EDGES Status Update

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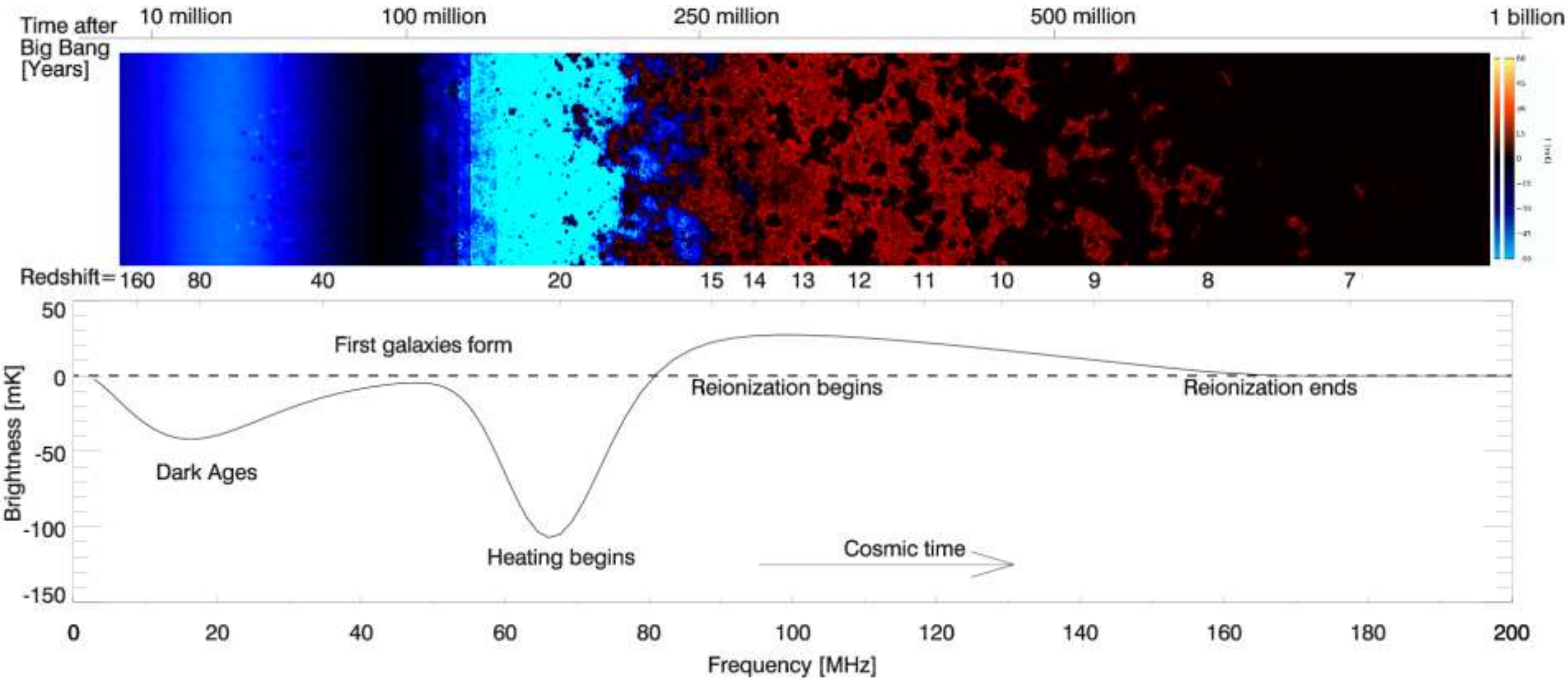
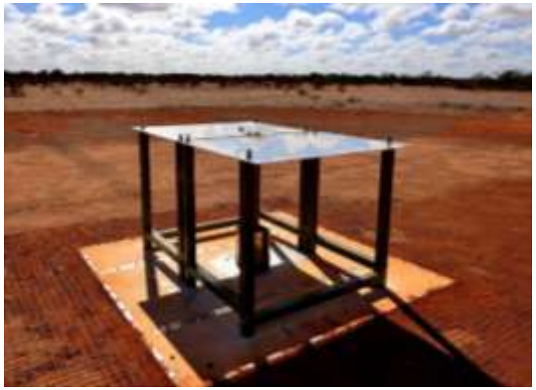
Sept. 24, 2019 – NESS Team Meeting

Science motivation: 21cm history



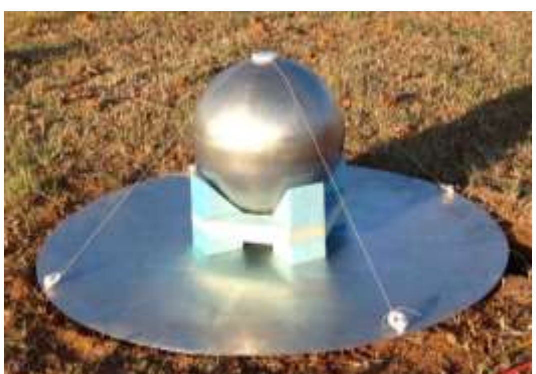
Pritchard & Loeb 2010

Ground-based global 21cm experiments



Experiment to Detect the Global EoR Signature (EDGES)

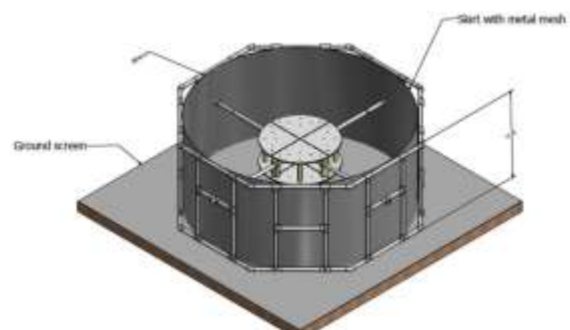
Large-Aperture Experiment to Detect the Dark Ages (LEDA)



Shaped Antenna measurement of the background RAdio Spectrum (SARAS 2)

SCI-HI and PRI^{Z}M

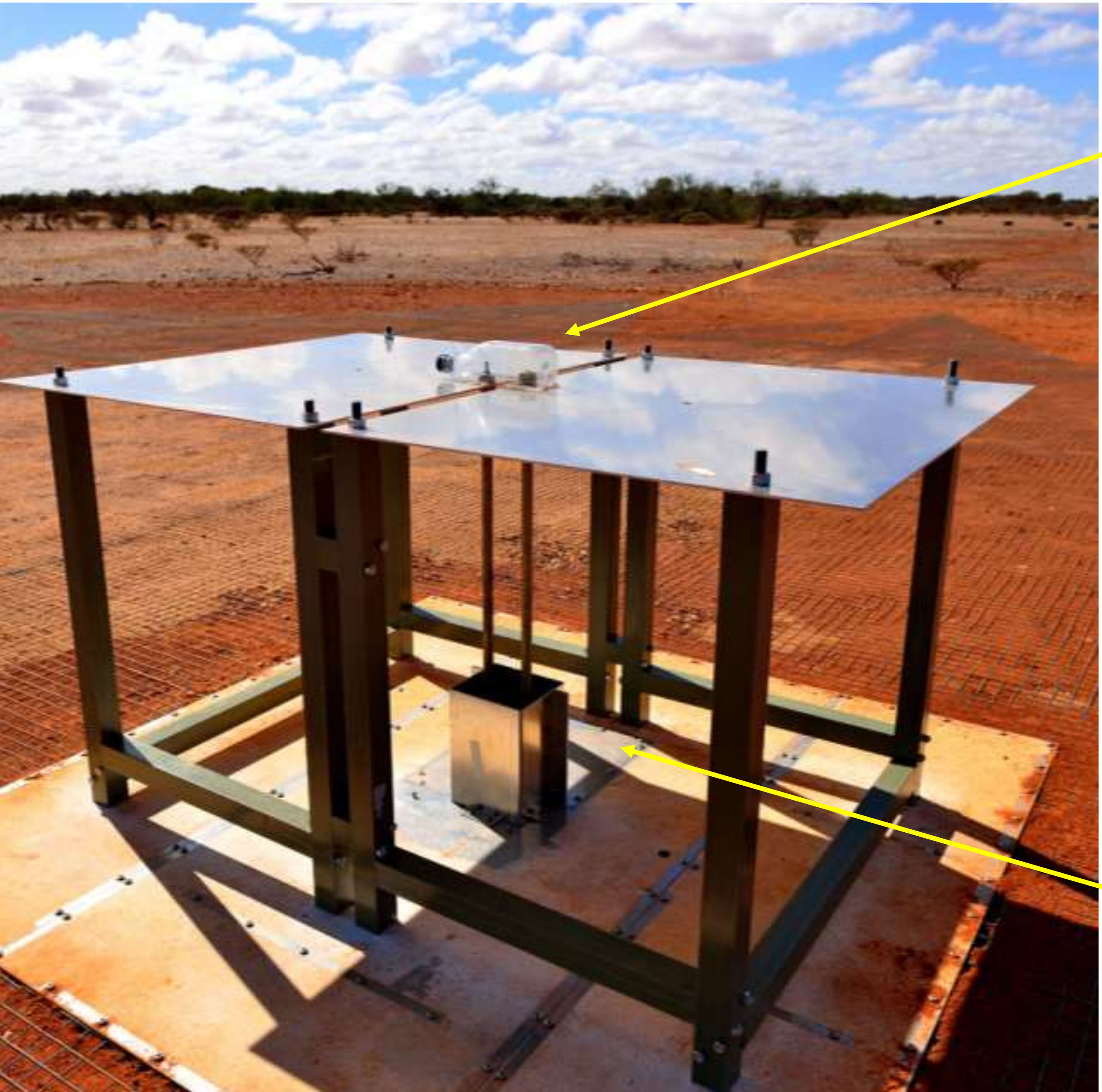
BIGHORNS

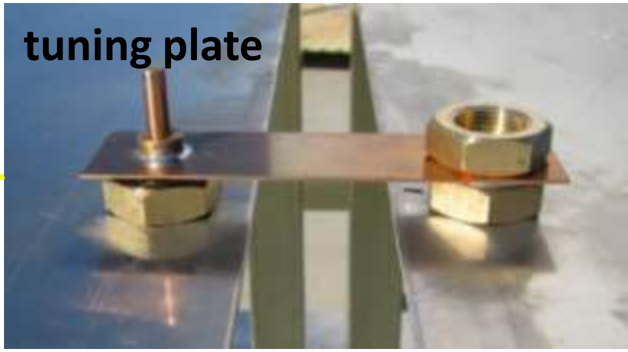


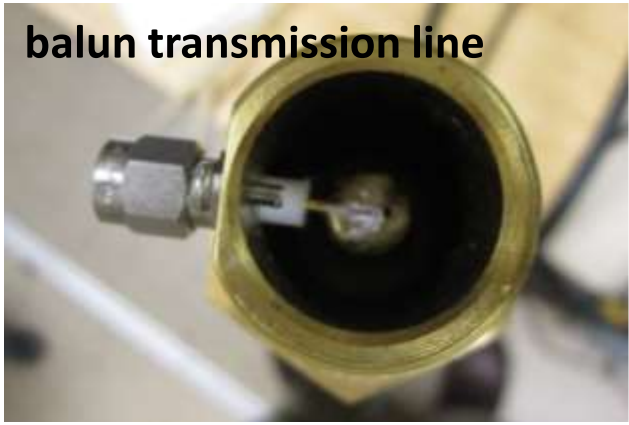
Cosmic Twilight Polarimeter (CTP)

2nd generation EDGES: 2012-2019

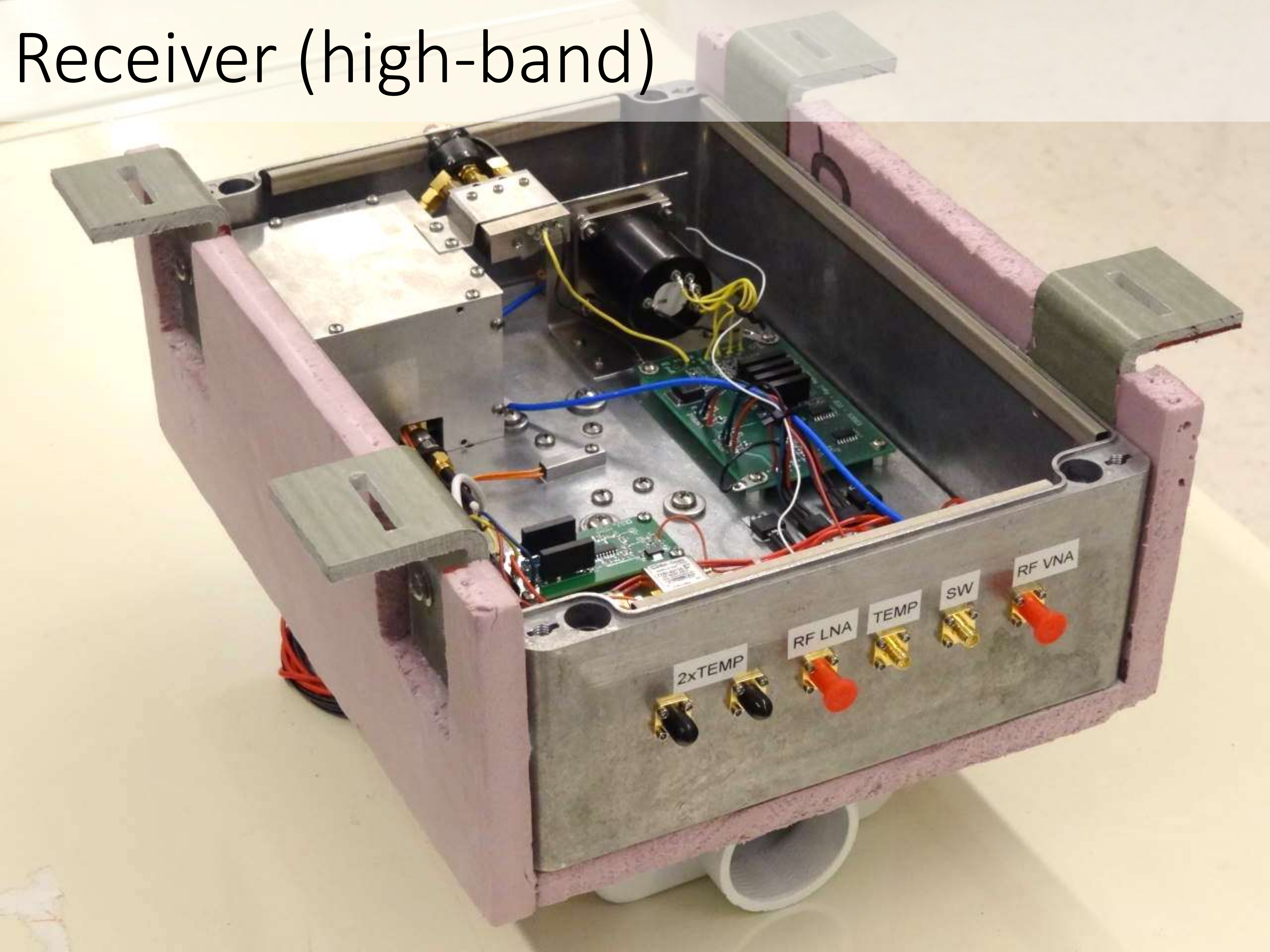
Antenna and balun



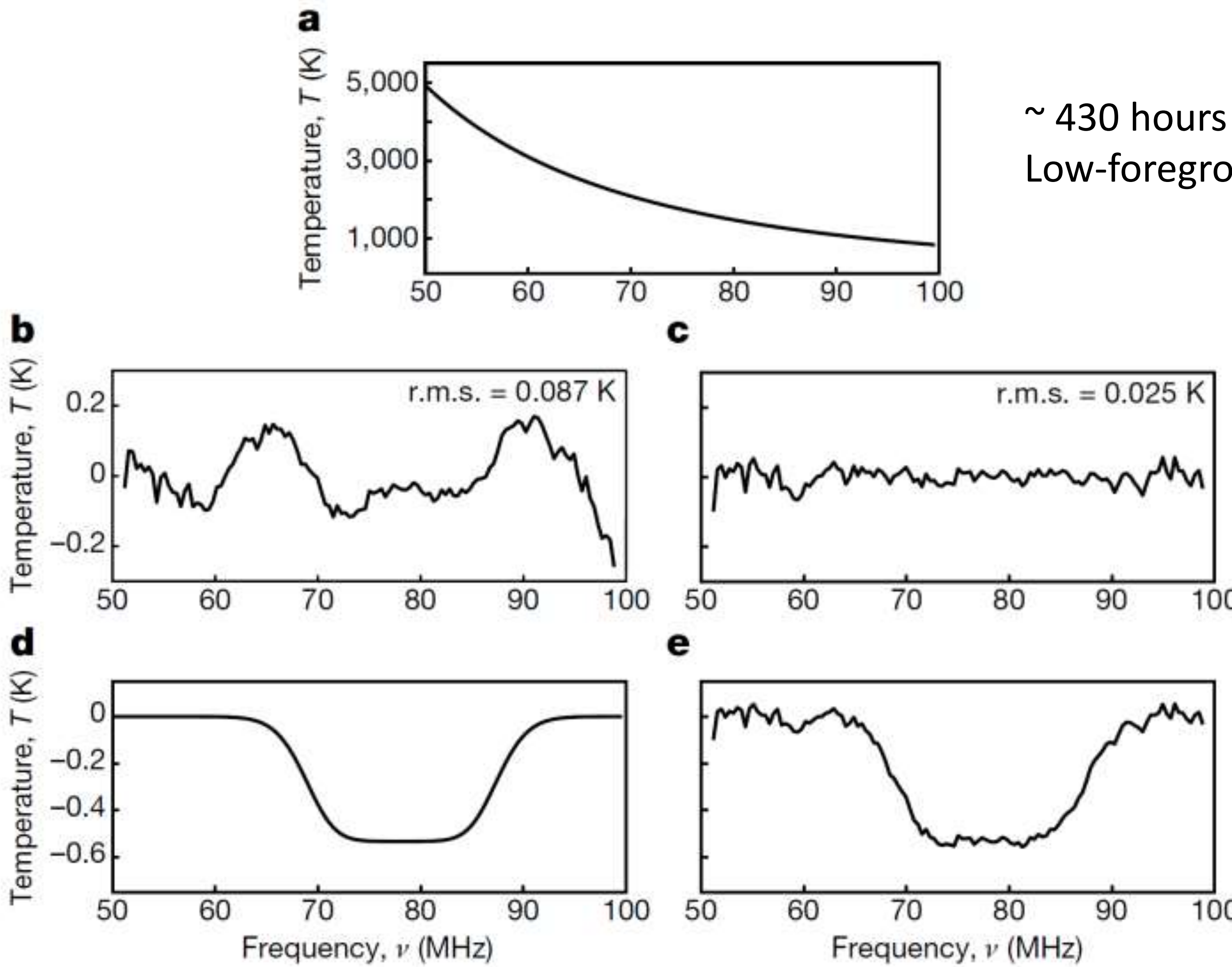




Receiver (high-band)



Evidence for detection



~ 430 hours
Low-foreground sky

Bowman et al. 2018

How to explain deep absorption?

$$T_{21}(z) \propto \left(1 - \frac{T_{\mathrm{CMB}} + \boldsymbol{T}_{\mathbf{EXCESS}}}{\boldsymbol{T}_{\mathbf{S}}}\right)$$

Suggested sources:

- Radio emission from **early black holes** [i.e., Ewall-Wice et al. 2018]
- Decay of **unstable particles** [Pospelov et al. 2018] [Aristizabal Sierra & Sheng Fong 2018]

Lower than expected

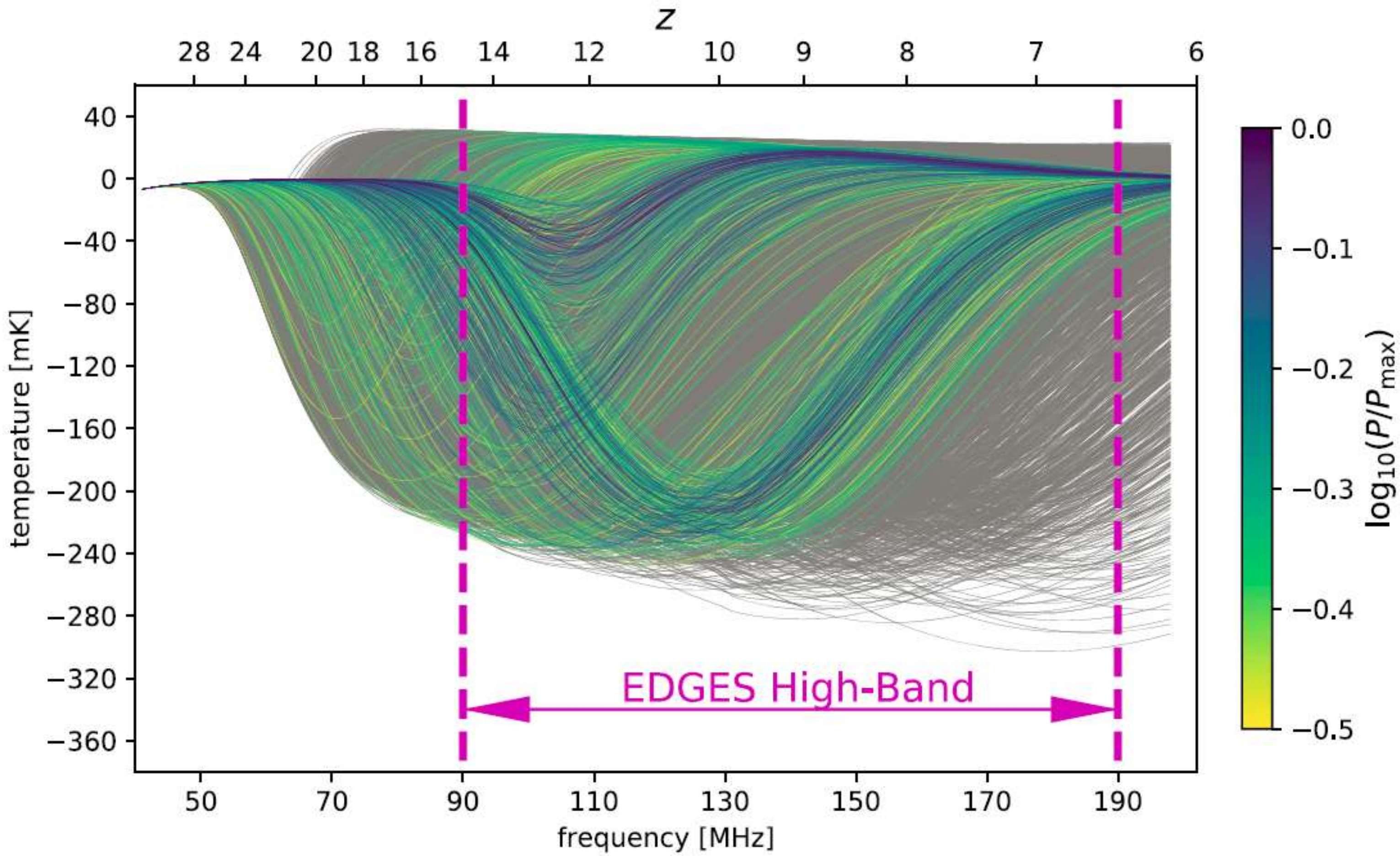
$\boldsymbol{T}_{\mathbf{IGM}}$ **Lower than expected**

Suggested source:

- Baryon-Dark matter **particle interactions** [i.e., Muñoz and Loeb 2018]

R. Monsalve

Additional constraints from EDGES



Example top 5% of parameter combinations most-consistent with data

Monsalve et al. 2017, 2018, 2019

EDGES verification tests

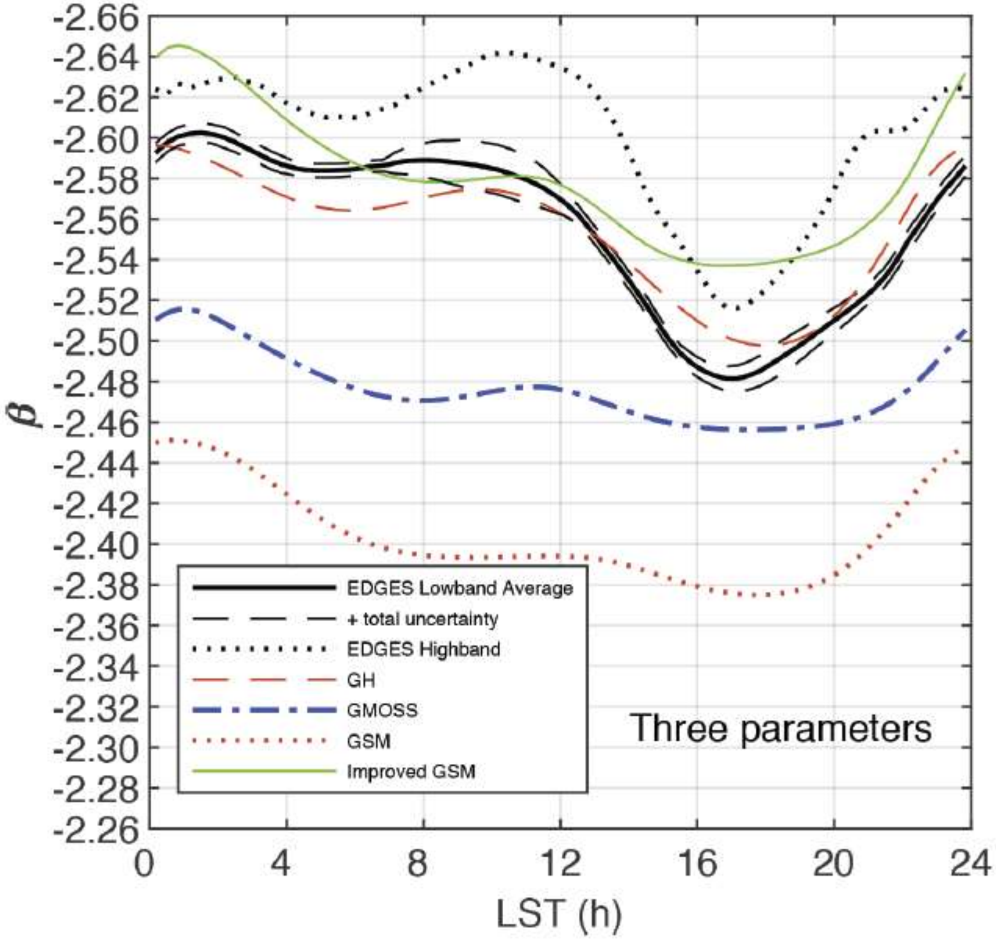
Four primary concerns:
- Physical foreground interpretation (Hills et al. 2019)
- Alternative models and goodness of model fits (Hills et al. 2019)
- Ground plane resonances (Bradley et al. 2019)
- Chromatic beam effects

Previously reported tests:
- 6 instrument configurations
- 18 data cuts and processing variations
- 6 injection, modeling, and laboratory null-result tests

New tests and analyses:
- ✓ Was our model selection appropriate?
    - Diffuse spectral index consistent with other surveys and models (Mozdzen et al. 2019)
    - BIC supports model/band selection used in Bowman et al. 2018 (EDGES report #122)
- ✓ Are unmodeled ground plane effects responsible?
    - Verification of DC electrical conductivity
    - Low-band antenna over different inner structure (although sensitivity to assumptions of soil properties)
- ✓ Are unmodeled chromatic antenna beam effects responsible?
    - Mid-band antenna (60-160 MHz)
    - Comparison of simulated observations to data (more in Nivedita's talk next)

Do we see physical foregrounds?

$$T_{\rm ant} = T_{75}\left(\frac{\nu}{\nu_{75}}\right)^{\beta+\gamma\ln(\frac{\nu}{\nu_{75}})+a_4[\ln(\frac{\nu}{\nu_{75}})]^2+a_5[\ln(\frac{\nu}{\nu_{75}})]^3} + T_{\rm CMB}$$



Param.	2 terms	3 terms	5 terms
T_{75}	1673 K	1673 K	1673 K
β	-2.571	-2.585	-2.585
γ	---	-0.47	-0.41
a_4	---	---	-0.004
a_5	---	---	-0.031

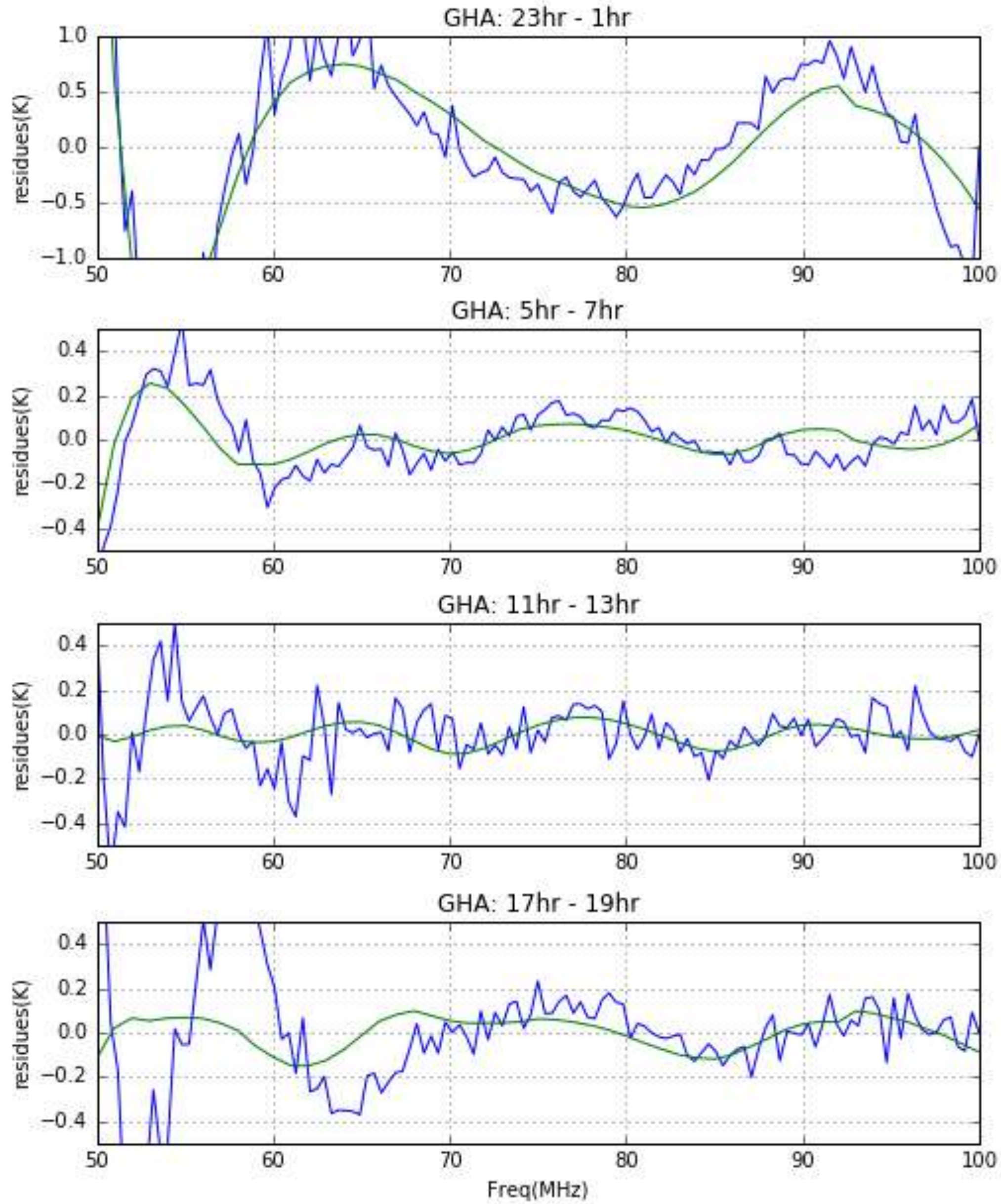
LST = 6h

Mozdzen, Mahesh, et al. 2019

Validating beam model

Blue: low-band 1 (30 meter ground plane) observations

Green: simulated observation using FEKO beam model and Haslam sky model + profile



Mahesh et al. (in prep)

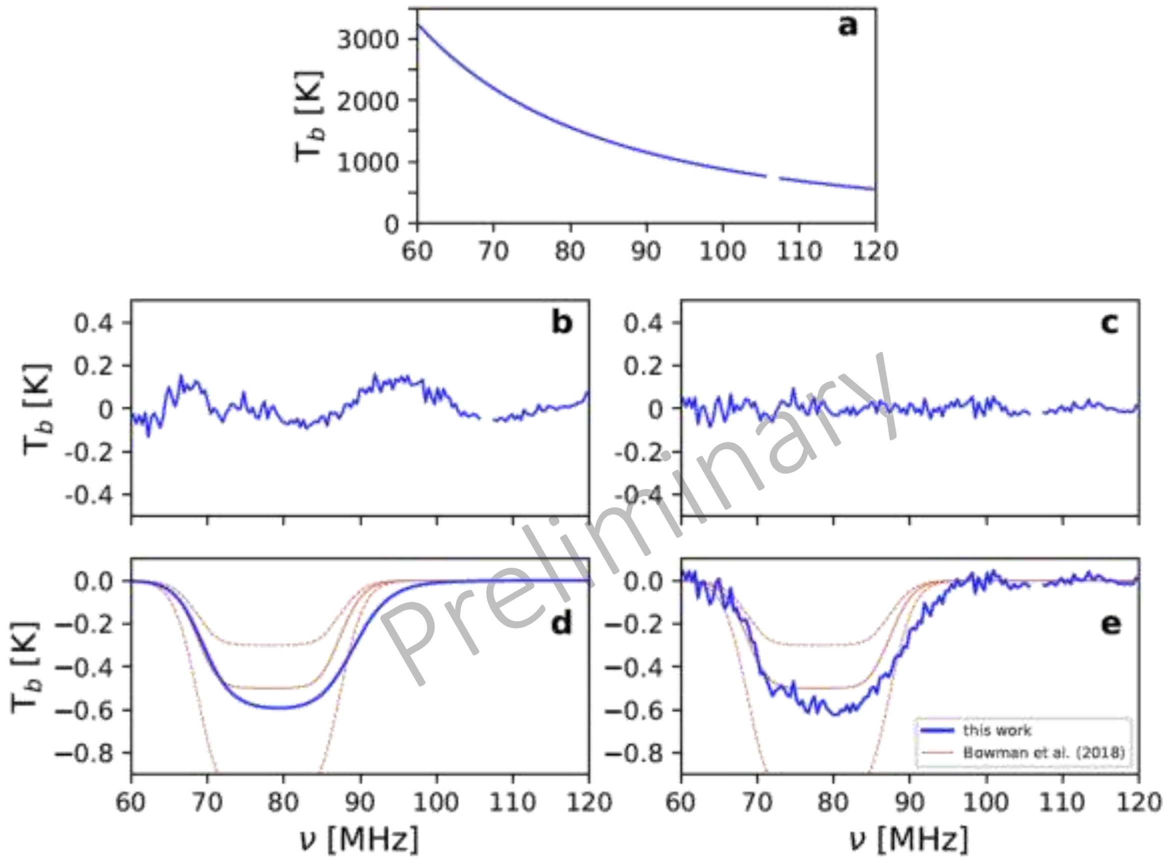
Disfavoring chromatic beam effects

Low-band

Mid-band (75% scale)

- 1.5” balun outer diameter

Additional evidence for absorption



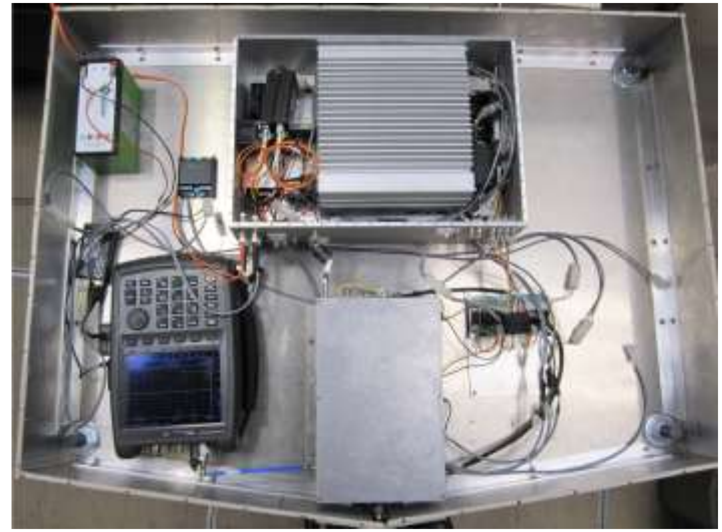
- Asymmetric tanh model with separate slopes on low- and high-z sides of profile
- Smoother bottom of feature (τ~4)
- Ongoing data quality assessment

Monsalve et al. *in prep*

EDGES-3

NSF ATI funding 2019-2022

Next generation EDGES-3



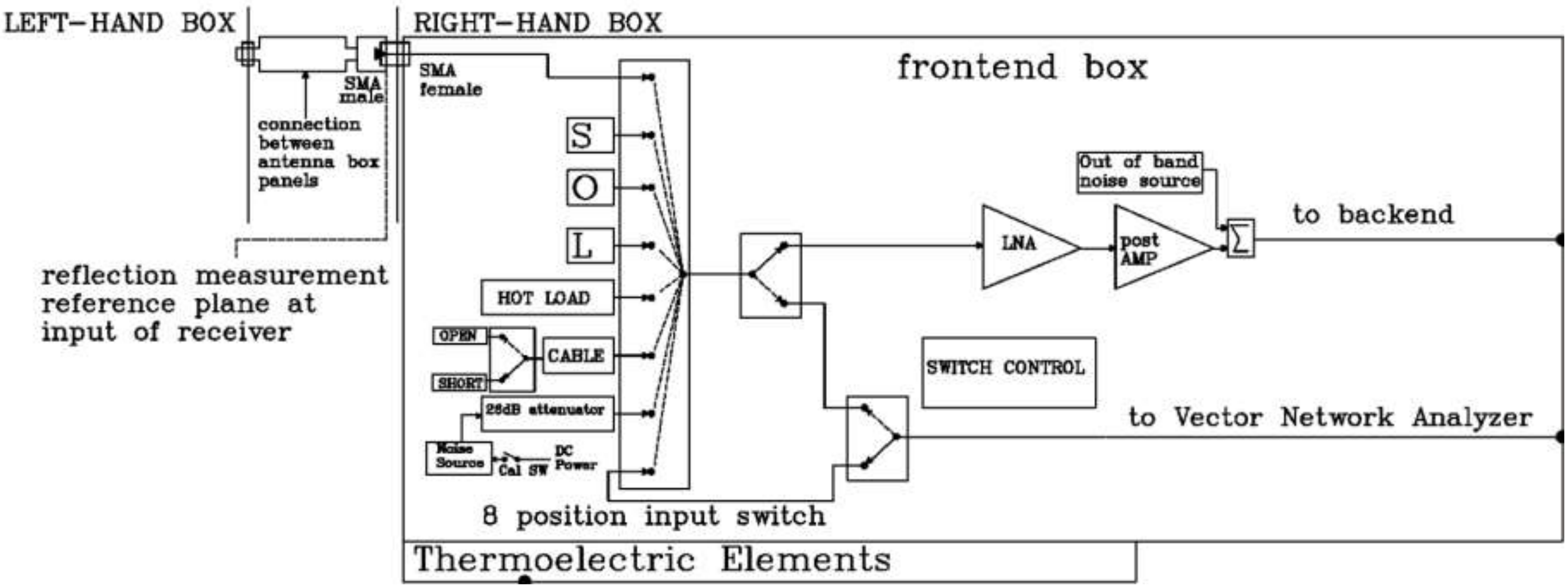
<u>Goal: Improve performance over current system by 3x - 10x</u>

- Address two largest sources of uncertainty based on error modeling:
  - Minimize propagation path delays and losses by removing balun and embedding receiver in antenna (3x)
  - Reduce beam chromaticity by using larger, terminated, or no ground plane (2-4x)
- Maintain MRO site (with extended ground plane)
- Temporary sites in southeast Oregon, possibly elsewhere

Secondary goal: Automated in-situ absolute calibration

Challenges: Self-interference

Receiver switch network (automated calibration)



A.Rogers, EDGES memo #300

EDGES-3 prototype in Skull Creek, southeast Oregon (last week)

Prototype large wire ground plane

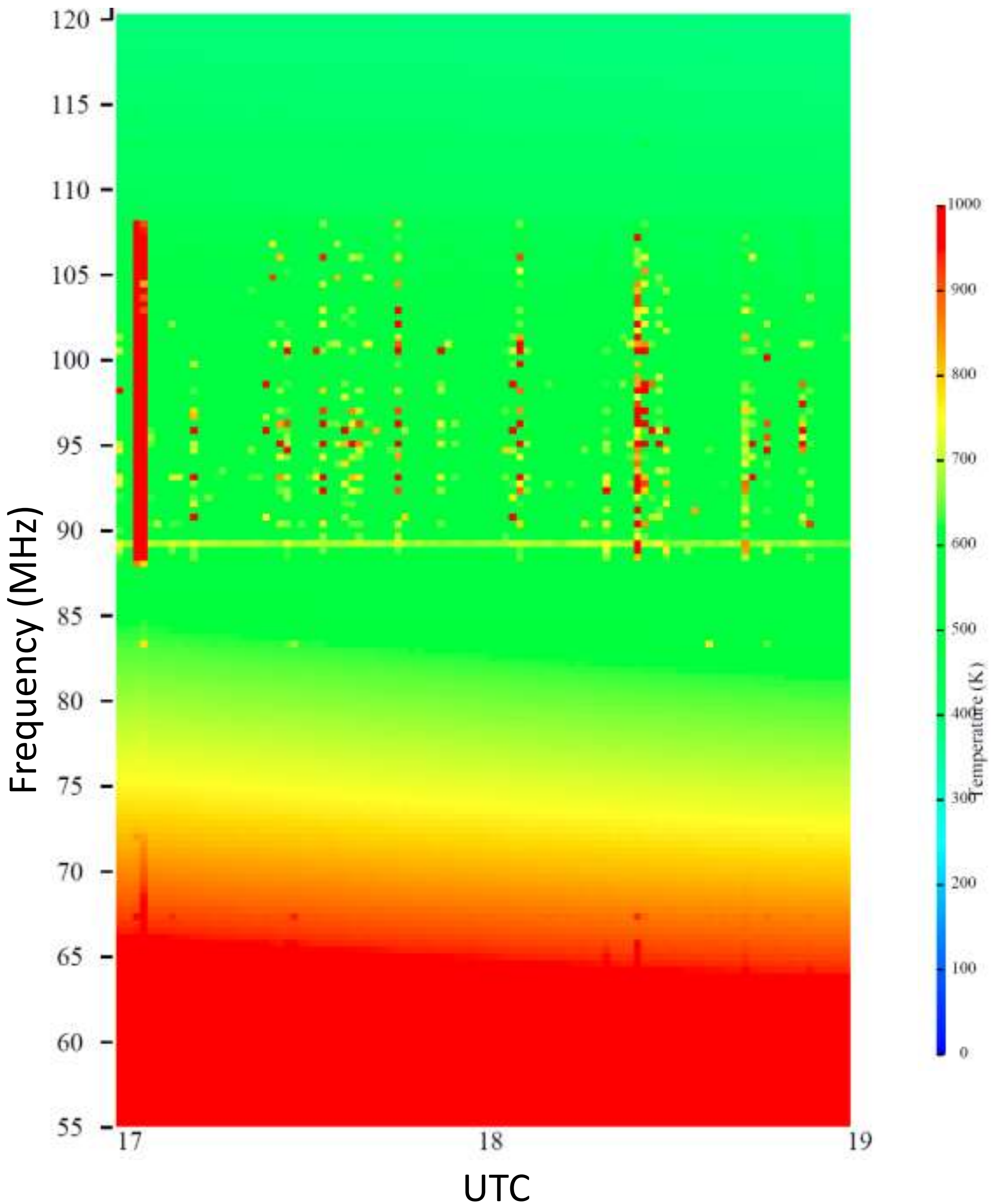
<u>Nominal size: 50 meters</u>

- 2x better chromaticity than 30 meters
- Within 33% of infinite ground plane

<u>No ground plane</u>

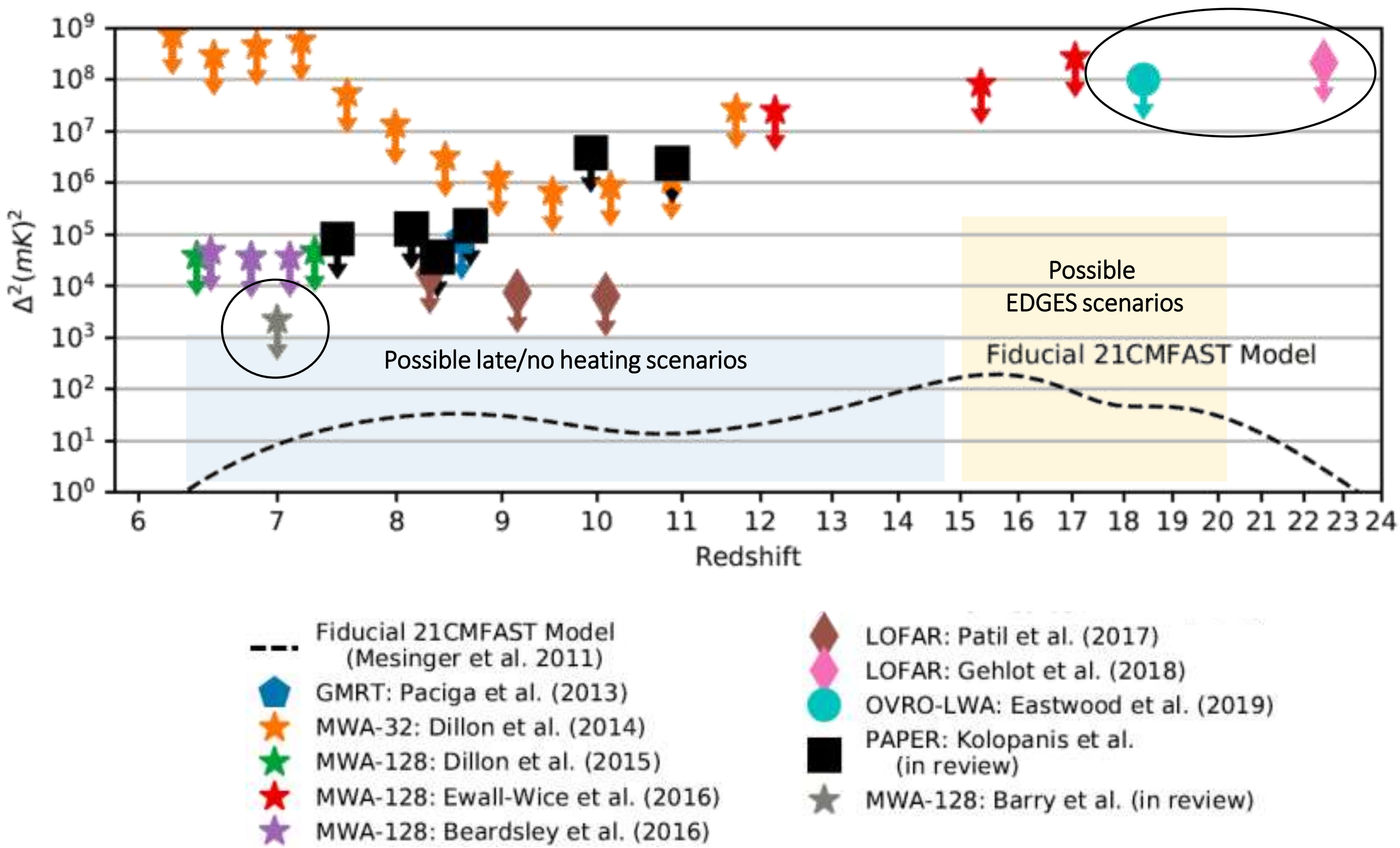
- 4x better than ground plane

Initial look at RFI at Skull Creek



Current status of 21cm power spectrum

Current 21cm power spectrum limits



Credit: M. Kolopanis / HERA 2020 whitepaper

Conclusion

EDGES has pioneered global 21cm measurements and reported the first evidence for detection of the 21cm signal from cosmic dawn.

Recent tests addressed concerns and strengthened the case for an astronomical origin of the reported profile (Monsalve et al., in prep).

EDGES-3 will reduce the largest sources of uncertainty, enabling substantial improvement in performance and strong new verification tests.