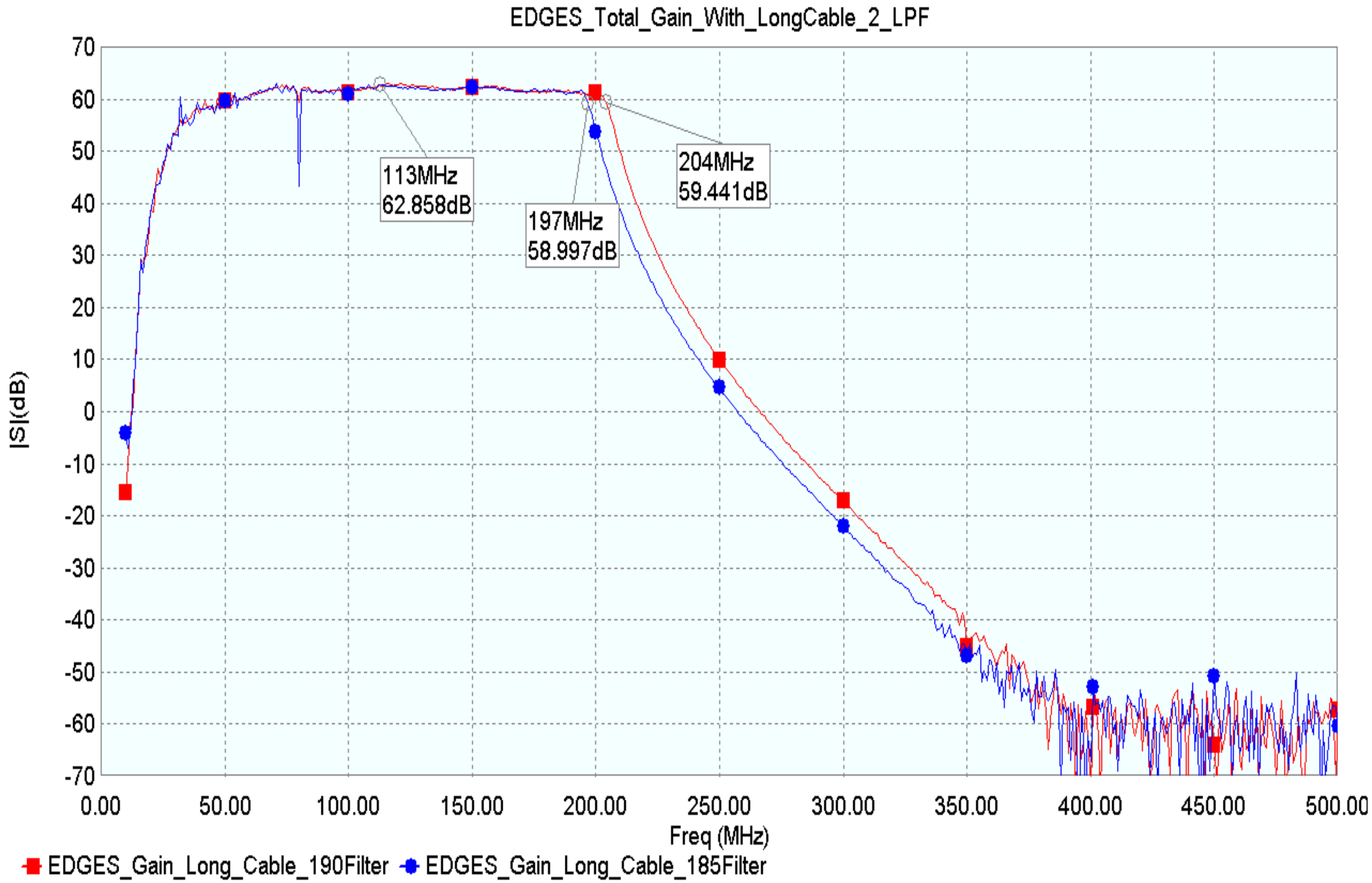



DIESEL ONLY
S.F.L. 1000LT
COMBUSTIBLE
LIQUID C1



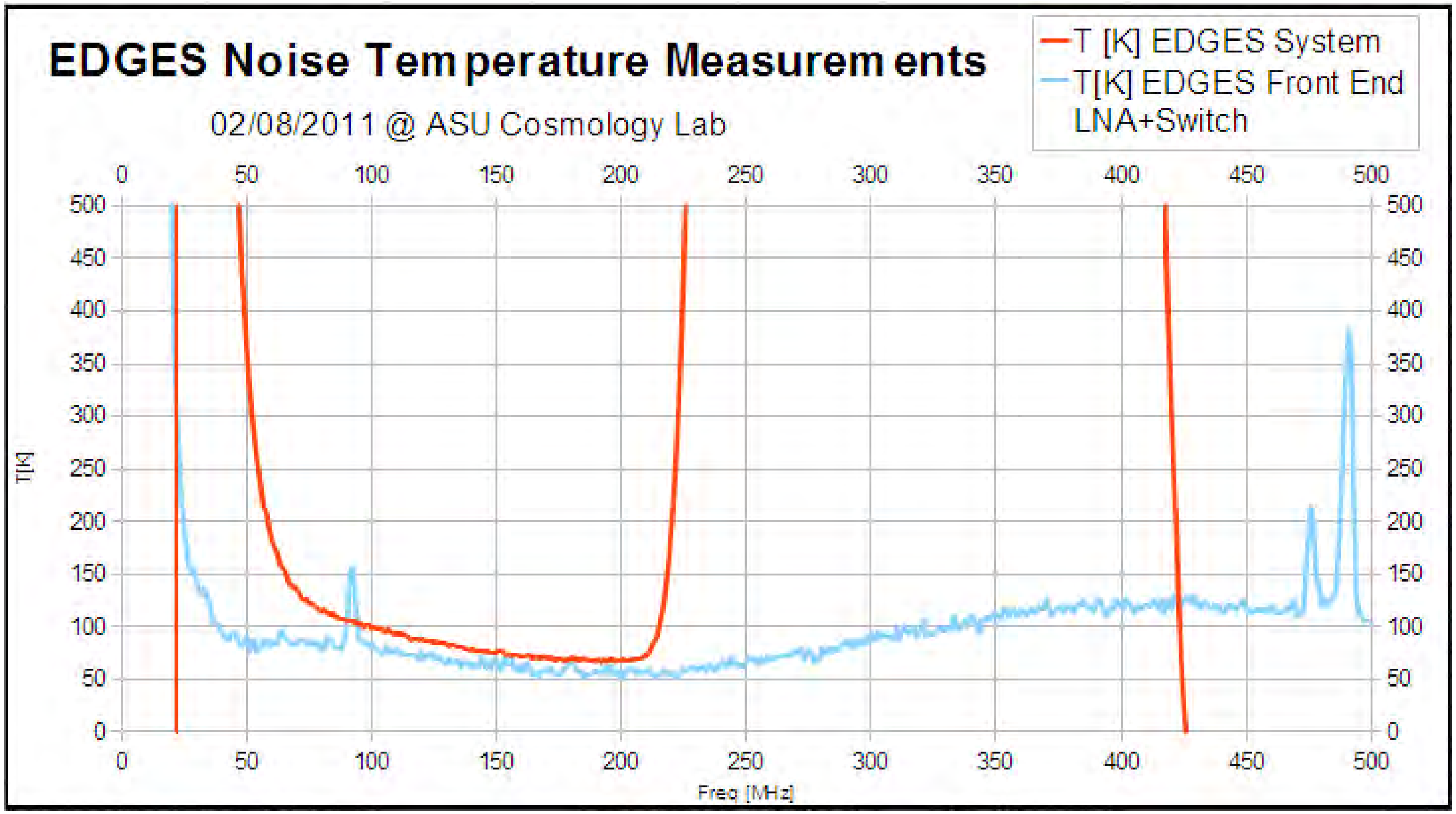
in from antenna
LNA
calibration source
switch
to 2nd stage
2nd stage amp
dithering noise source
to digitizer

System gain



Hamdi Mani

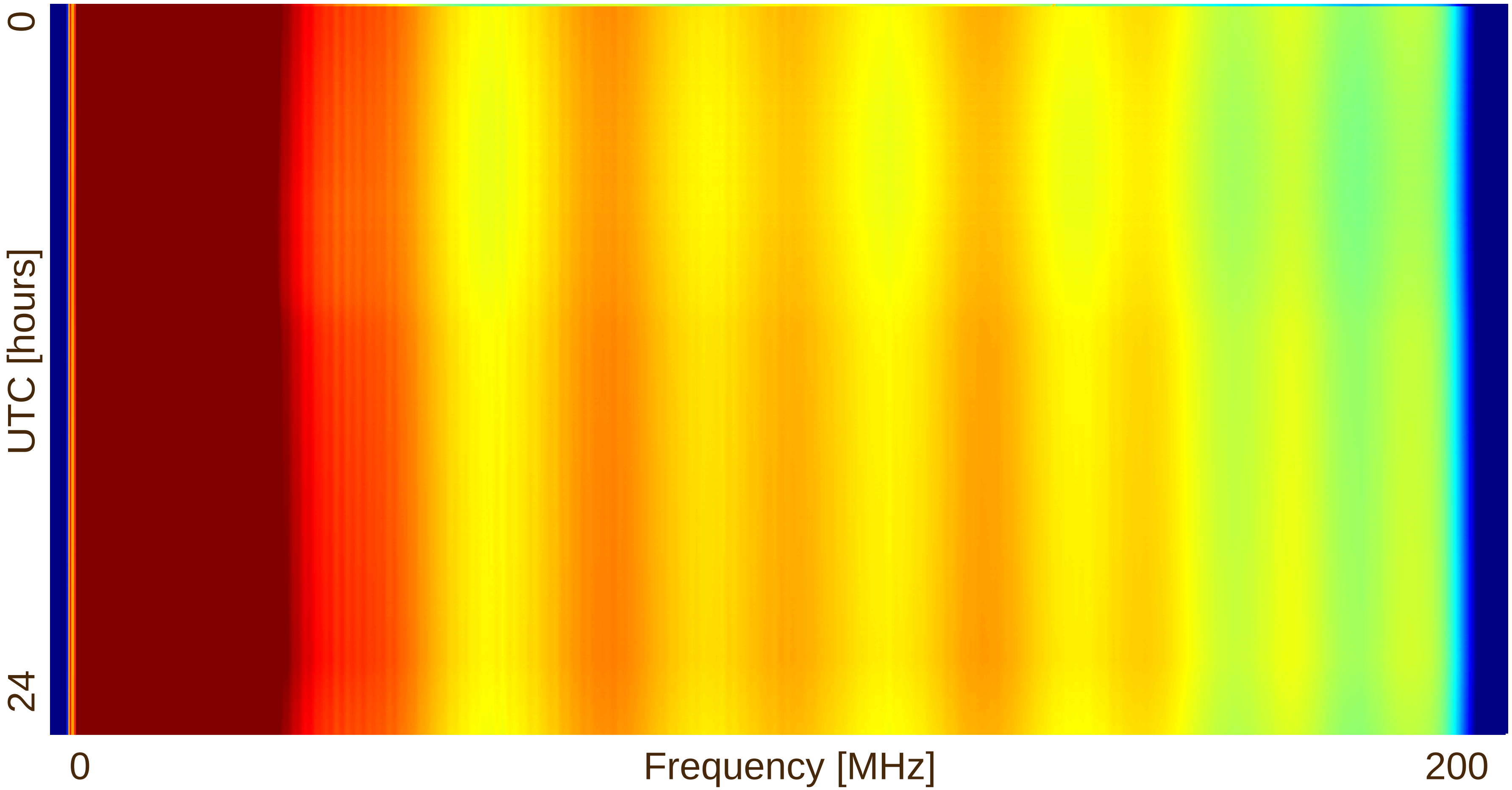
Receiver temperature



Hamdi Mani

3-position switch data

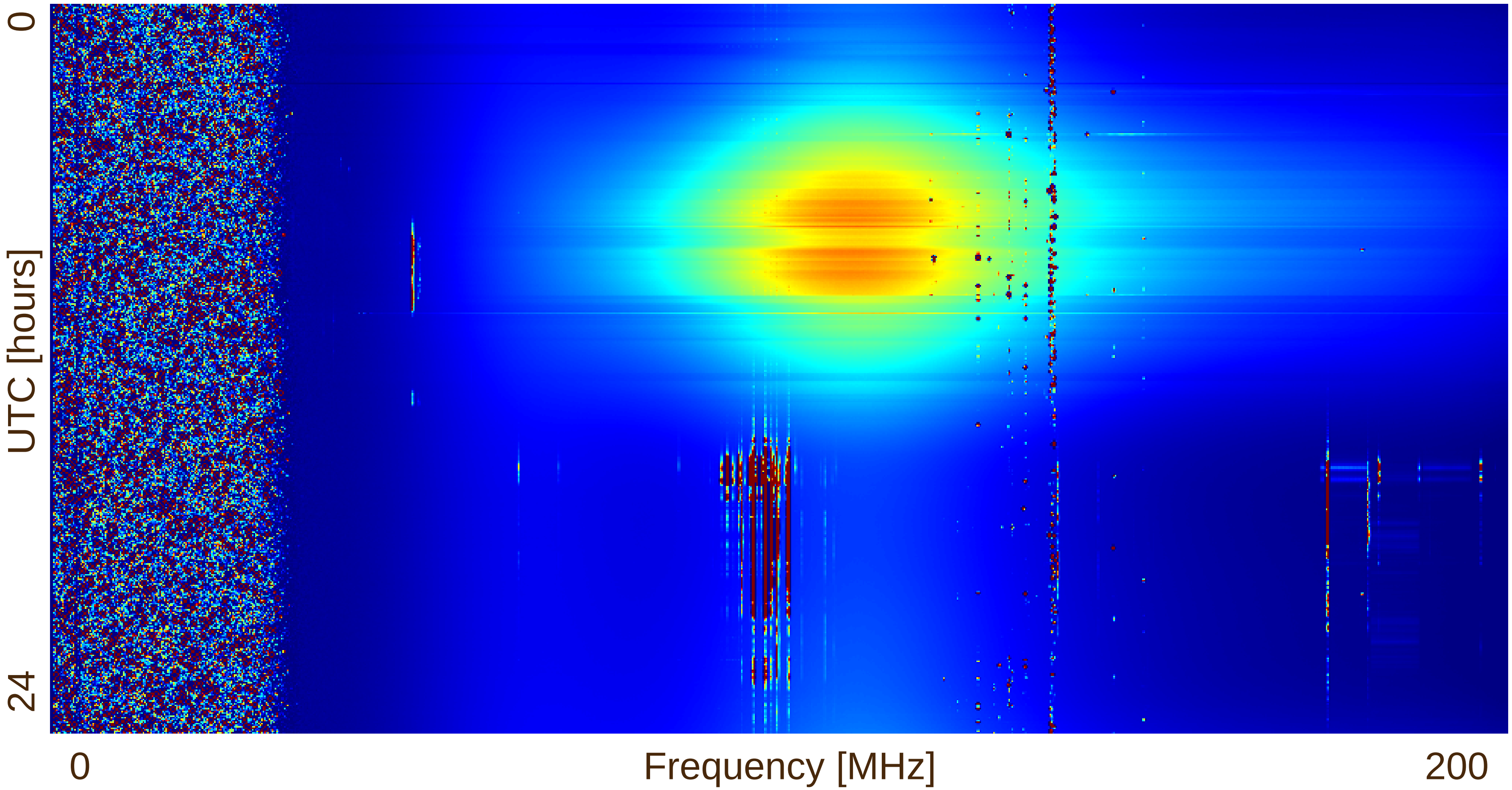
07-Nov-2012
P0 - sky
P1 - cold
P2 - hot



http://loco.lab.asu.edu/edges

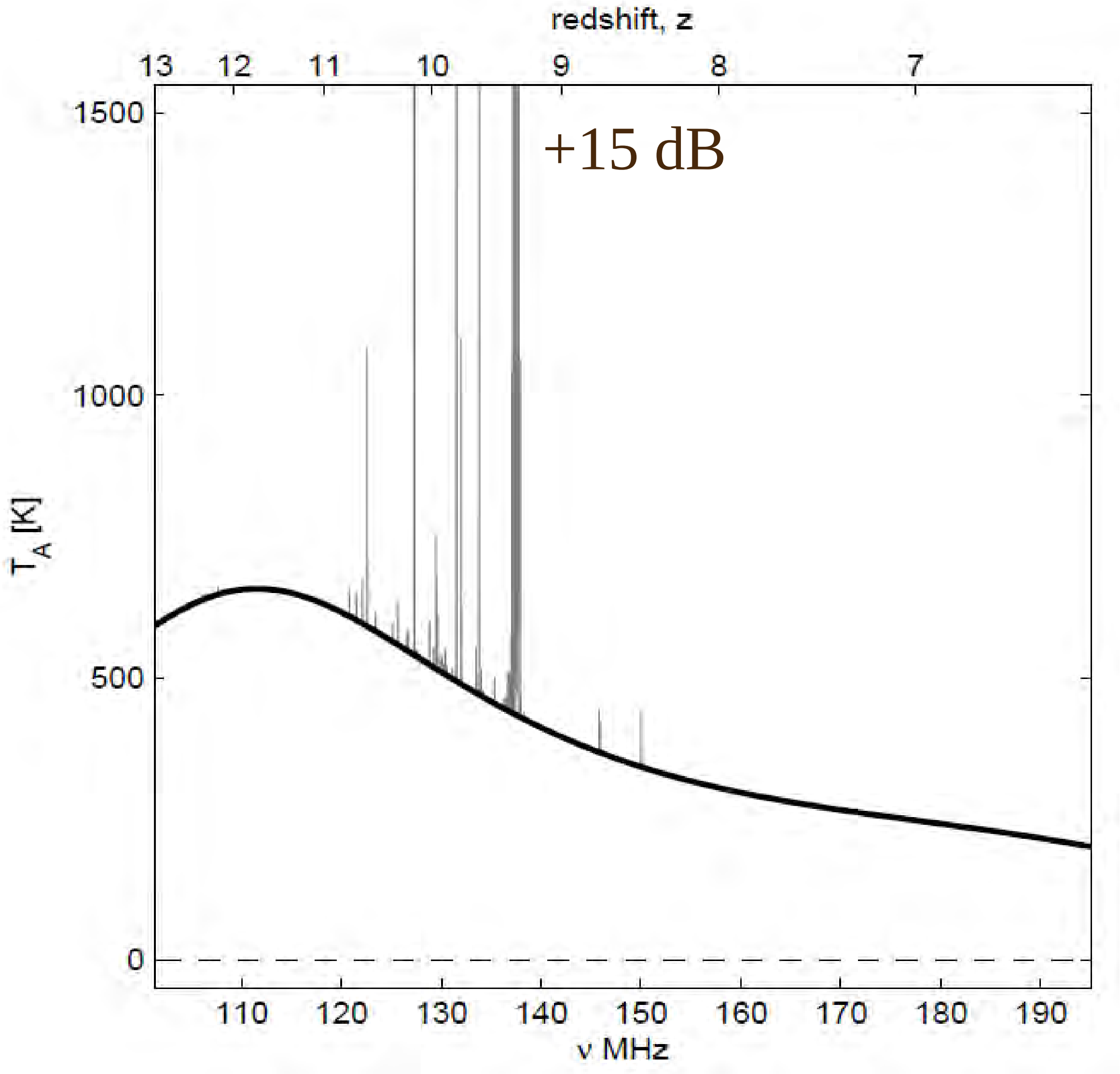
Example data

07-Nov-2012
28-Oct-2012
21-Oct-2012



http://loco.lab.asu.edu/edges

EDGES-1 results



Murchison Radio-astronomy Observatory (MRO)

Aug 20 – Oct 20, 2009

1440 wall-clock hours on sky

500 hours after RFI cuts

50 hours eff. integration

EDGES-1 results

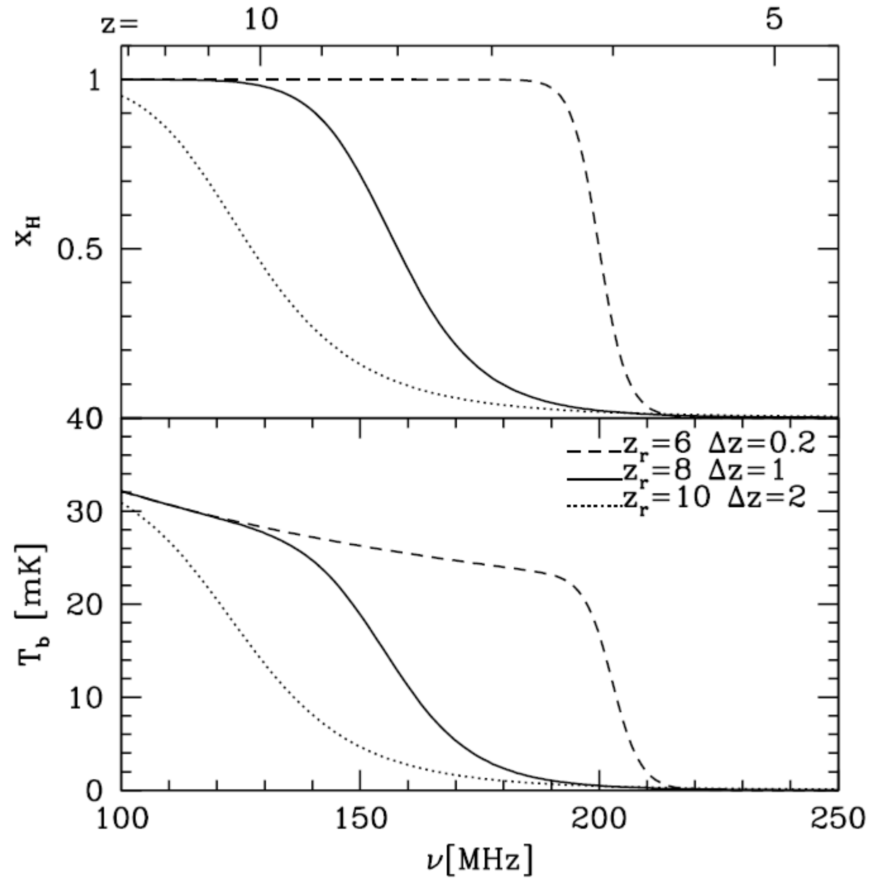
#1: 21 cm reionization model

$$T_b(z) = \frac{T_{21}}{2}\left(\frac{1+z}{10}\right)^{1/2}\left[\tanh\left(\frac{z-z_r}{\Delta z}\right)+1\right]$$

#2: Foreground model

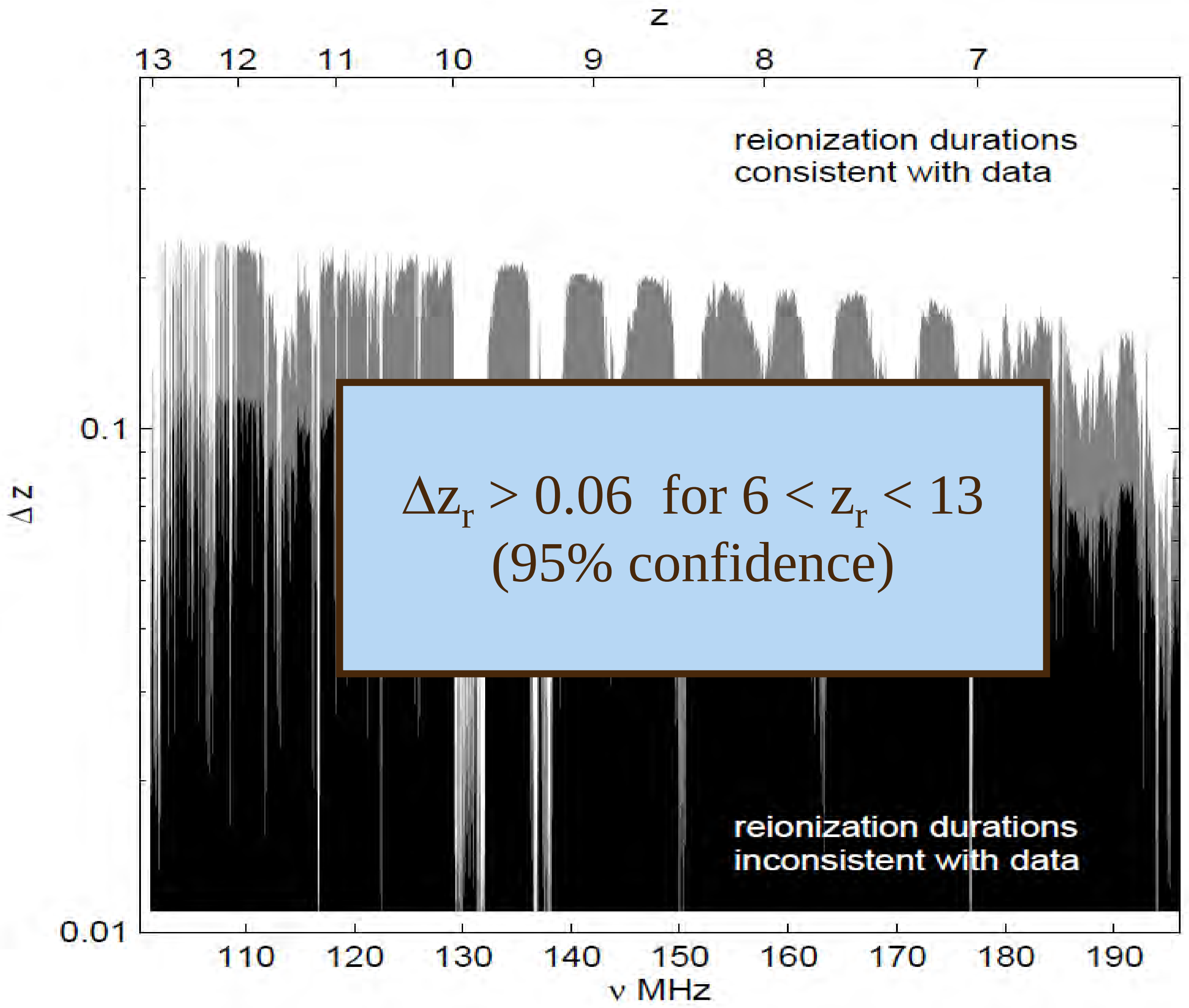
$$T_F = \sum_{n=0}^{m} a_n (1+z)^{-n}$$

2 science parameters: Δz and z_r
4-19 nuisance parameters: a_n



Pritchard & Loeb (2011)

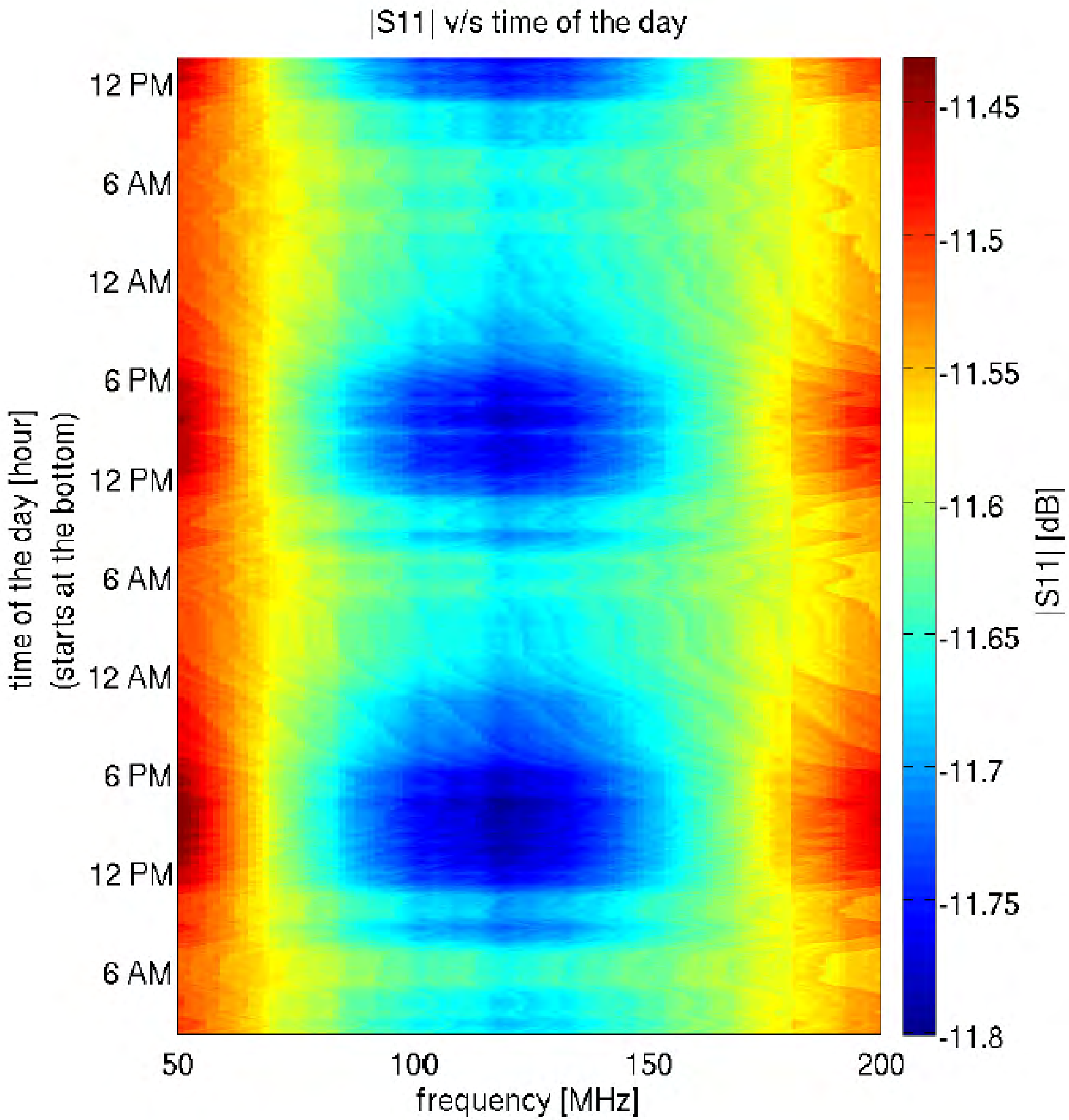
EDGES-1 results



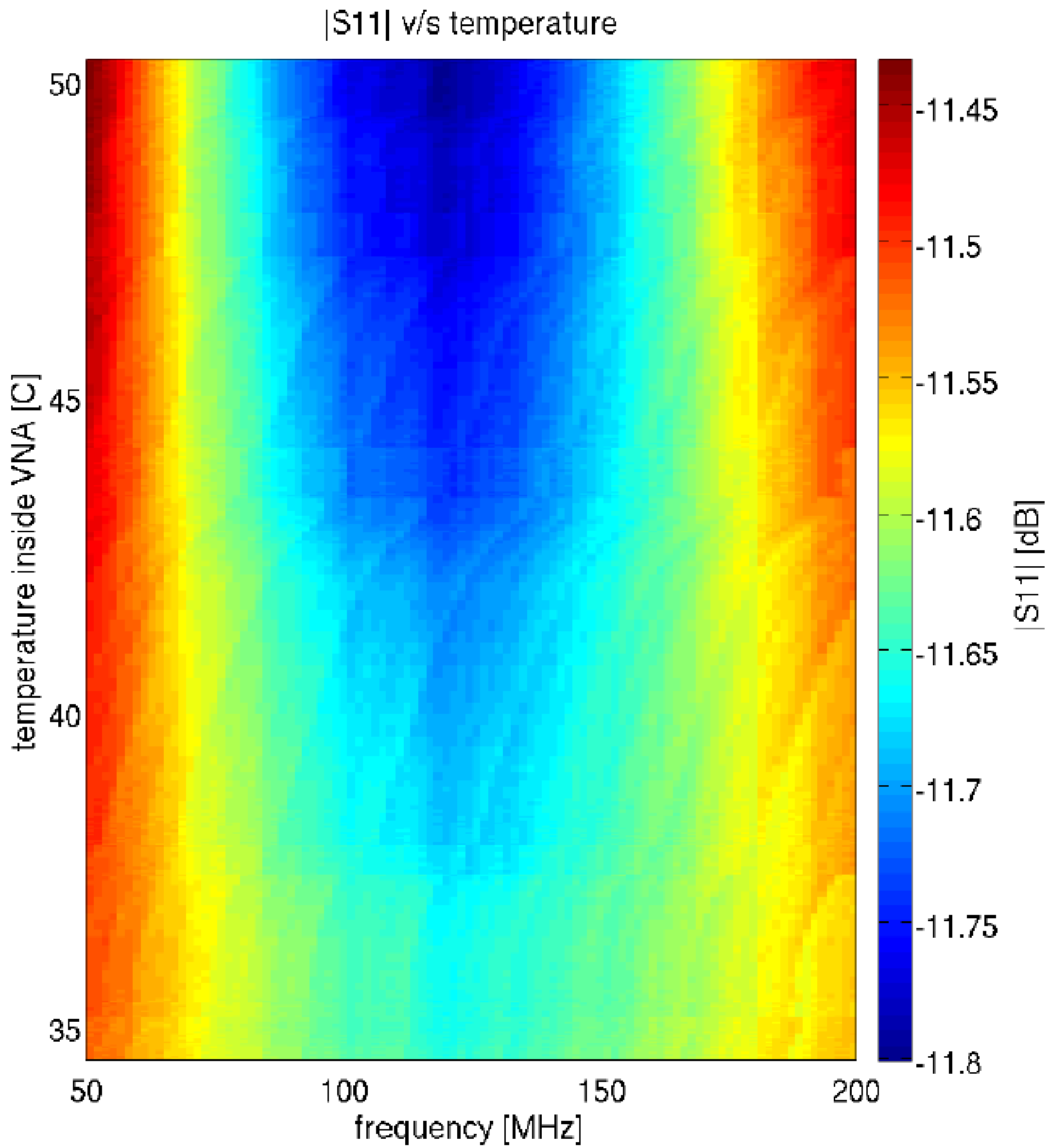
$\Delta z_r > 0.06$ for $6 < z_r < 13$
(95% confidence)

Bowman & Rogers, Nature, 468, 7325, pp. 796-798 (2010)

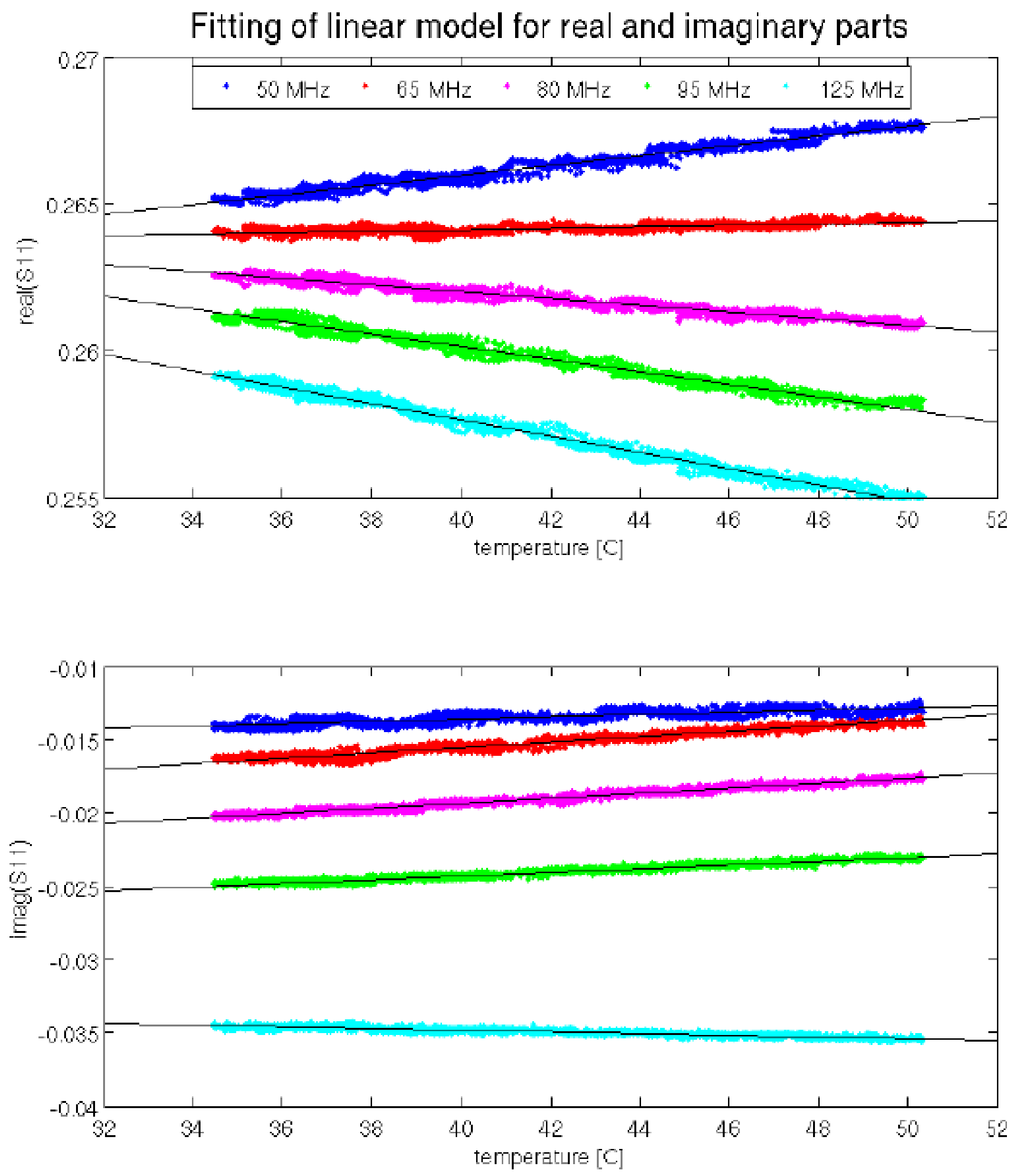
VNA temperature dependence



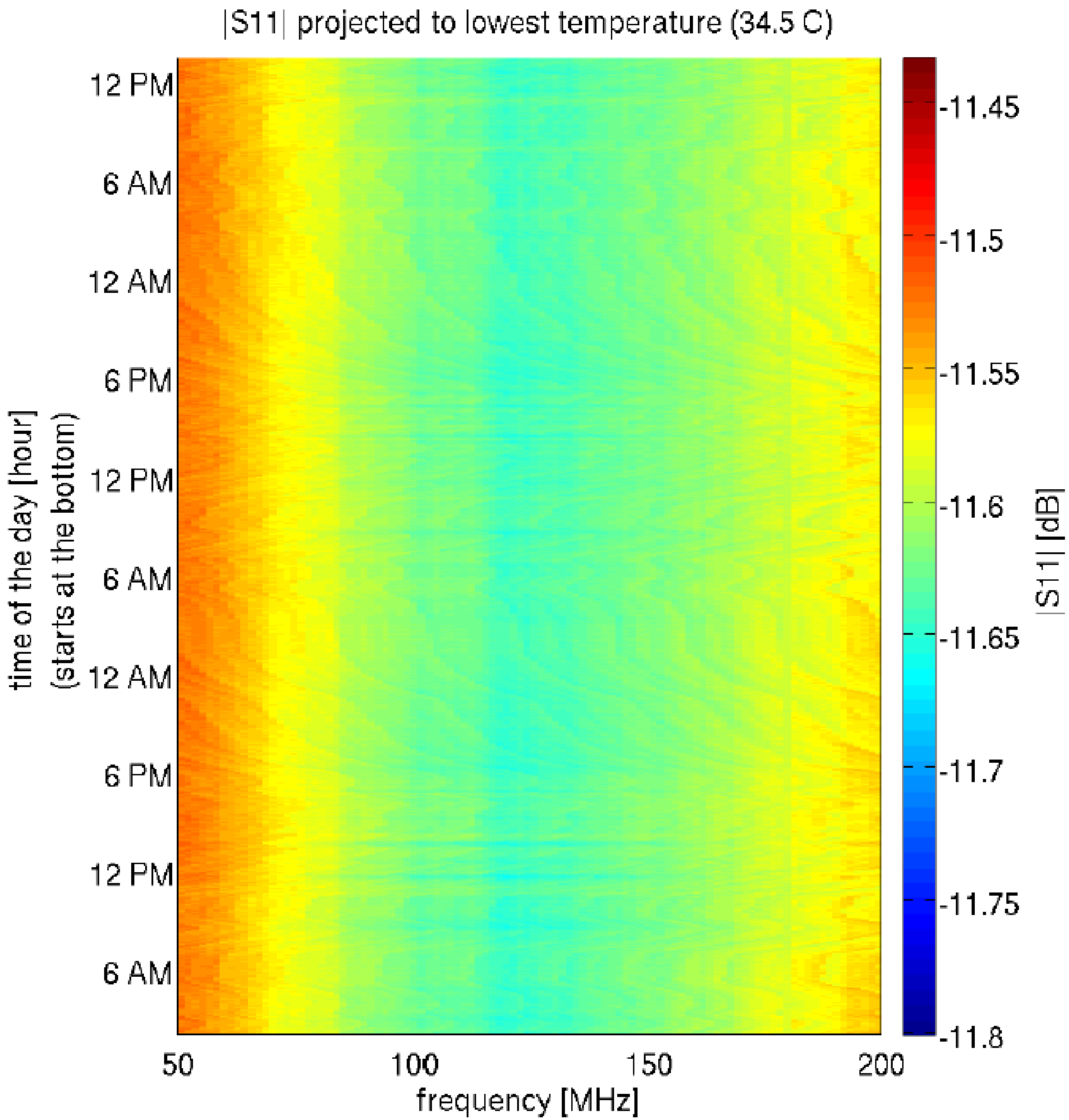
S11 temperature folding



VNA temperature fits



S11 temperature projection



EDGES summary

- EDGES-1 successfully demonstrated viable limits on reionization with only 3-position calibration (no accounting for reflection terms) and polynomial fitting
- Nearly 2-years of RFI (and other event) monitoring at MRO, posted at http://loco.lab.asu.edu/edges
- EDGES-2 attempting absolute calibration, expect first deployment by mid-2013
- Spin-offs including improved calibration and characterization of temperature-dependence of VNAs at low-frequencies, calibration of noise diodes, antenna simulator
  + The dependence of S11 on temperature is linear (for real and imaginary parts), but different for each value of frequency.
  + STD of the residuals is < 0.01 [dB] for |S11| and < 0.0015 [deg] for angle(S11).

Observing Cosmic Dawn with the LWA

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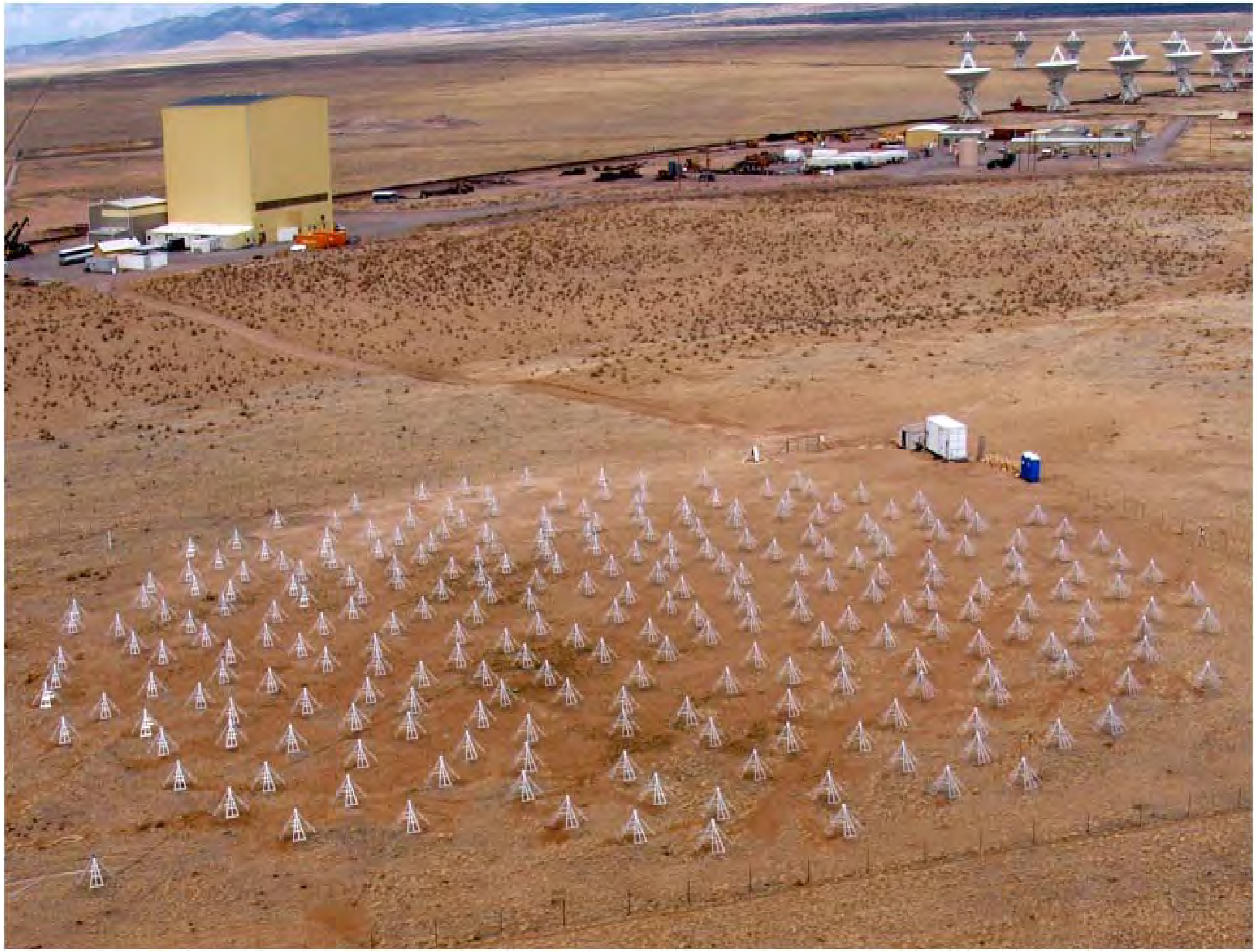
LWA-1:

- 256 dual-pol dipoles (and 1 outrigger)
- 10-88 MHz, 4 beams
- TBN (100 kHz, 100% duty) and TBW voltage capture



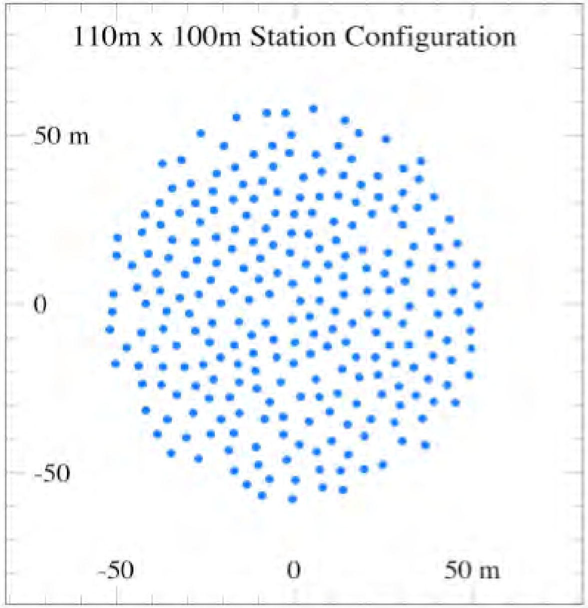
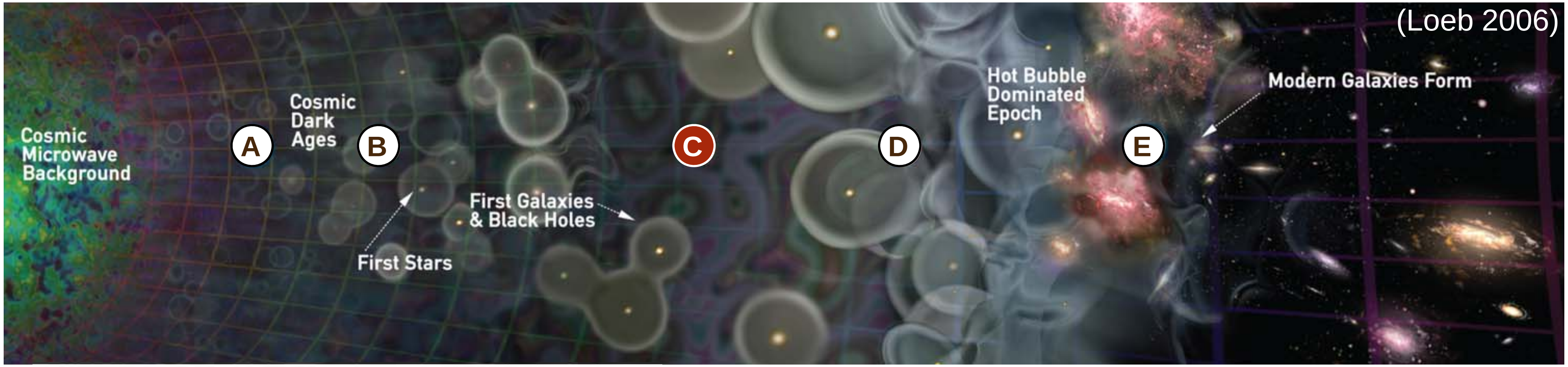
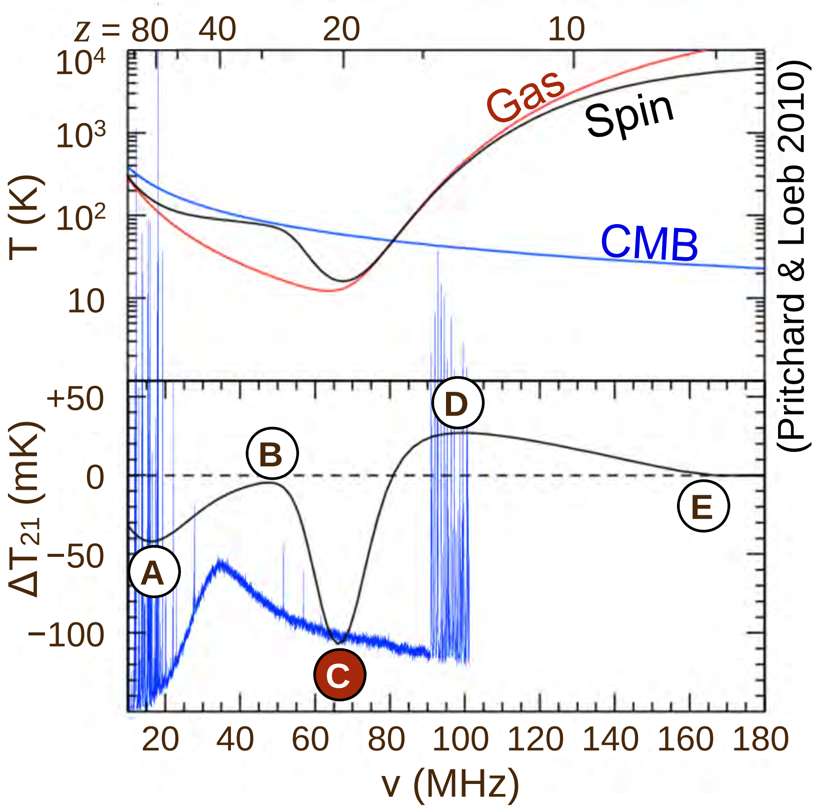


Table 1. Specifications for the LWA1

Specification	Details	Comments
Frequency range	10–88 MHz	
Number of beams	4	independently steerable and shapable
Number of tunings	2 per beam	tunable over 10–88 MHZ
Bandwidth per tuning	0.2–16 MHz	divided into 4096 channels
Polarization isolation	≥ 20 dB	dual circular polarizations
Baseline lengths	5–110 m	up to 385 m using an outrigger antenna
Beam width	$2^\circ \times (80\ \mathrm{MHz}/\nu)$	at zenith
Sky coverage	elevation $\geq 20^\circ$	antenna gain < 0 dB below 20°
Temporal resolution	1 ms	
Thermal noise	20 mJy	1 hr integration at zenith, 8 MHz BW, 74 MHz center freq, dual polarization
Confusion noise	25 Jy	for a 2° beam at 80 MHz, at zenith

LWA



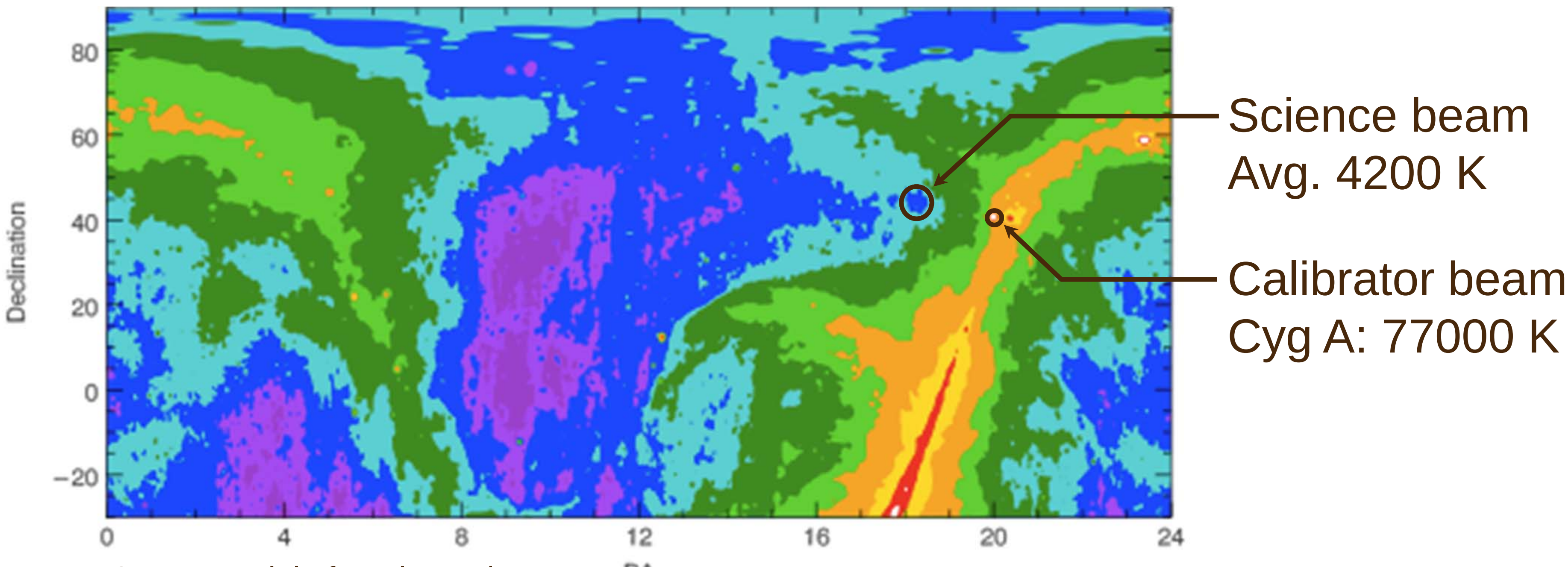


$$\Delta T_{21} \approx x_{HI}\left(1-\frac{T_{CMB}}{T_S}\right)\times 30\,\mathrm{mK}$$

LWA Long Wavelength Array

Experiment strategy

- Observations will use four beamformers to make two effective beam, each spanning ~40 MHz, up to 500 hours of integration
- Science beam targets relatively cold region of the sky
- Calibrator beam targets bright, smooth spectrum source
- Beams are large enough to average over angular variations



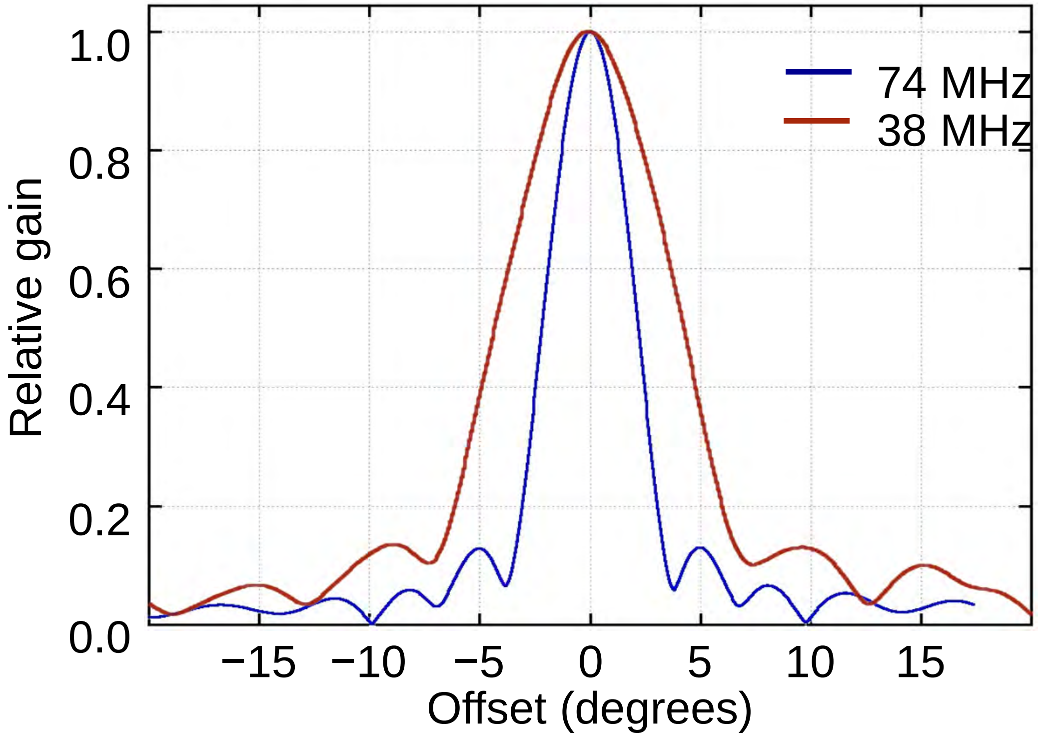
50 MHz model of northern sky

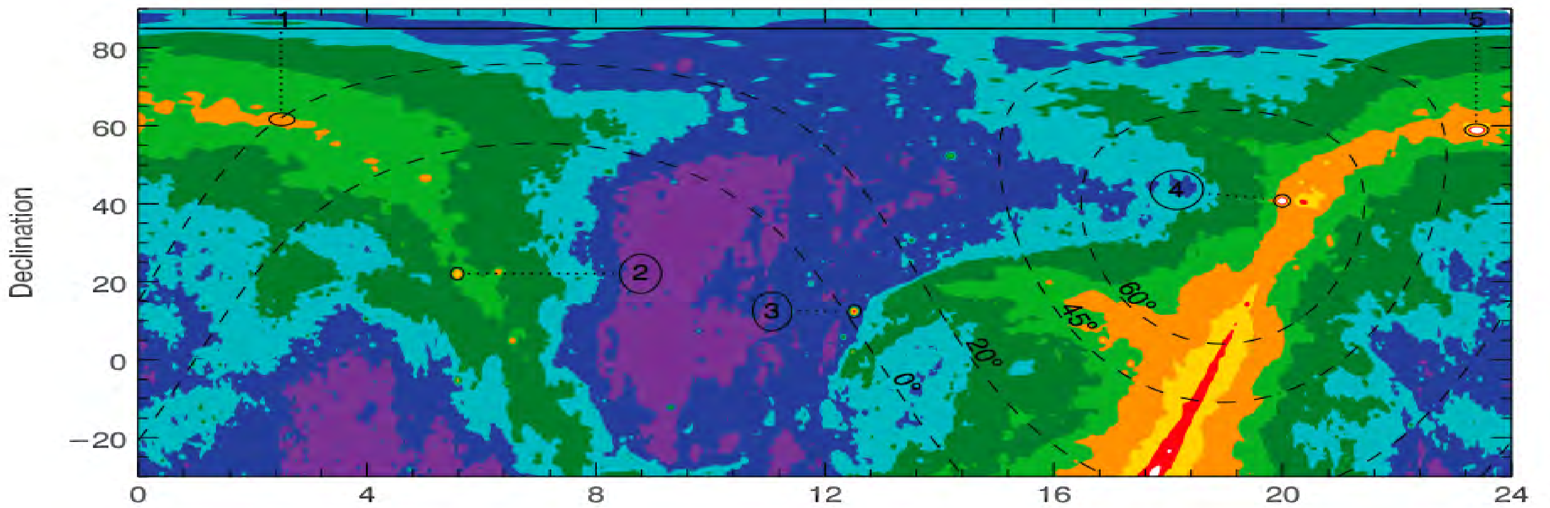
(Oliveira-Costa et al. 2008)

LWA Long Wavelength Array

Sidelobes

- Chromatic variation of beam couples foreground structure to spectrum
- Much larger sidelobes (10%) than single dipole experiments





Beamforming

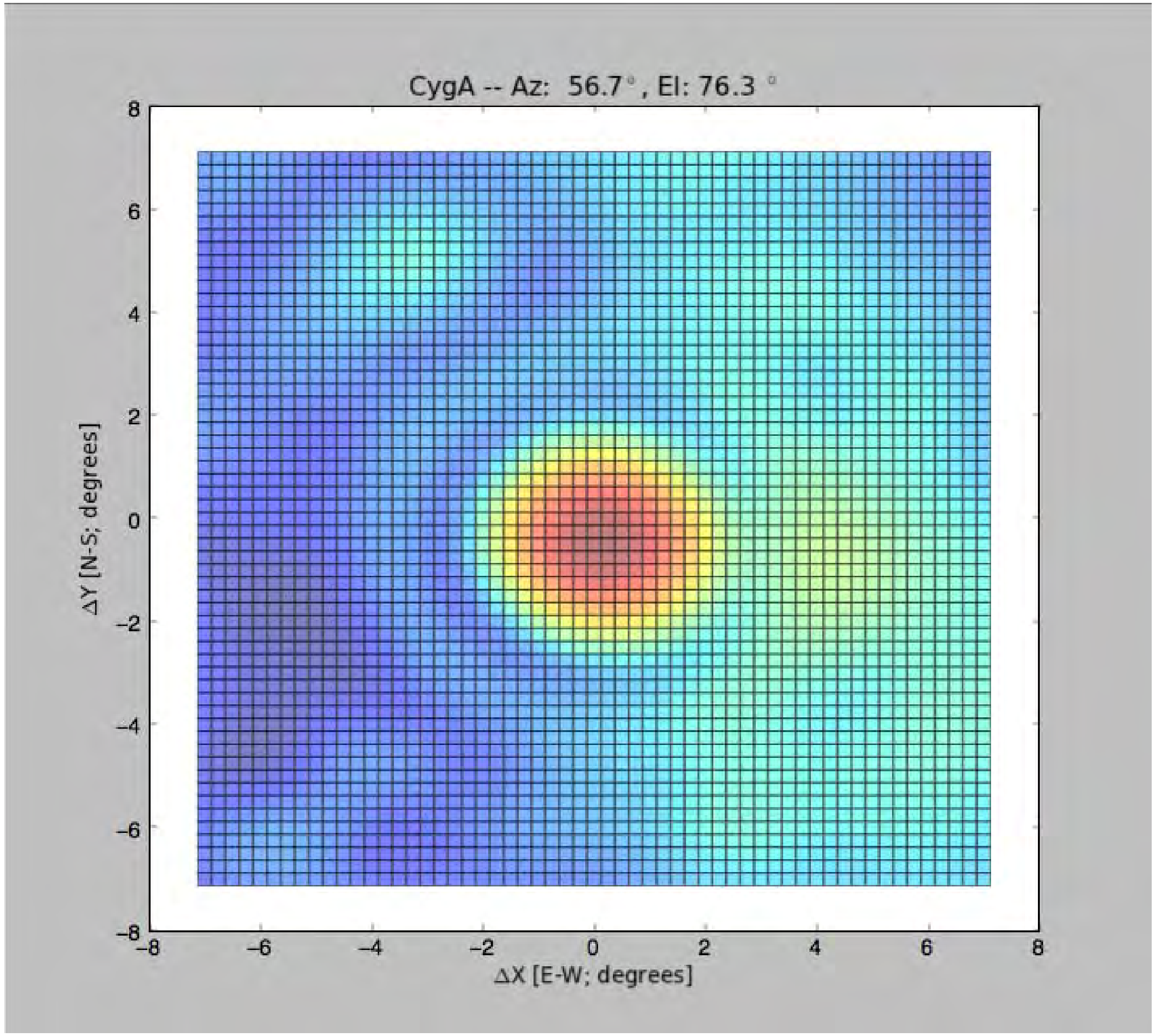
Goal: Prevent frequency-dependent variations in sidelobes from coupling foreground angular structure into spectrum

Techniques planned for investigation:

1. Defocusing primary beam averages over more foreground, can lower sidelobe power. Option of heterogeneous beams
2. Steering sidelobes away from bright sources. Requires excellent model of the electromagnetic profile of station
3. Sidelob blurring by continuously varying weighting coefficients to constantly "shimmer" sidelobes
4. Optimal beamforming by accounting for mutual coupling

Raster Mapping

Use bright source in TBN data to map structure of sidelobes --- “Pseudo-beam”

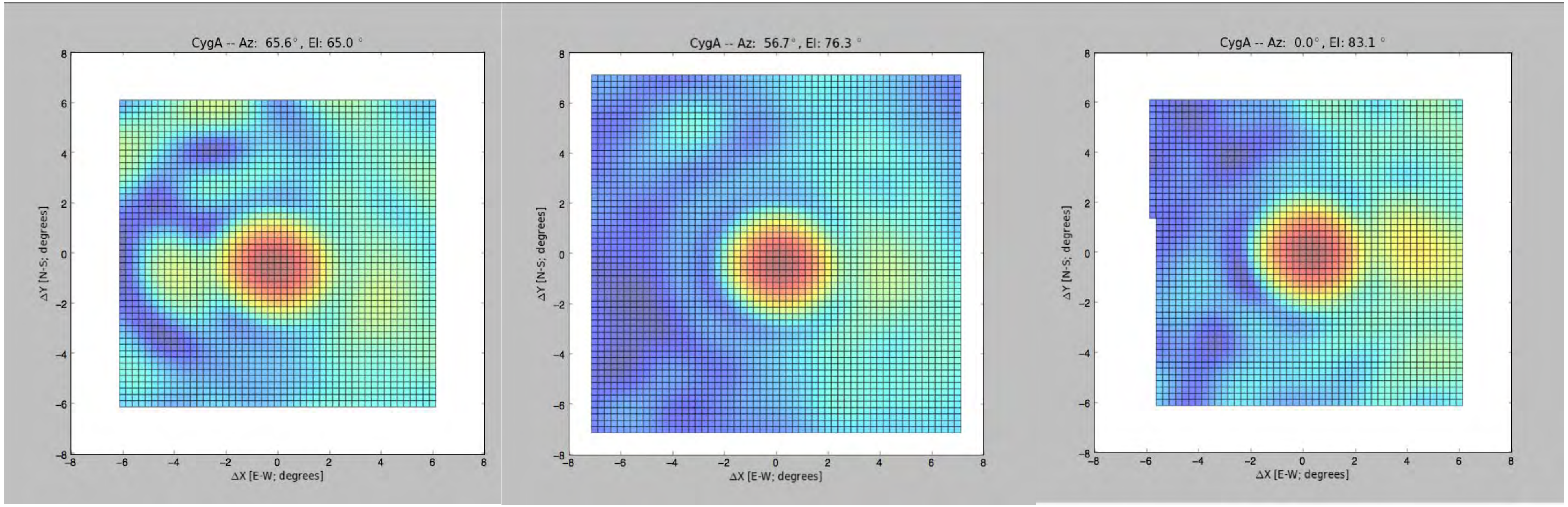


2 minutes

74 MHz

Variation with Elevation

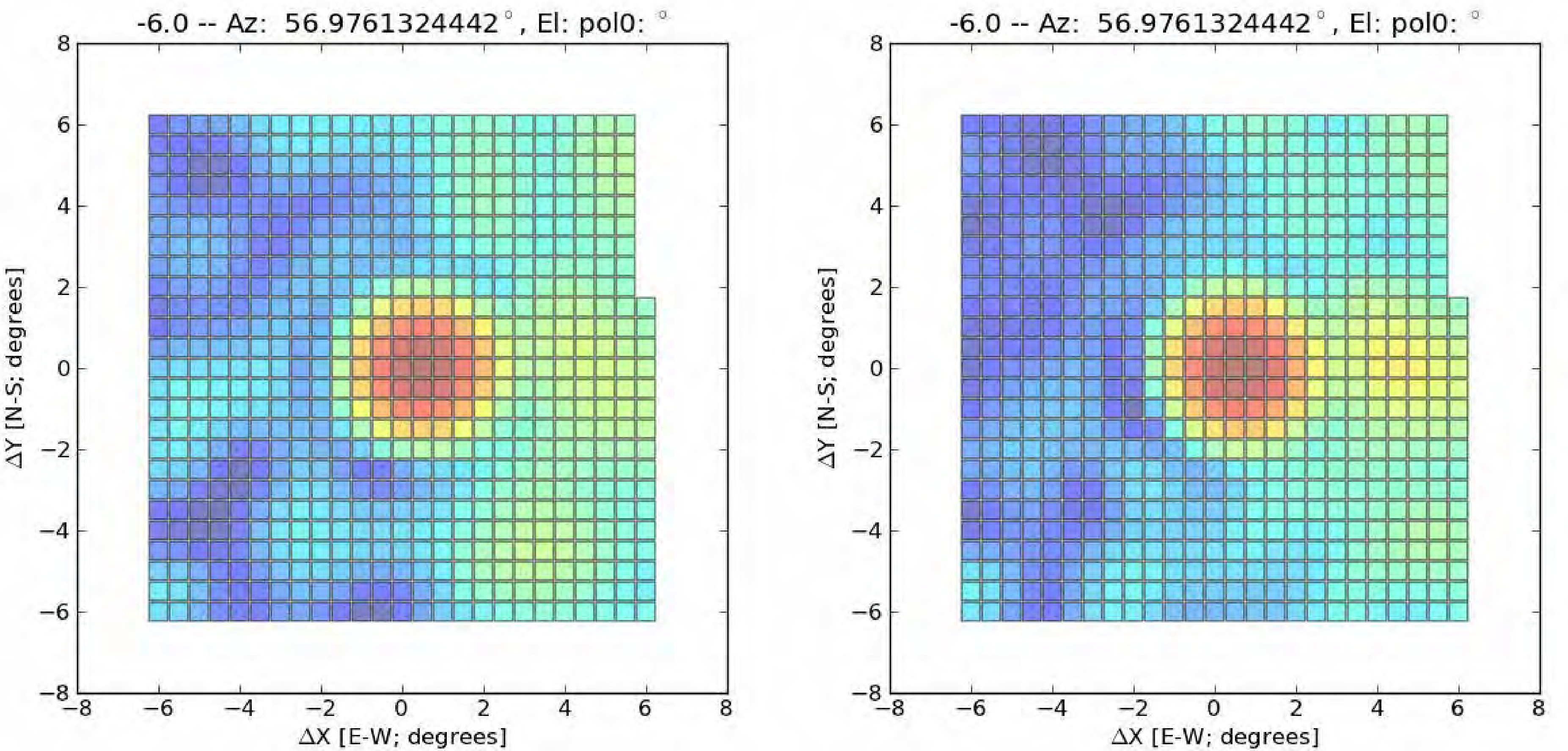
Cyg A



-2 hours	-1 hour	Transit
EL = 65 deg	EL = 76 deg	EL = 83 deg

Variation with Time

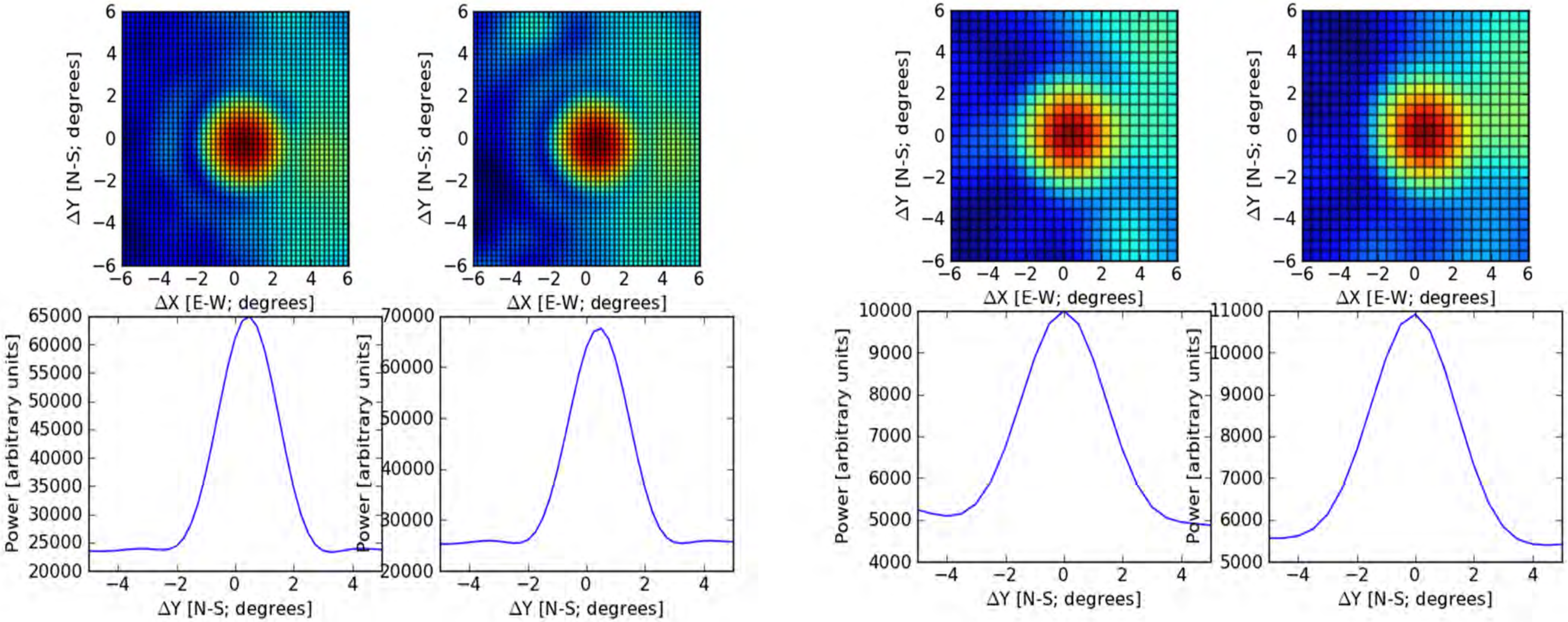
Pol 0 Pol 1



2 seconds per frame 60 frames 74 MHz

Blurring with Gaussian weights

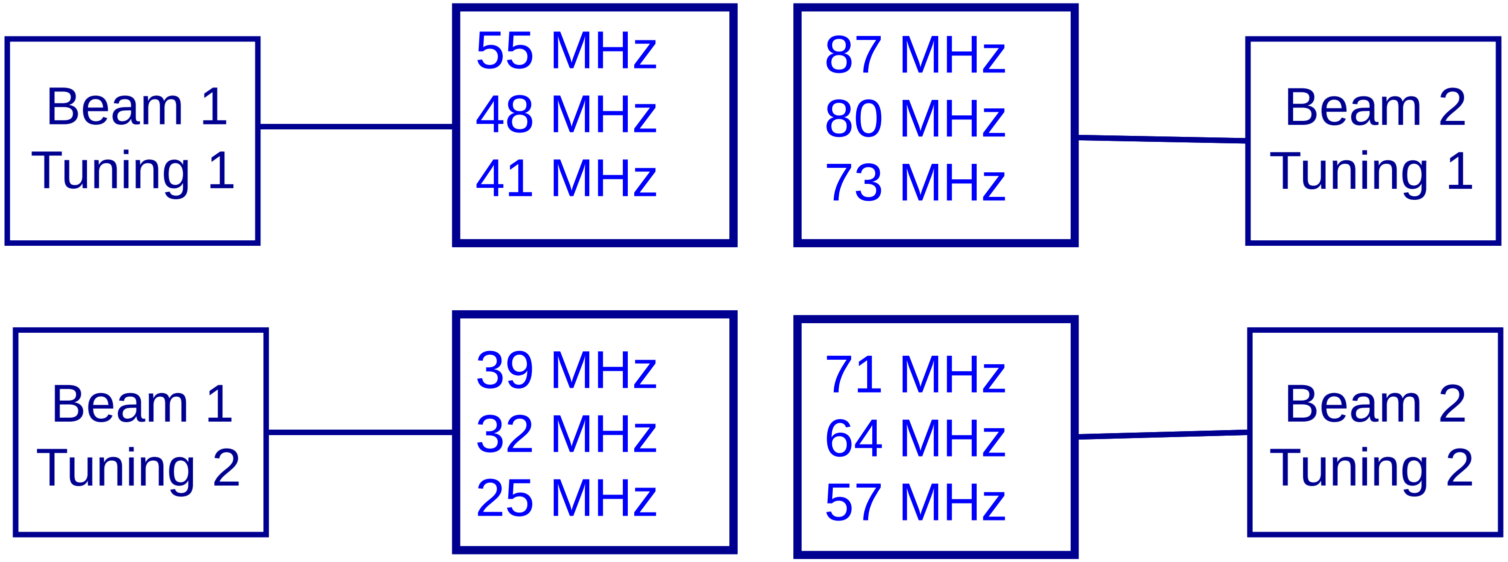
standard LWA beam — defocused, FWHM = 20m



Acquiring raster maps of customized DRX beams to compare with TBN predictions, confirm shape

Status & Next Steps

- Adding cross-correlation with outrigger to TBN analysis to reduce Galactic background
- Explore weighting coefficients in TBN data
- Just acquired ~10 TB of TBN observations in 4 frequency blocks to mimic plans for DRX mode observing



- Planning first DRX observations for deep RFI testing and starting beamforming analysis

LWA Long Wavelength Array

Summary

- LWA1 offers a novel method to detect or constrain the all-sky 21 cm signal using multiple simultaneous beams on the sky for bandpass calibration.
- Preliminary work on beamforming supporting LWA community by characterizing beams on the telescope and developing new capabilities
- Will contribute to overall calibration of LWA1 and hopefully constrain Cosmic Dawn

Extras

Candidate target/cal field pairs

Table 3. Potential science target / calibrator pairs

#	Science target	Calibrator	$T_{\rm sci}$ [a]	$T_{\rm cal}$ [a]
1	$0^{\rm h}00^{\rm m}$ $+90°00'$	Galaxy[b]	4100 K	13400 K
2	$8^{\rm h}46^{\rm m}$ $+22°01'$	Tau A	2600 K	14100 K
3	$11^{\rm h}04^{\rm m}$ $+12°23'$	Vir A	3200 K	12600 K
4	$18^{\rm h}08^{\rm m}$ $+43°32'$	Cyg A	4200 K	77000 K
5	$0^{\rm h}00^{\rm m}$ $+90°00'$	Cas A	4100 K	97000 K

[a] $T_{\rm sci}$ and $T_{\rm cal}$ give the mean brightness temperatures at 50 MHz within a 10° science beam and a 3.2° calibrator beam according to the sky model of de Oliveira-Costa et al. (2008).
[b] Science target 1 is a particularly bright region of the Galactic plane at $2^{\rm h}30^{\rm m}$ $+61°38'$.

Long Wavelength Array