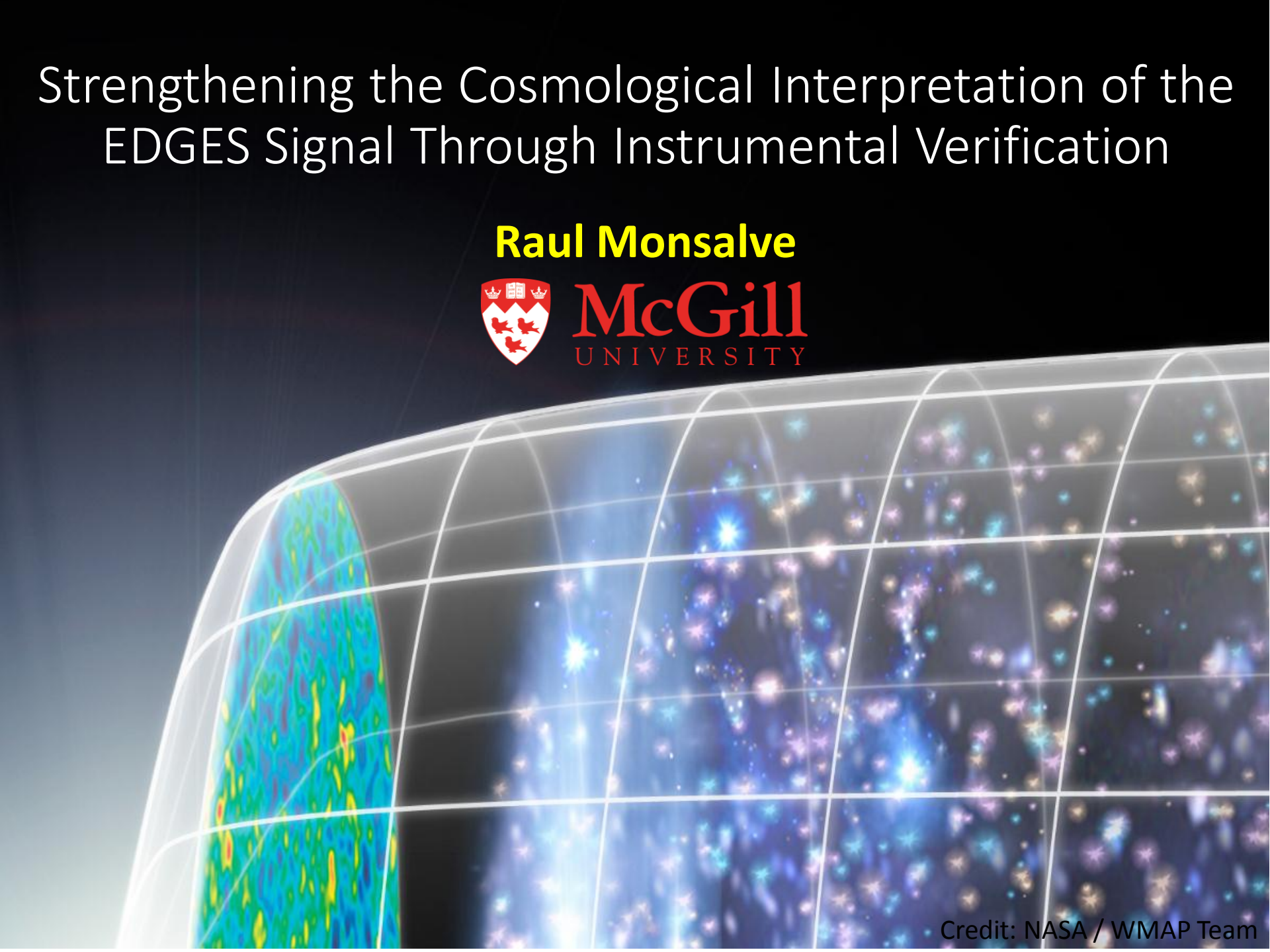
Strengthening the Cosmological Interpretation of the EDGES Signal Through Instrumental Verification

Raul Monsalve

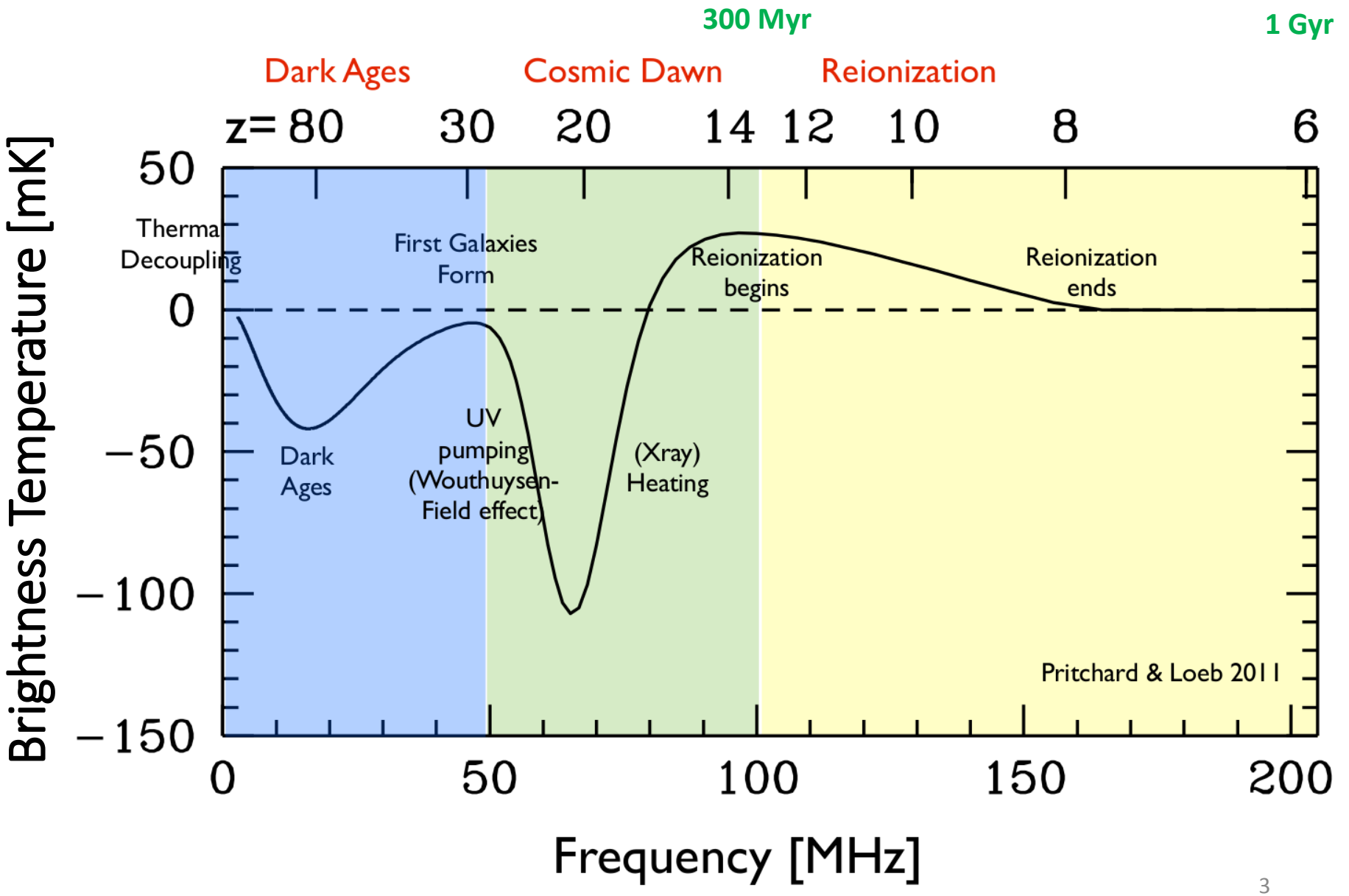
McGill UNIVERSITY



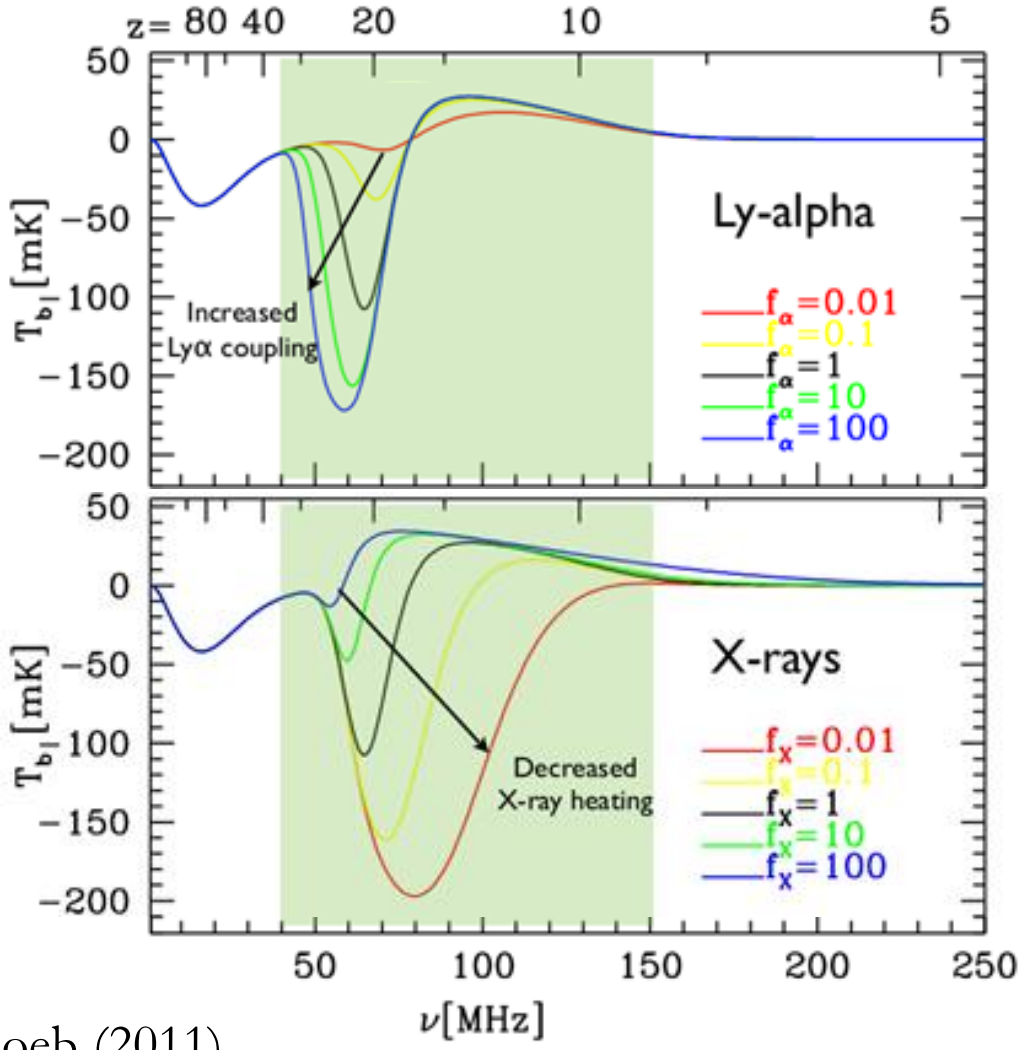
Credit: NASA / WMAP Team


Time
380.000 years
100 million years
300 million years
1 Gyr
13.8 Gyr
CMB
DARK AGE
COSMIC DAWN
REIONIZATION
Redshift
1100
30
14
6
0
Neutral Hydrogen in the Intergalactic Medium (IGM)
Targeted by EDGES
Fraction of neutral hydrogen < 6%
[McGreer et al. 2015]
JWST unlikely to detect first galaxies at z > 15
[Mason et al. 2015]
S.G. Djorgovski et al. & Digital Media Center, Caltech

Standard Prediction for Sky-Averaged 21-cm Signal



Nature and Timing of First Sources



From Pritchard & Loeb (2011)

EDGES

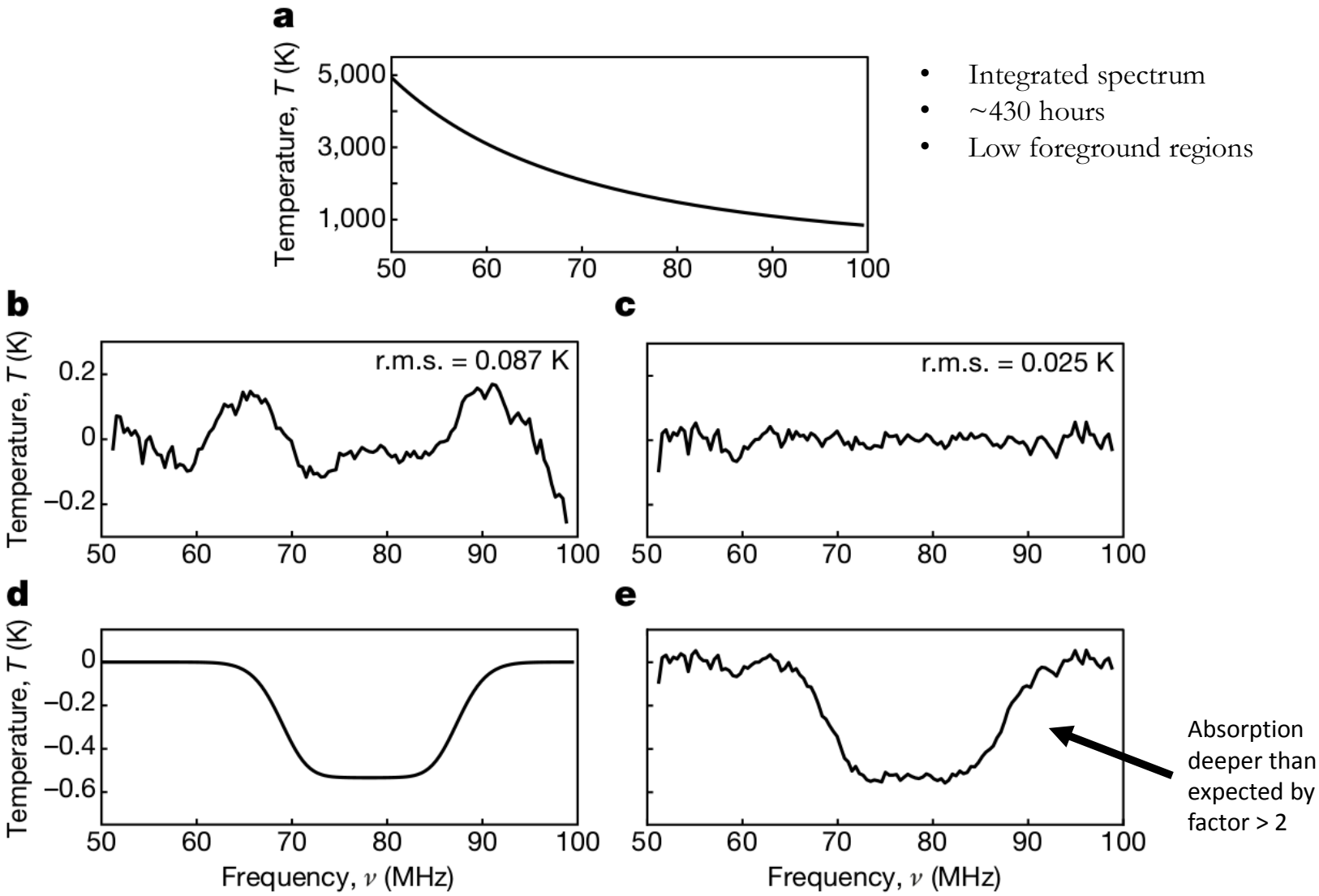
Experiment to **D**etect the **G**lobal **E**oR **S**ignature

Prof. Judd Bowman (PI)
Dr. Alan Rogers
Dr. Raul Monsalve
Dr. Thomas Mozdzen
Ms. Nivedita Mahesh

ARIZONA STATE UNIVERSITY

MIT HAYSTACK OBSERVATORY

Summary of the EDGES Detection

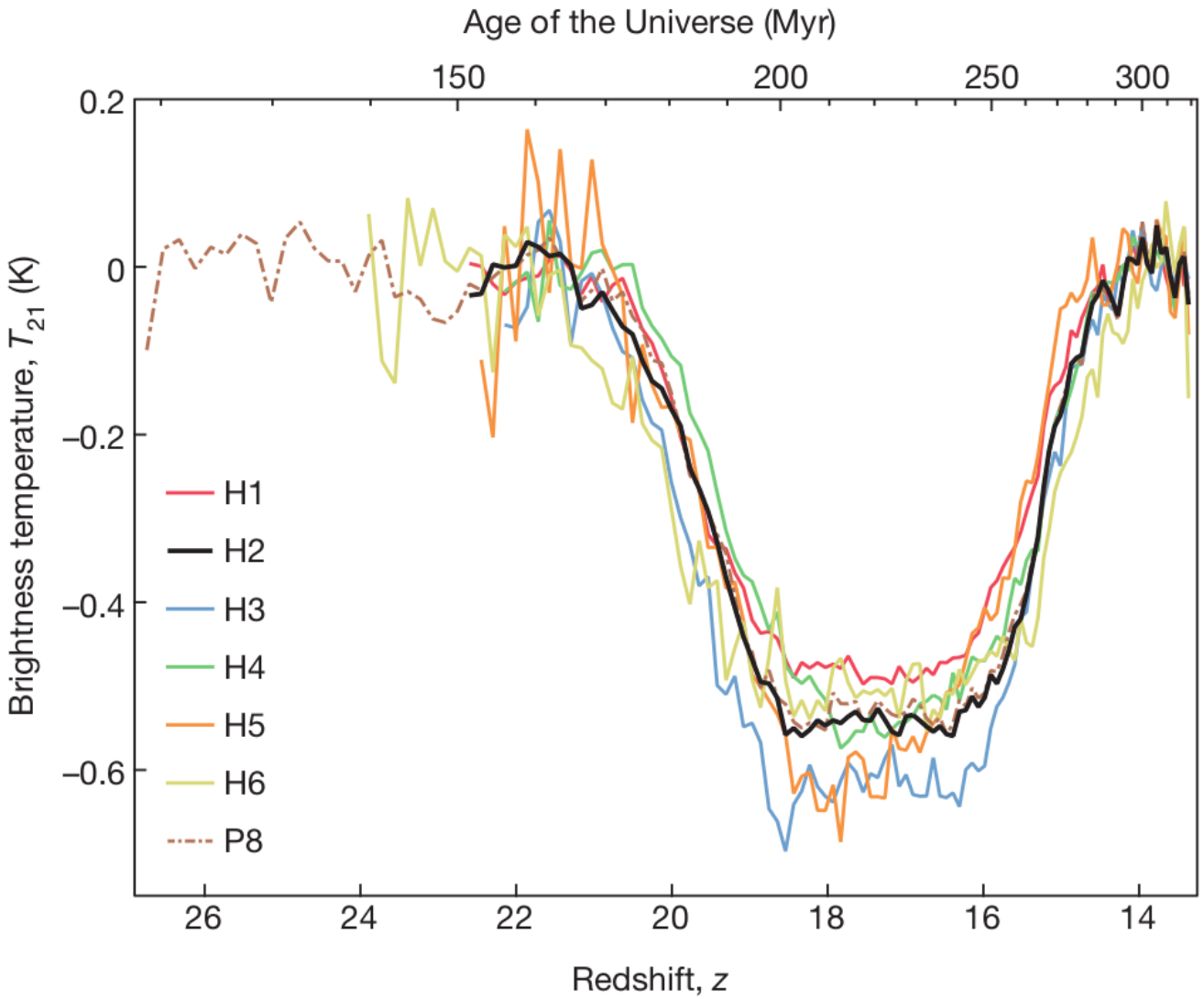


- Integrated spectrum
- ~430 hours
- Low foreground regions

Absorption deeper than expected by factor > 2

Bowman, Rogers, Monsalve, Mozdzen, Mahesh 2018, **Nature**, 555, 67

Two Instruments / Several Configurations



Bowman, Rogers, Monsalve, Mozdzen, Mahesh 2018, **Nature**, 555, 67

Parameter Estimates

From All Cases Processed

Parameter	Best Fit	Uncertainty (3σ)
Amplitude	0.5 K	+0.5/-0.2 K
Center	78 MHz	+/-1 MHz
Width	19 MHz	+4/-2 MHz
Flatness	7	+5/-3

How to Explain Deep Absorption?

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

Suggested sources:

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

Lower than expected

$\boldsymbol{T_{\mathrm{IGM}}}$ **Lower than expected**

Suggested source:

- Baryon-Dark matter **particle interactions** [Muñoz and Loeb 2018]

IOP Publishing

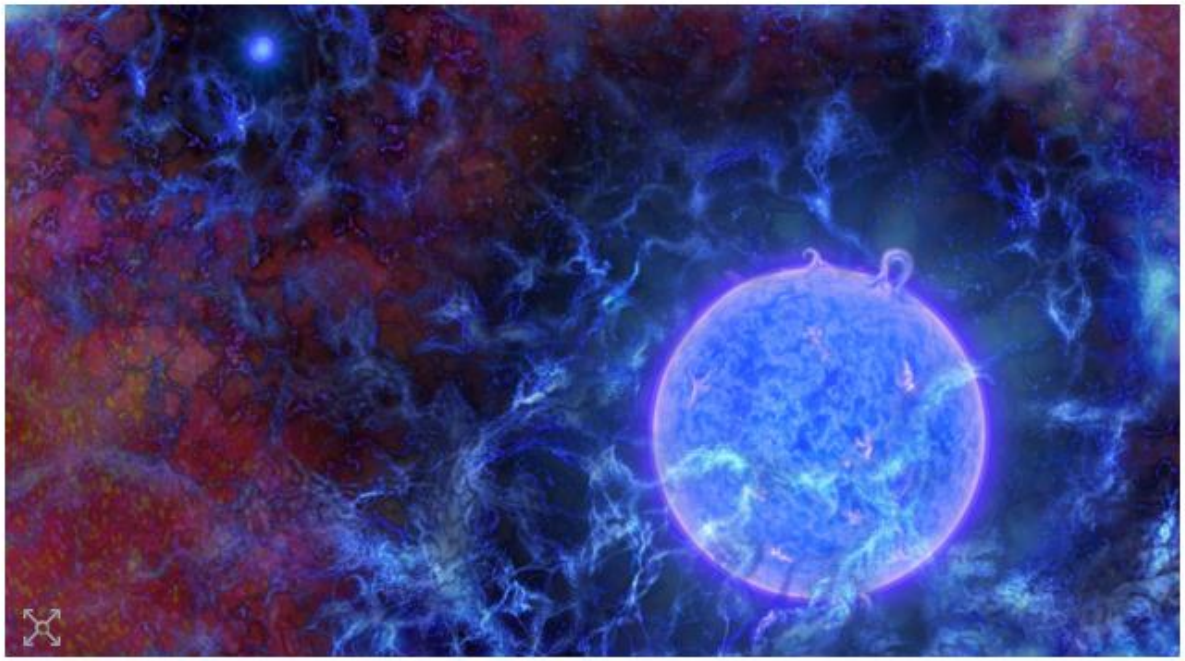
physicsworld

Dec 13, 2018

TOP 10 Breakthrough in 2018

Ancient hydrogen reveals clues to dark matter's identity

To Judd Bowman, Raul Monsalve, Thomas Mozdzen and Nivedita Mahesh of Arizona State University Arizona State University and Alan Rogers of the Massachusetts Institute of Technology for using the EDGES radio telescope to observe colder-than-expected hydrogen gas that existed just 180 million years after the Big Bang; and Rennan Barkana, of Tel Aviv University for calculating that this could be the first direct observation of a non-gravitational interaction between dark matter and conventional matter. While further observations are needed to back-up this hypothesis, the research could help resolve one of the most important unsolved mysteries of physics: what is the nature of dark matter?



Light and dark: did dark matter cool ancient hydrogen?

BRIEF COMMUNICATIONS ARISING

Concerns about modelling of the EDGES data

ARISING FROM J. D. Bowman, A. E. E. Rogers, R. A. Monsalve, T. J. Mozdzen & N. Mahesh *Nature* **555**, 67–70 (2018); https://doi.org/10.1038/nature25792

A Ground Plane Artifact that Induces an Absorption Profile in Averaged Spectra from Global 21-cm Measurements - with Possible Application to EDGES

Richard F. Bradley, Keith Tauscher, David Rapetti, and Jack O. Burns

Addressing Concerns: Recent Tests in the Field

Null Tests (**feature should not be found)**

1) Measuring noise sources that produce a **flat spectrum**.
2) Measuring noise sources that produce a spectrum **resembling the diffuse foregrounds**.

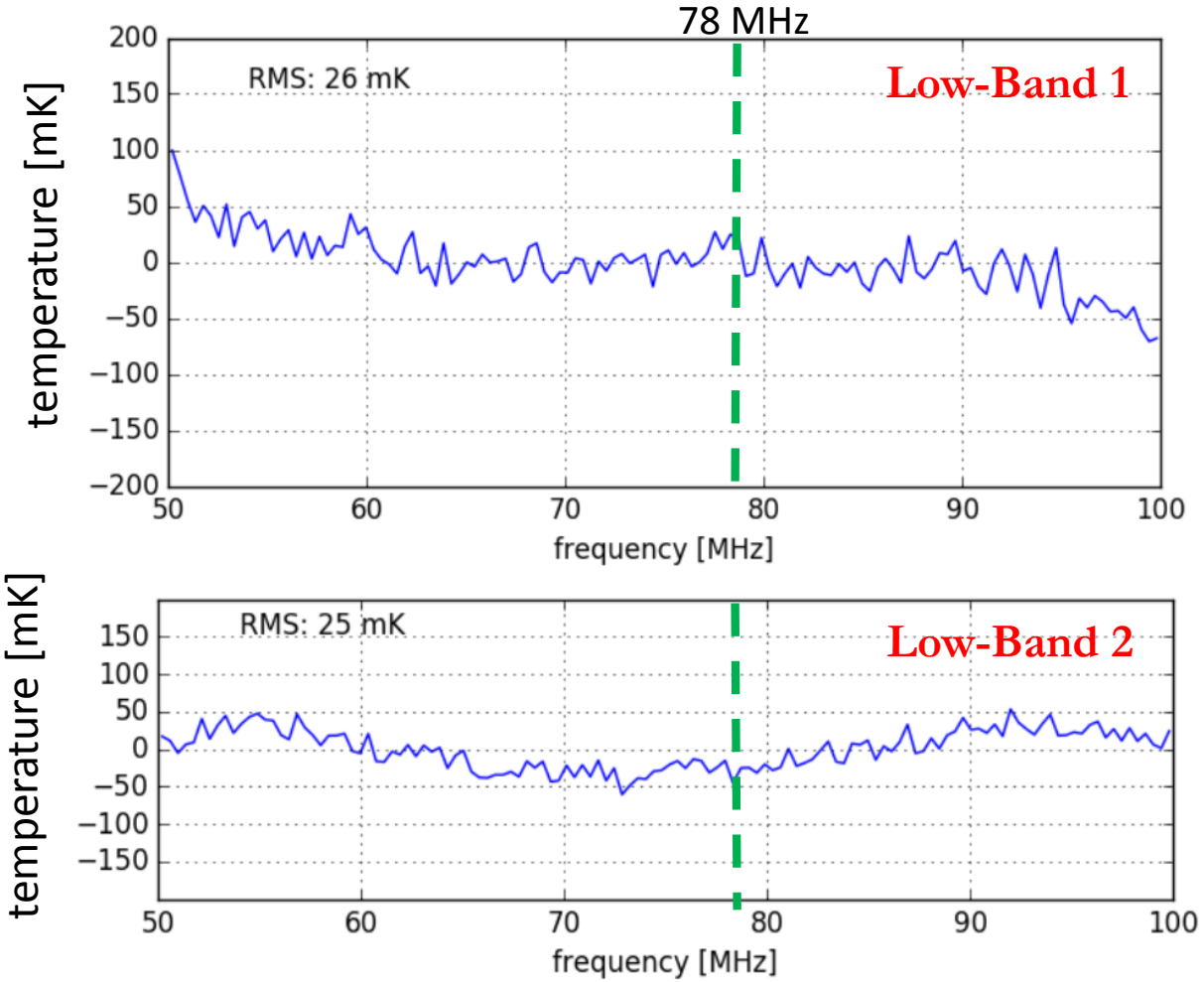
Tests Addressing Antenna Beam Effects (**feature should be found**)

1) Using **smaller Mid-Band antenna** covering 60-160 MHz.
2) Using Low-Band antenna over a **smaller 9m x 9m ground plane**. We call this **Low-Band 3**.

These **tests have been passed successfully**. This supports a **spectral feature from the sky**.

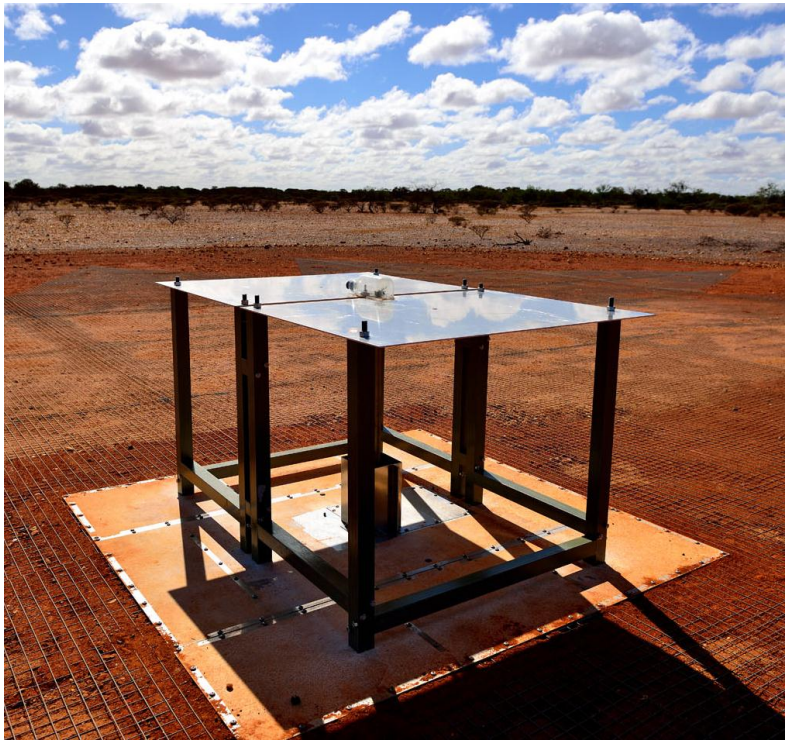
Verification Using ~300K Passive Noise Sources

Residuals After Removing a Constant



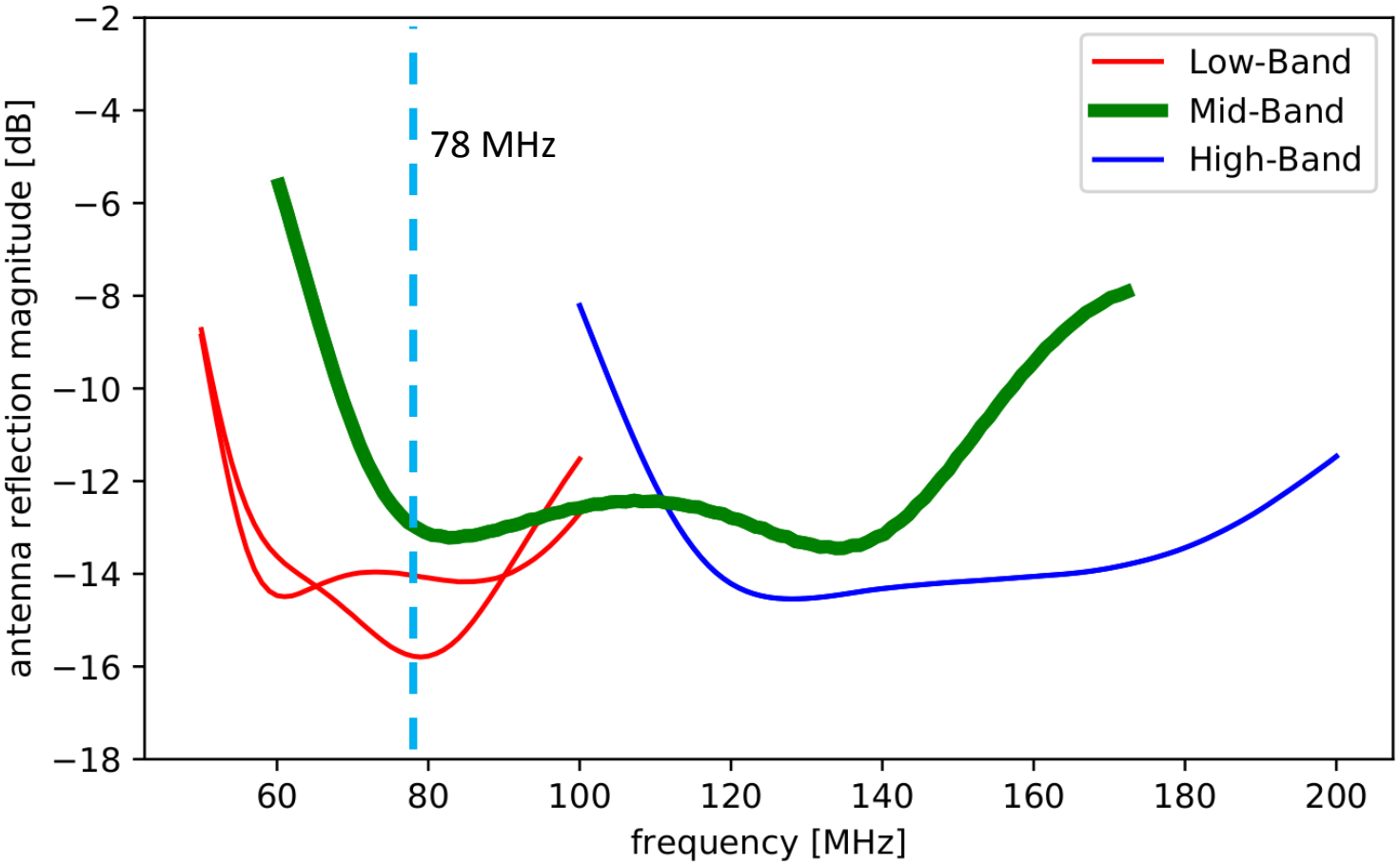
Verification with EDGES **Mid-Band**

Low-Band



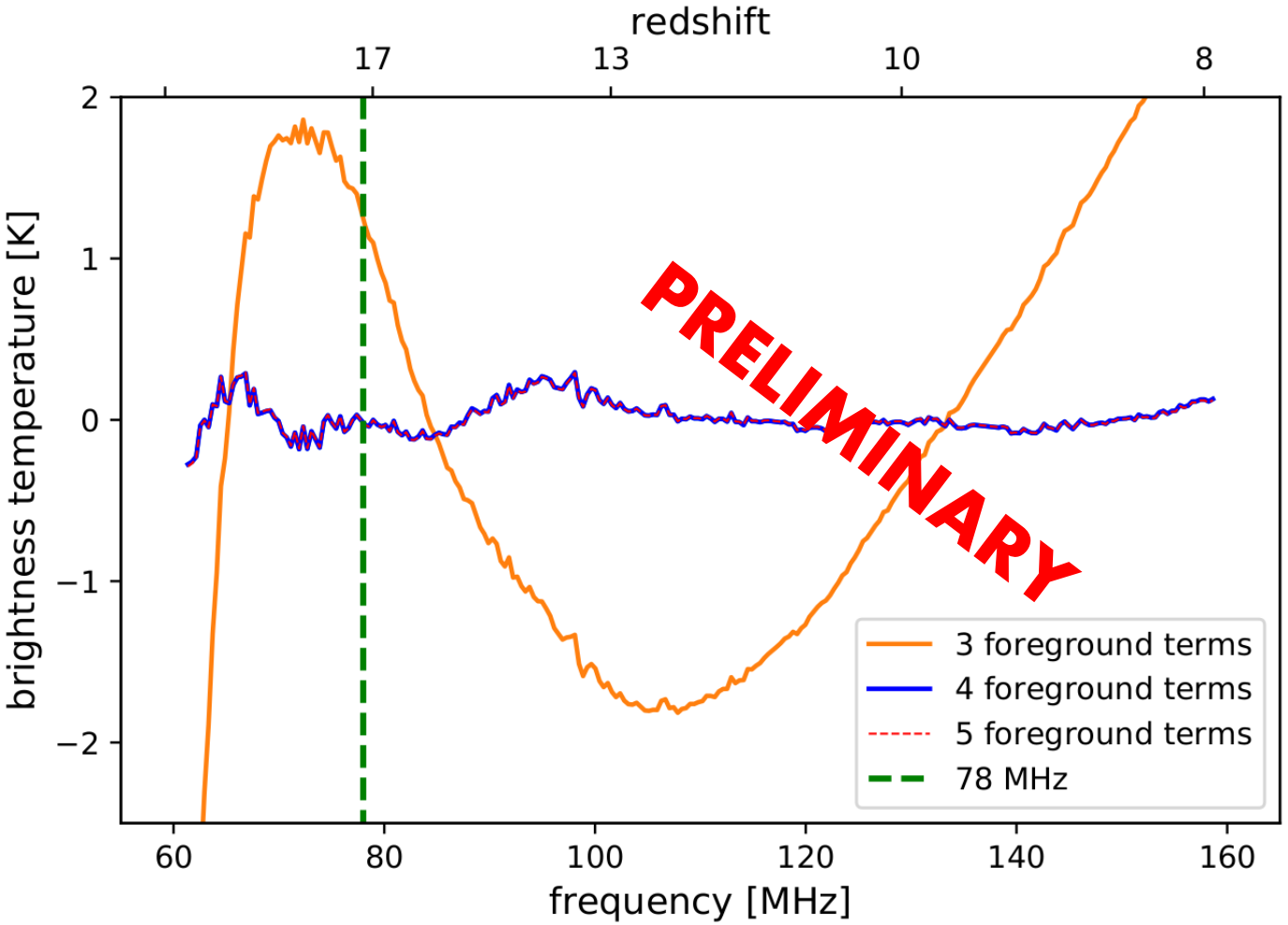
Mid-Band

Antenna Reflection Coefficients



Preliminarily …..

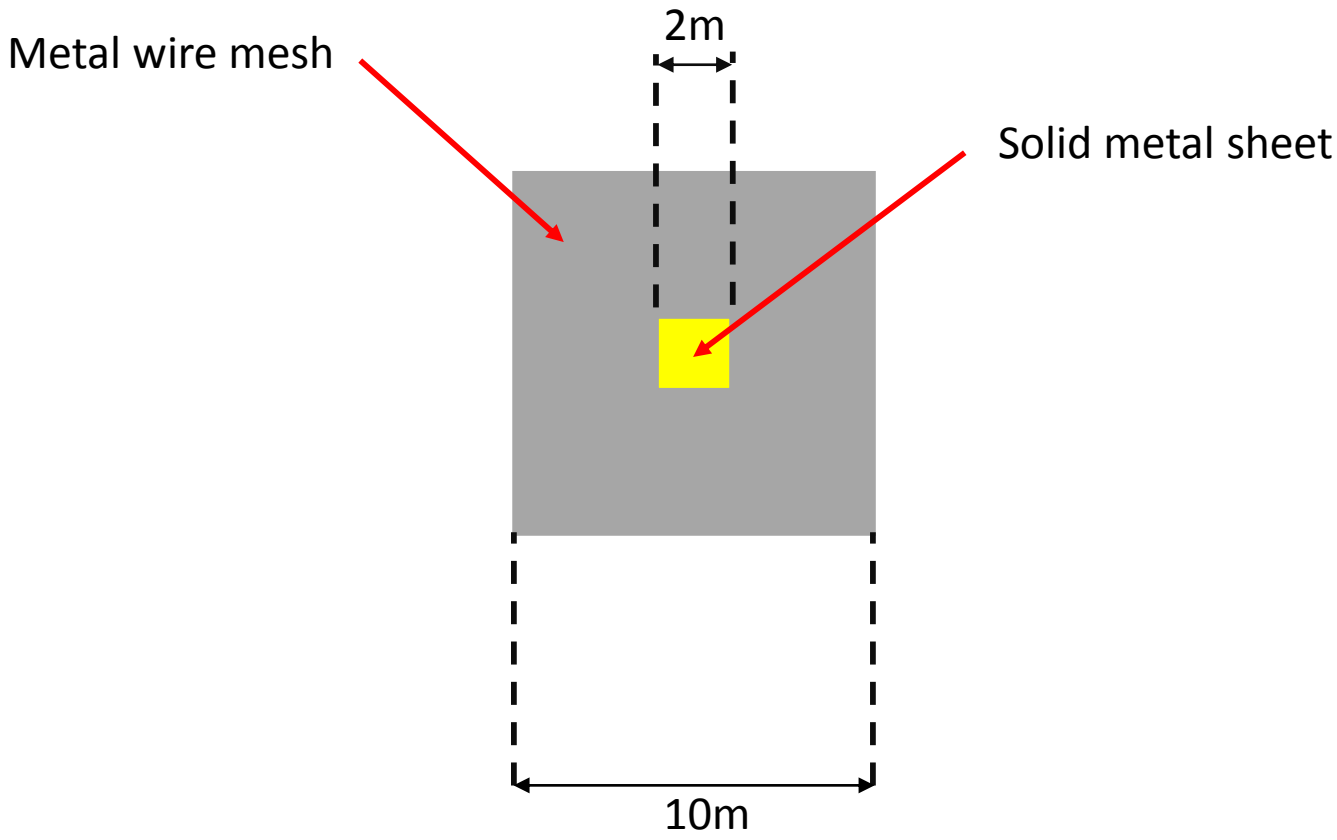
Preliminary **Mid-Band** Results



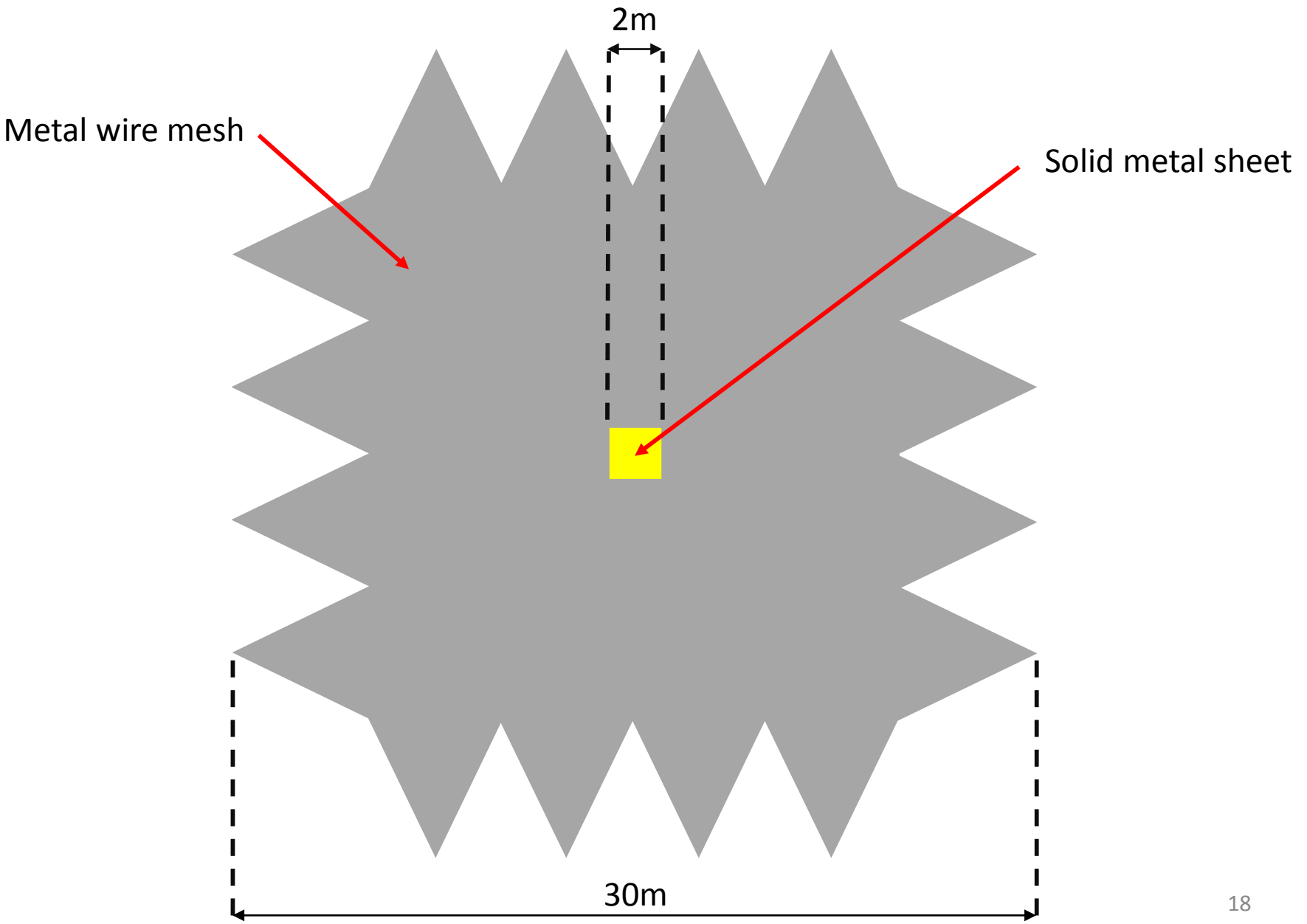
Monsalve, Mahesh, Rogers, Bowman, Mozdzen, & Johnson (in preparation)

1) Data from **May - August 2018.**
2) **Low foregrounds**.
3) Best-fit absorption parameters **consistent with Bowman et al. (2018)**.
4) Some alternative models suggested **can be disfavored**.

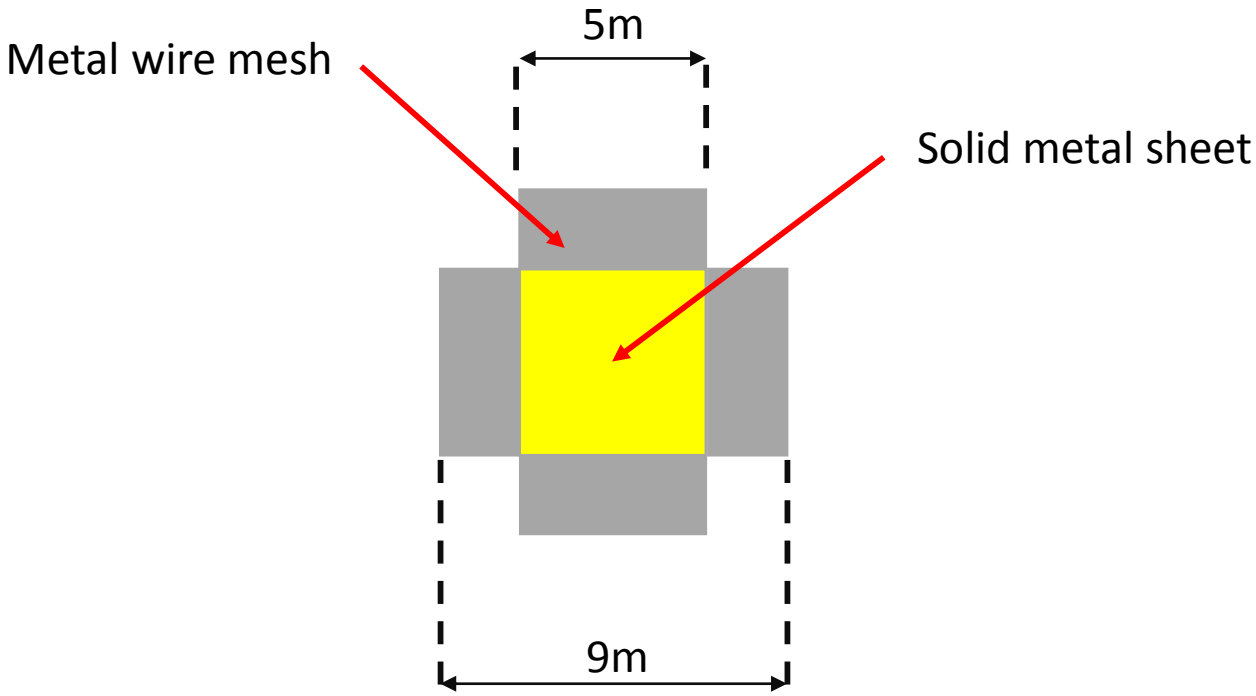
Low-Band Ground Plane: 2015-2016



Low-Band Ground Plane: 2016-2018



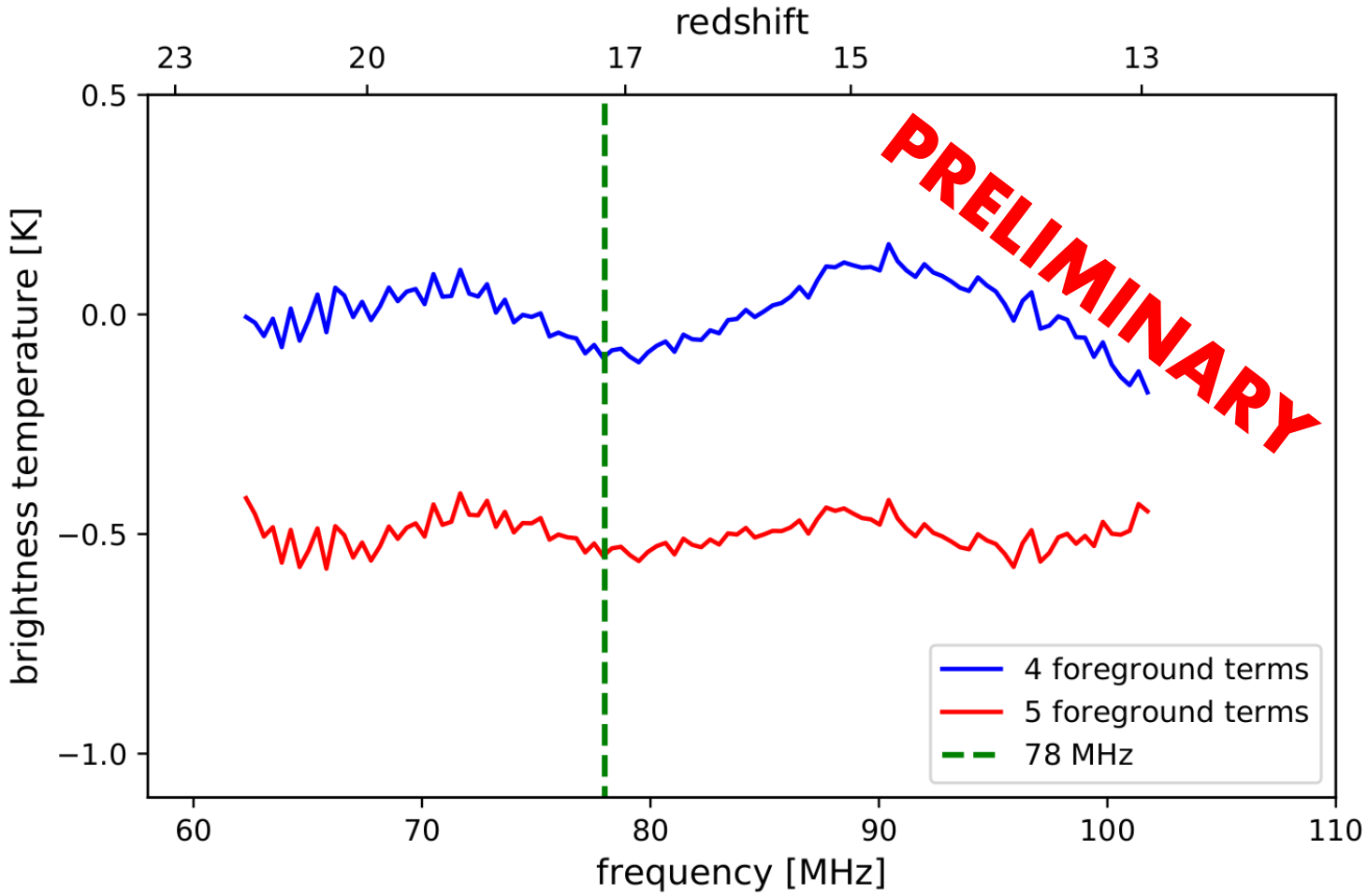
Low-Band Ground Plane: 2018-2019



We call this configuration

"Low-Band 3"

Preliminary **Low-Band 3** Results



Monsalve, Mahesh, Rogers, Bowman, Mozdzen, & Johnson (in preparation)

1) Data from **August - October 2018.**
2) **Low foregrounds**.
3) Best-fit absorption parameters **consistent with Bowman et al. (2018)**.

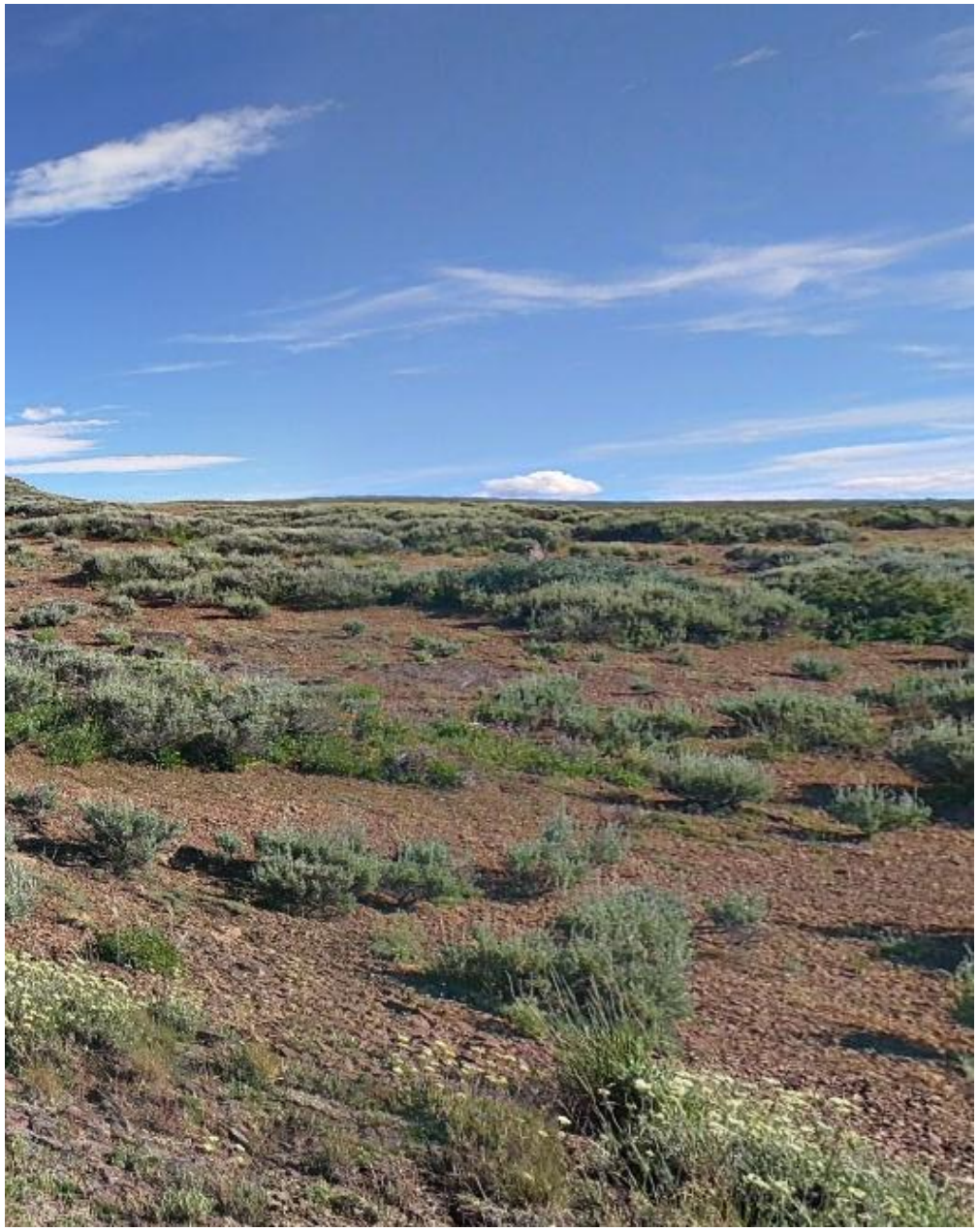
EDGES-3 Recently Proposed to NSF-ATI

1) Observe from **Oregon, USA**.

2) **Improved** hardware.

3) More **portable design**.

4) Electronics **within antenna**.



ARIZONA STATE UNIVERSITY

HAYSTACK OBSERVATORY

New Global 21-cm Experiment

MIST: Mapper of the IGM Spin Temperature

Chilean Andes Site elevation: 4,500 m PI: Ricardo Bustos

McGill UNIVERSITY

UCSC

NRAO

UNIVERSIDAD DE CHILE

We continue disfavoring the EDGES instrument as the source of the absorption feature

Working toward verifying its astrophysical origin