EDGES Mid-Band Analysis

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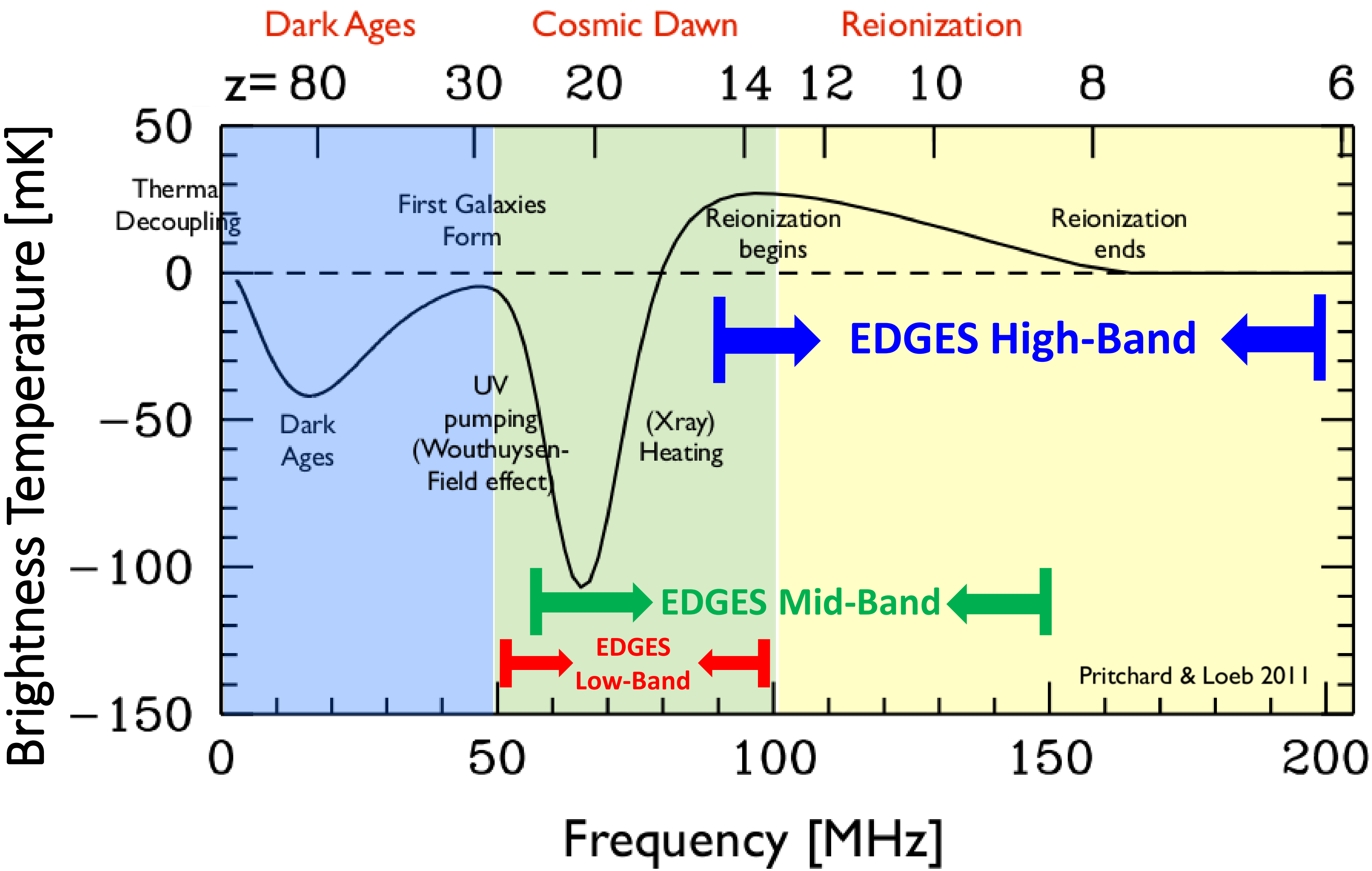
Motivation for EDGES **Mid-Band**

- Contribute to verifying the Low-Band detection by measuring with an **antenna 25% smaller** than Low-Band and a recalibrated receiver.

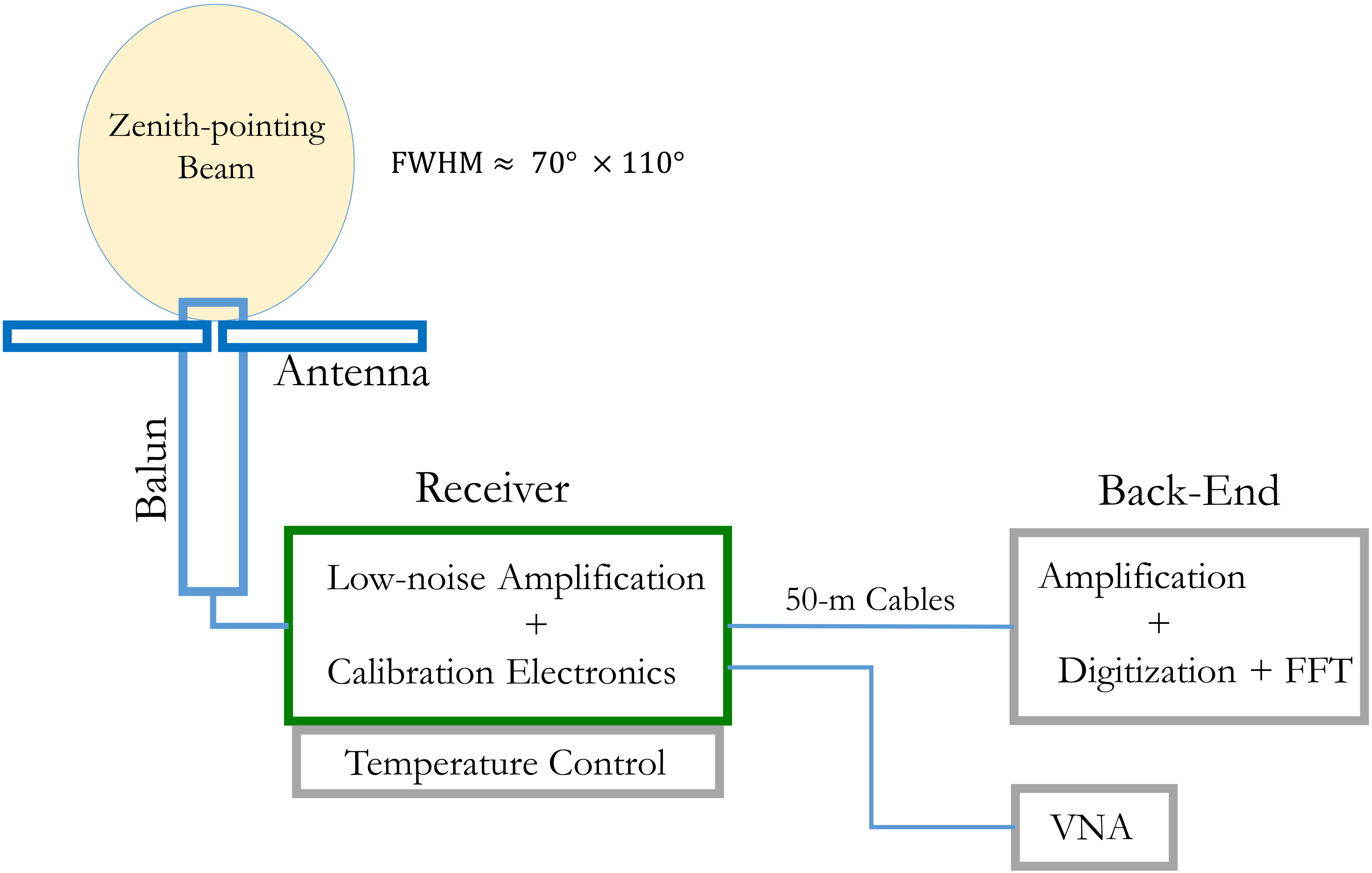
- This would test for antenna **effects that scale with antenna size**.

- This might **not test for all** antenna effects, or effects from the ground plane that are independent from the antenna.

EDGES Instruments

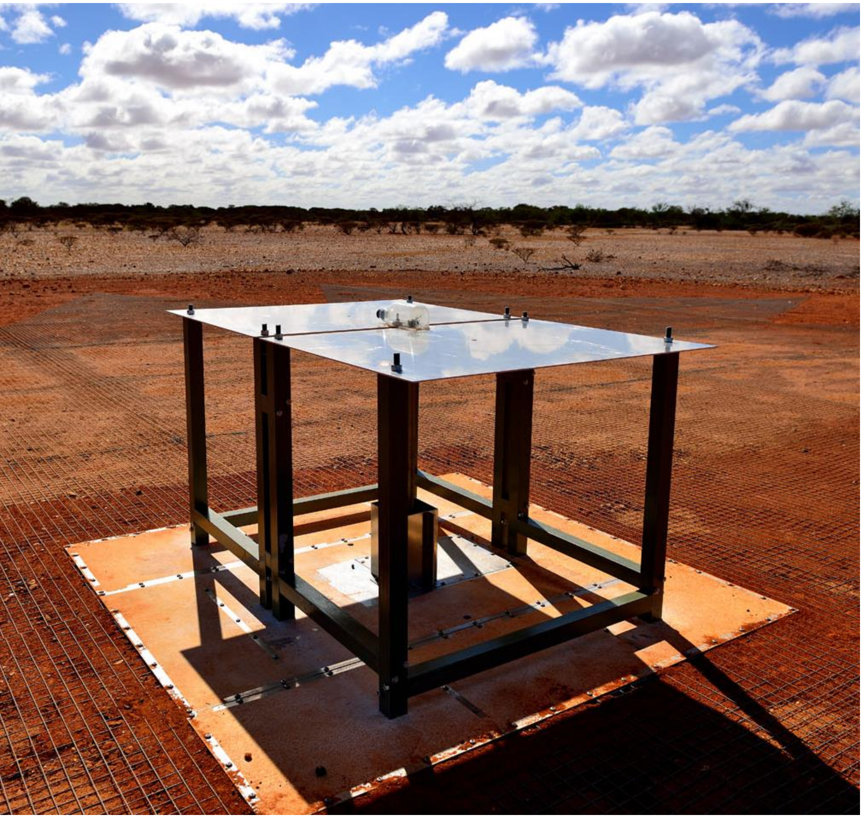


Mid-Band Block Diagram



Mid-Band Antenna

Low-Band

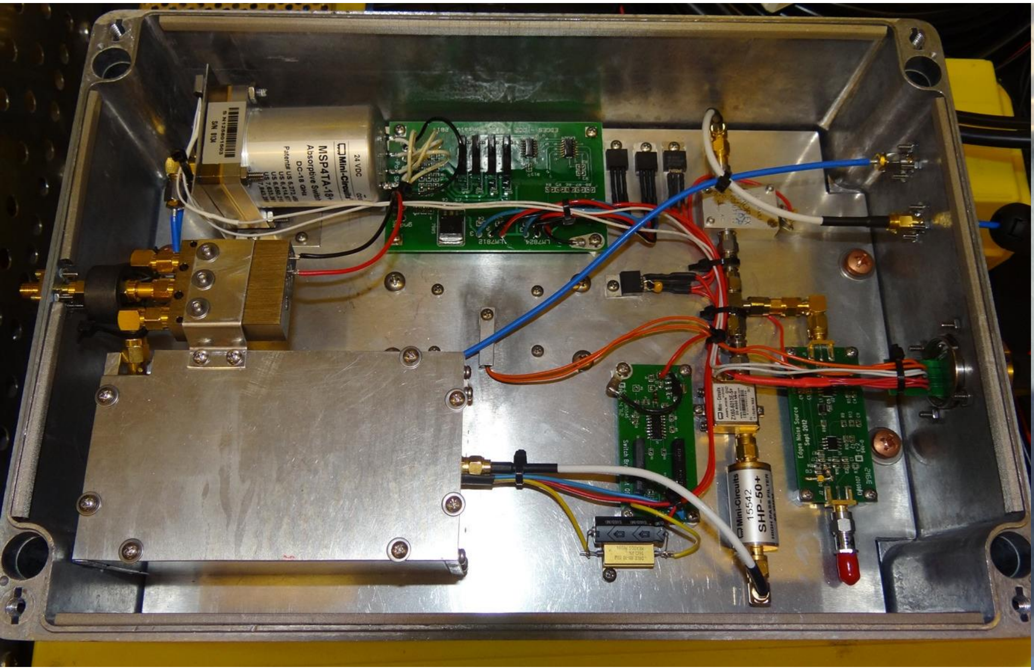


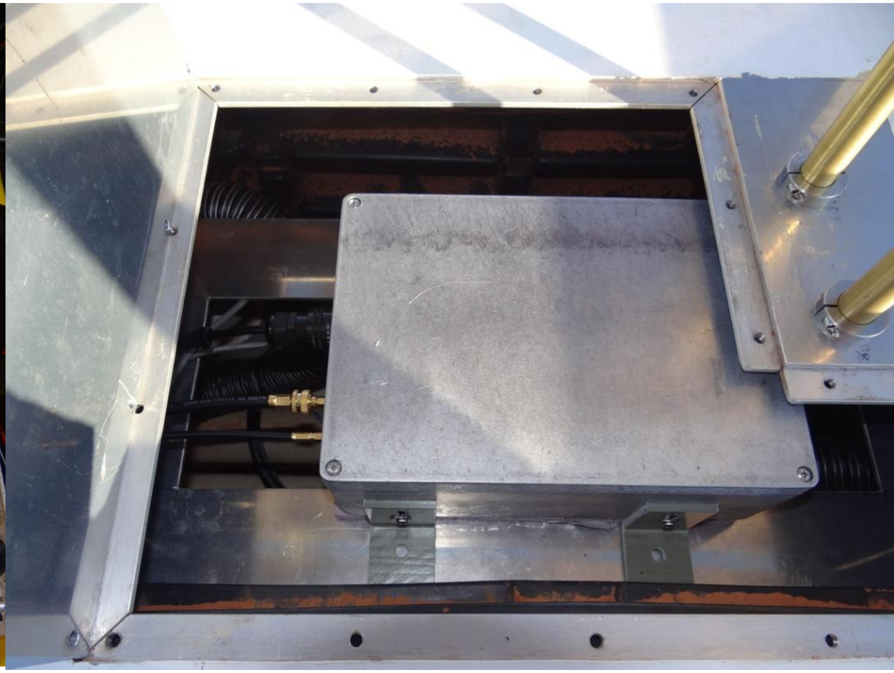
Mid-Band (~25% smaller)

Antenna size:
Length: 2 m
Width: 1.25 m
Height: 1 m

Antenna size:
Length: 1.5 m
Width: 0.95 m
Height: 0.79 m

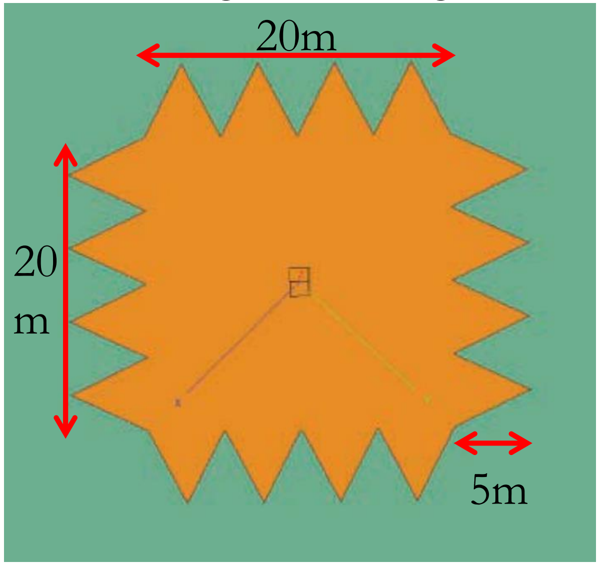
Same Receiver as **Low-Band 1**





Same Ground Plane as **Low-Band 1**

Central Square: 20m x 20m
16 Triangles: 5m-long



Instrumental Calibration

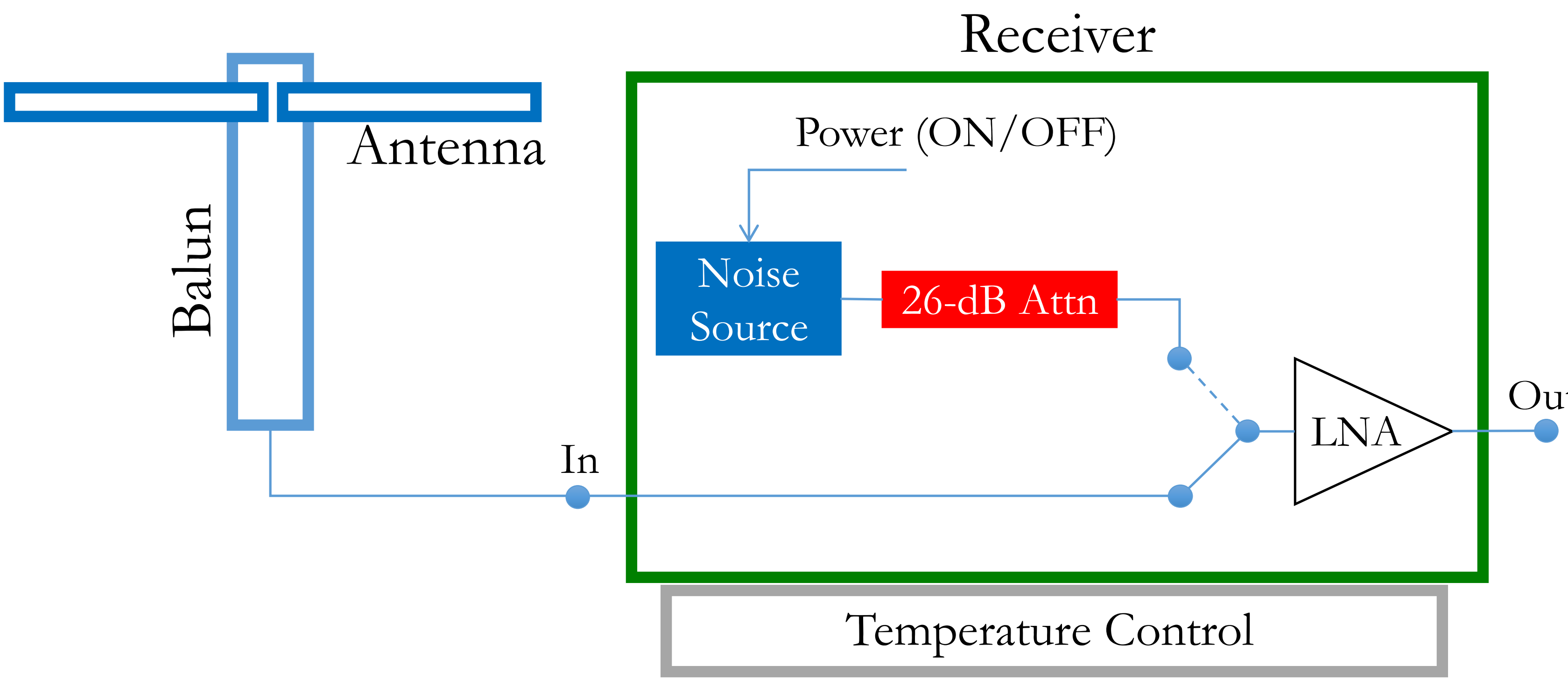
1) **Instrument gain and noise offset.**

2) **Impedance mismatch between receiver and antenna.**

3) **Antenna and ground losses.**

4) **Antenna beam chromaticity.**

Field Relative Calibration

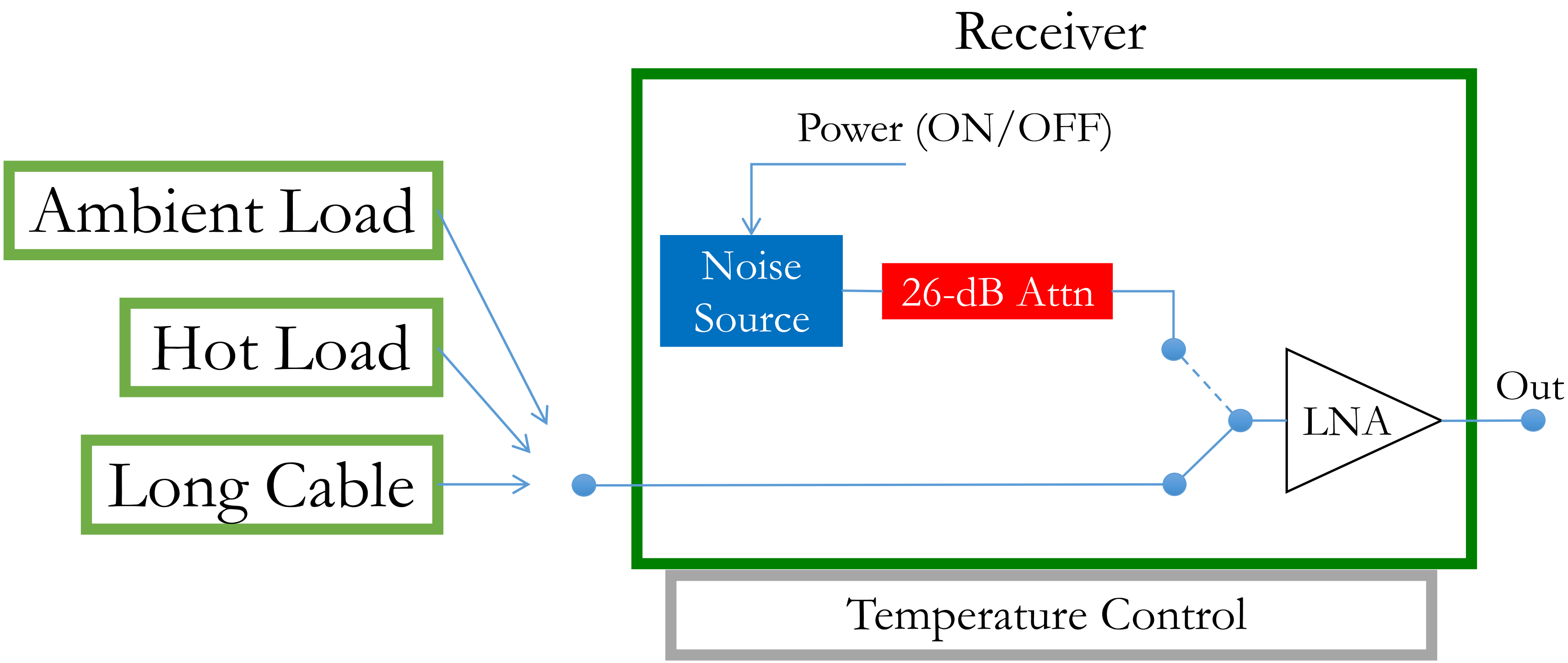


3-position switching **removes time variable instrument gain + noise offset.**

In each 3-position switching cycle we measure **power spectral density** from:

1) **Antenna**
2) **Ambient Load**
3) **Ambient Load + Noise Source**

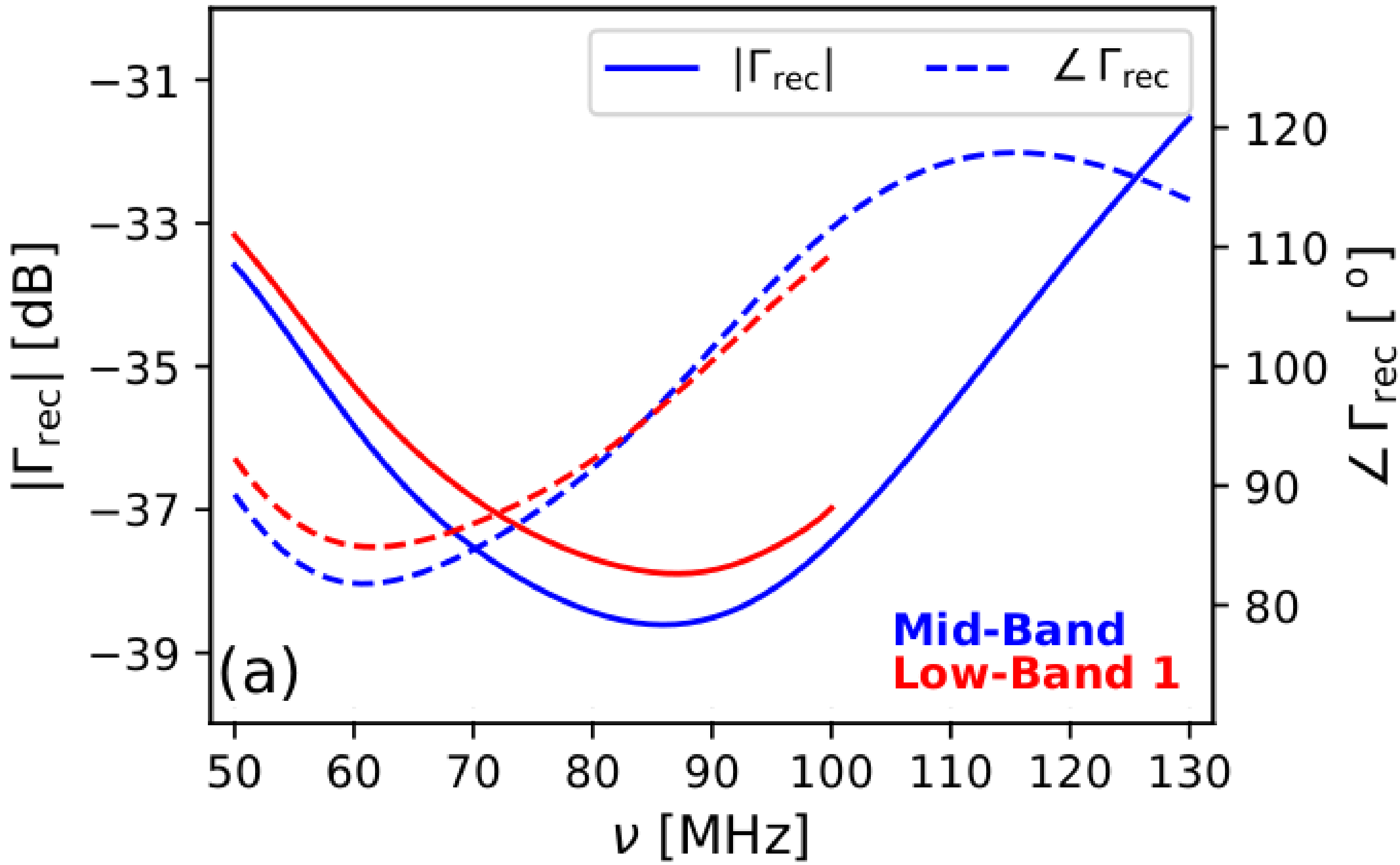
Lab Absolute Calibration



Receiver parameters are obtained measuring **calibration standards in the lab**.

We measure with high precision and accuracy the **spectrum, reflection, and temperature of the standards**.

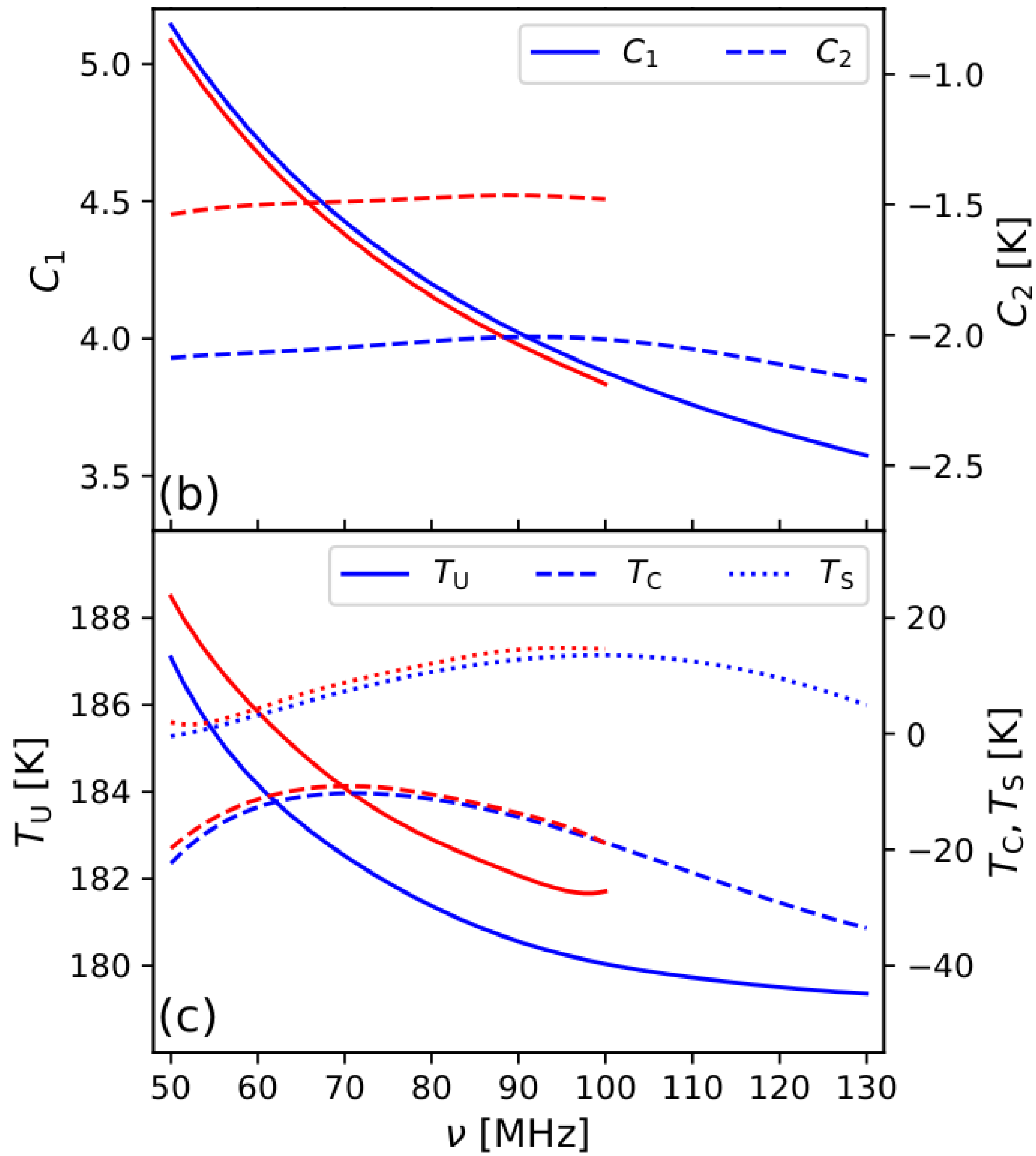
Mid-Band Receiver Parameters



Monsalve et al (2019, in preparation)

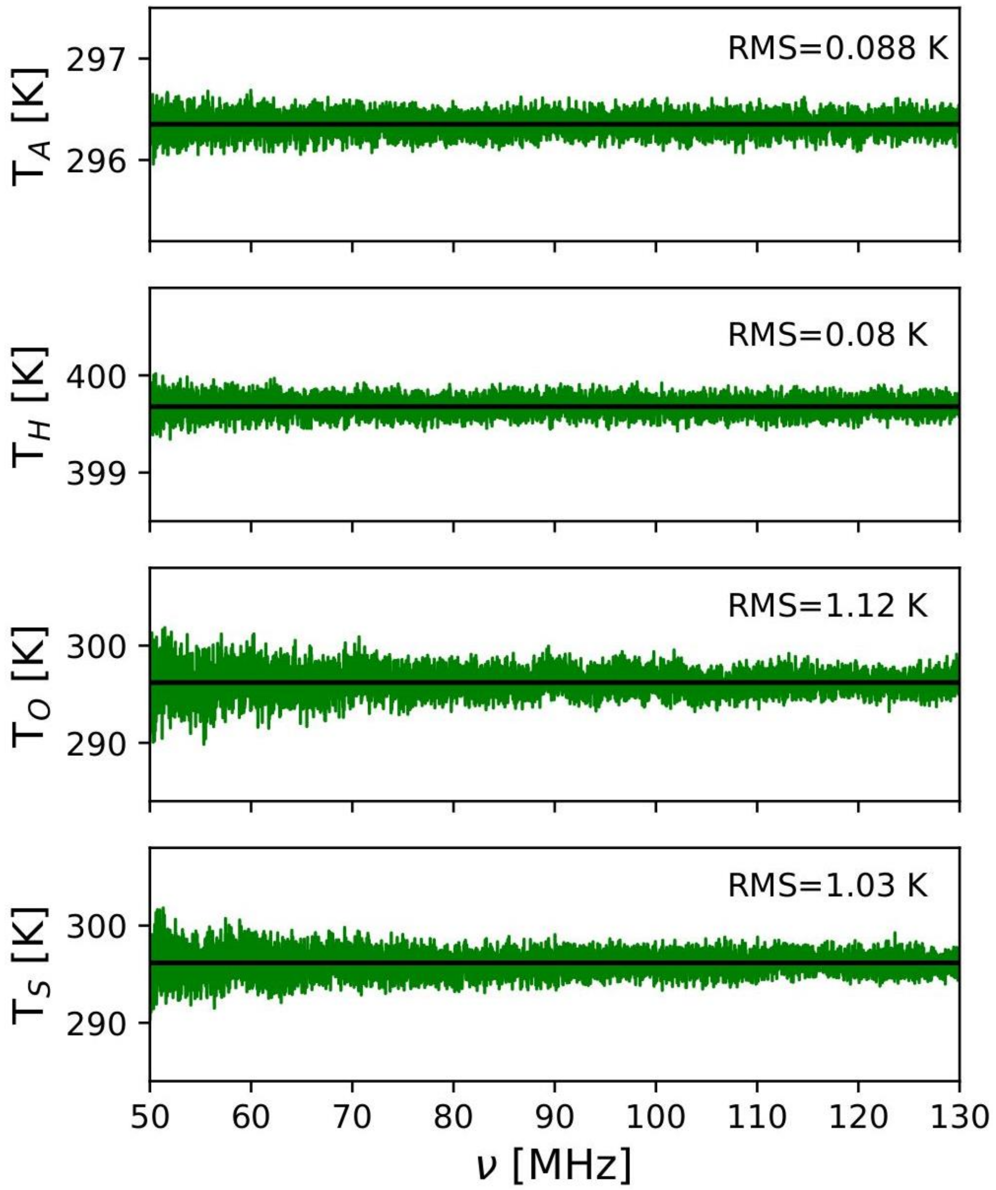
Mid-Band Receiver Parameters

Mid-Band
Low-Band 1



Monsalve et al (2019, in preparation)

Mid-Band Receiver Cross-Check



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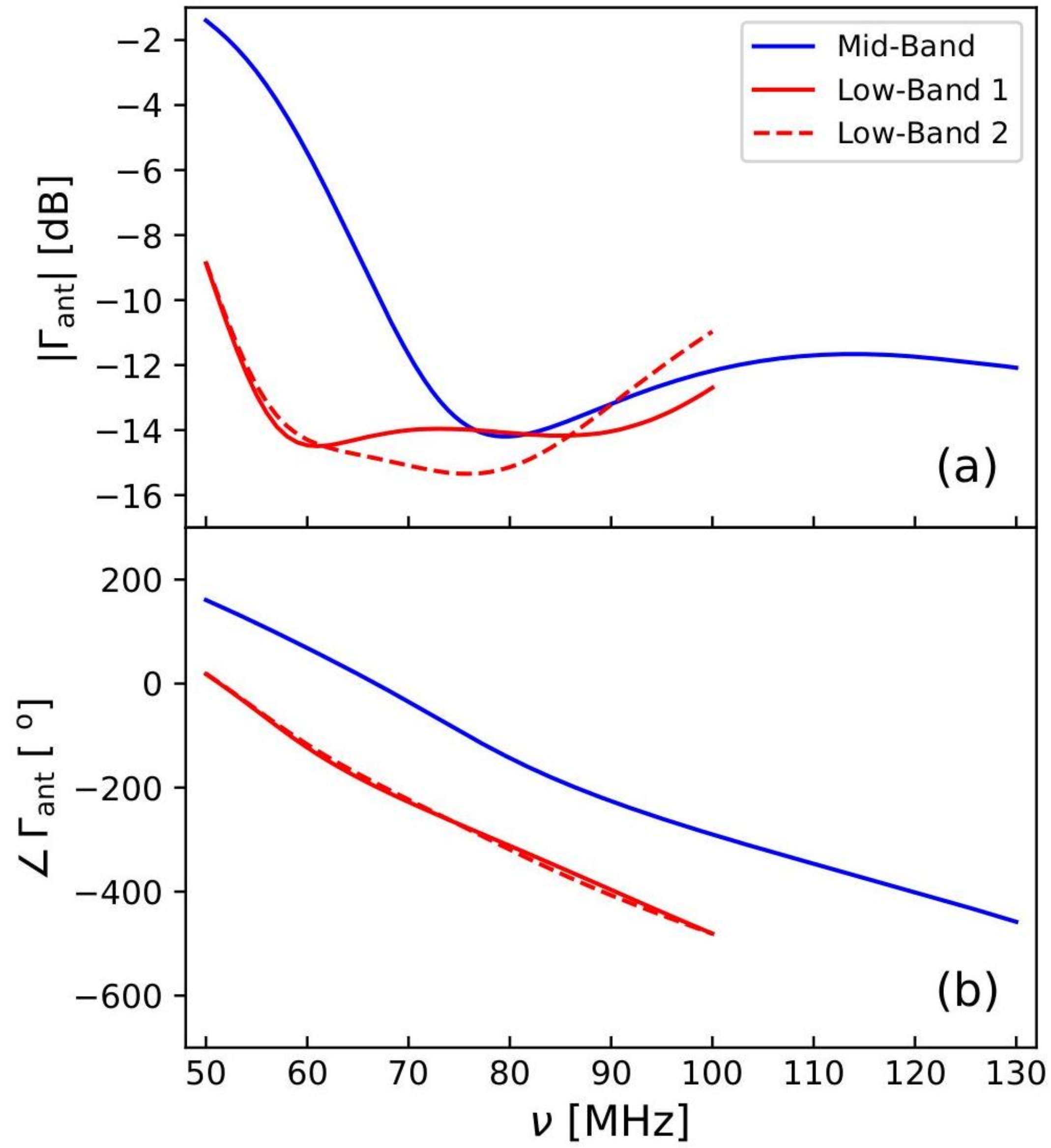
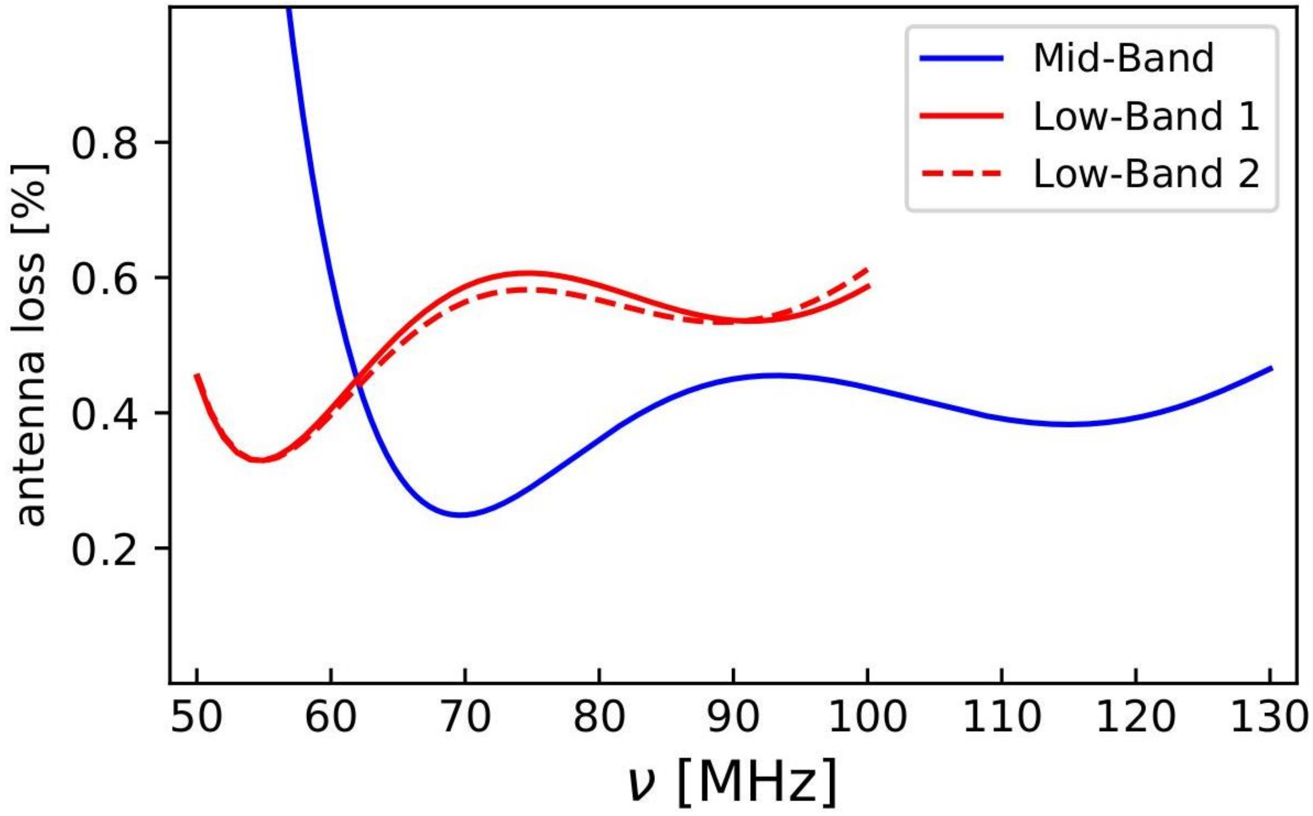
Mid-Band Antenna Reflection



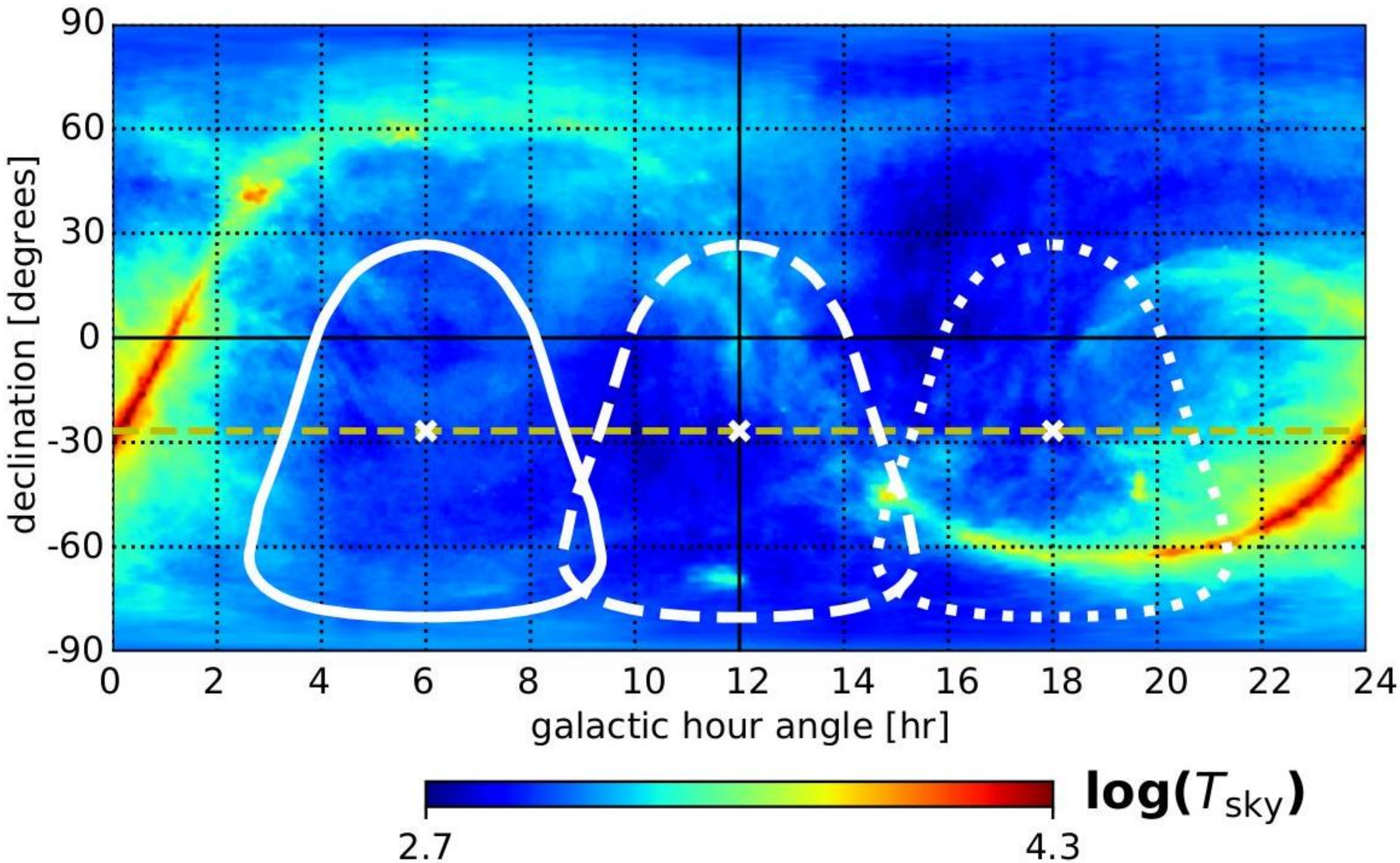
Monsalve et al (2019, in preparation)

Mid-Band Antenna Loss



Monsalve et al (2019, in preparation)

Mid-Band Beam FWHM Projected onto Sky



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Beam Chromaticity

Antenna to Sky Temperature

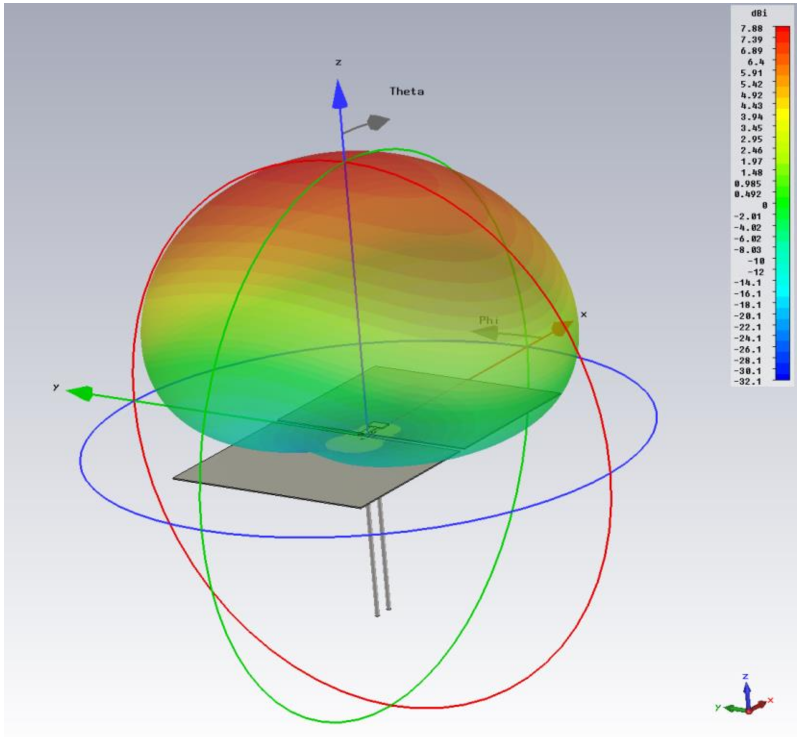
$$T_{\text{ant}}\,(\nu, \text{GHA}) = \int T_{\text{sky}}(\nu, \text{GHA}; \theta, \varphi) \cdot D(\nu, \text{GHA}; \theta, \varphi)\; d\Omega$$

$$T_{\text{ant}}\,(\nu, \text{GHA}) = \; C(\nu, \text{GHA}) \;\cdot\; T_{\text{sky}}\,(\nu, \text{GHA})$$

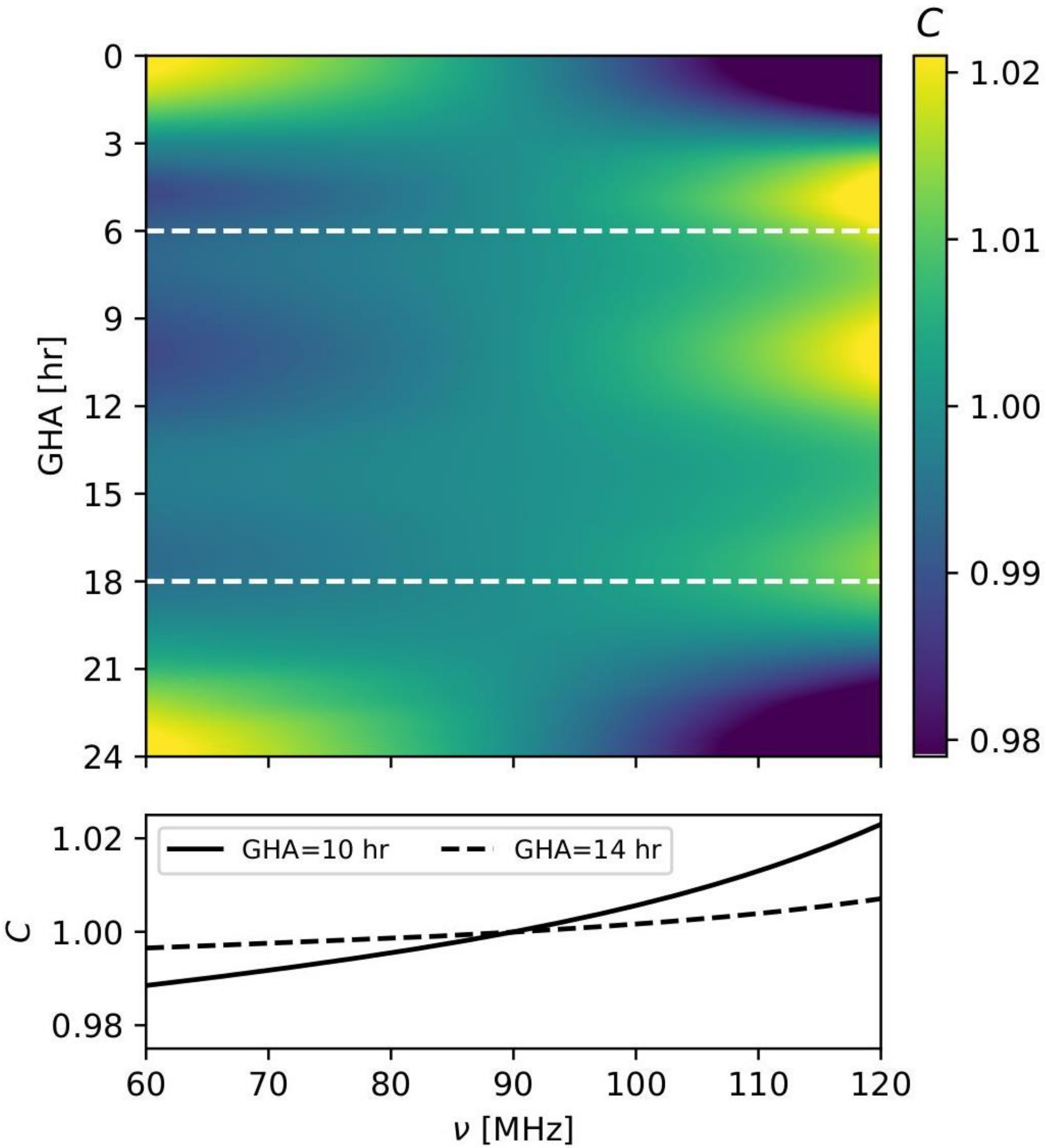
Chromaticity Correction

$$C(\boldsymbol{\nu}, \text{GHA}) = \frac{\int T_{\text{sky}}(\boldsymbol{\nu}_{\textbf{ref}}, \text{GHA}; \theta, \varphi) \cdot D(\boldsymbol{\nu}, \text{GHA}; \theta, \varphi)\; d\Omega}{\int T_{\text{sky}}(\boldsymbol{\nu}_{\textbf{ref}}, \text{GHA}; \theta, \varphi) \cdot D(\boldsymbol{\nu}_{\textbf{ref}}, \text{GHA}; \theta, \varphi)\; d\Omega}$$

Antenna Directive Gain from Simulation



Mid-Band Chromaticity Correction



Monsalve et al (2019, in preparation)

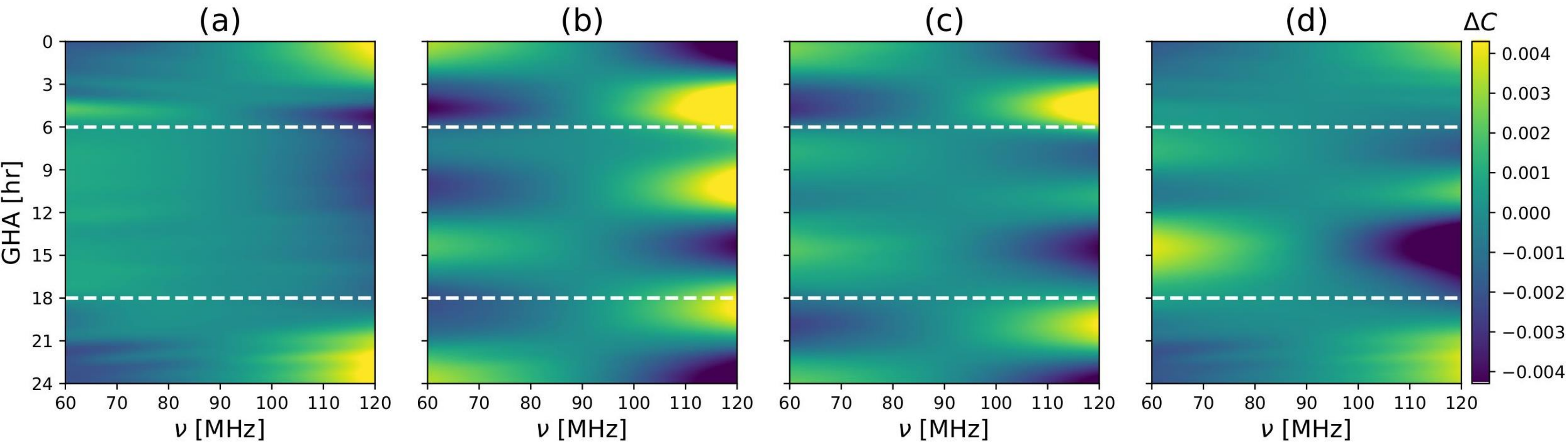
Mid-Band Chromaticity Correction

Infinite metal ground plane

Haslam 408 MHz map flat spectral index

LW 150 MHz map (Landecker & Wielebinski 1970)

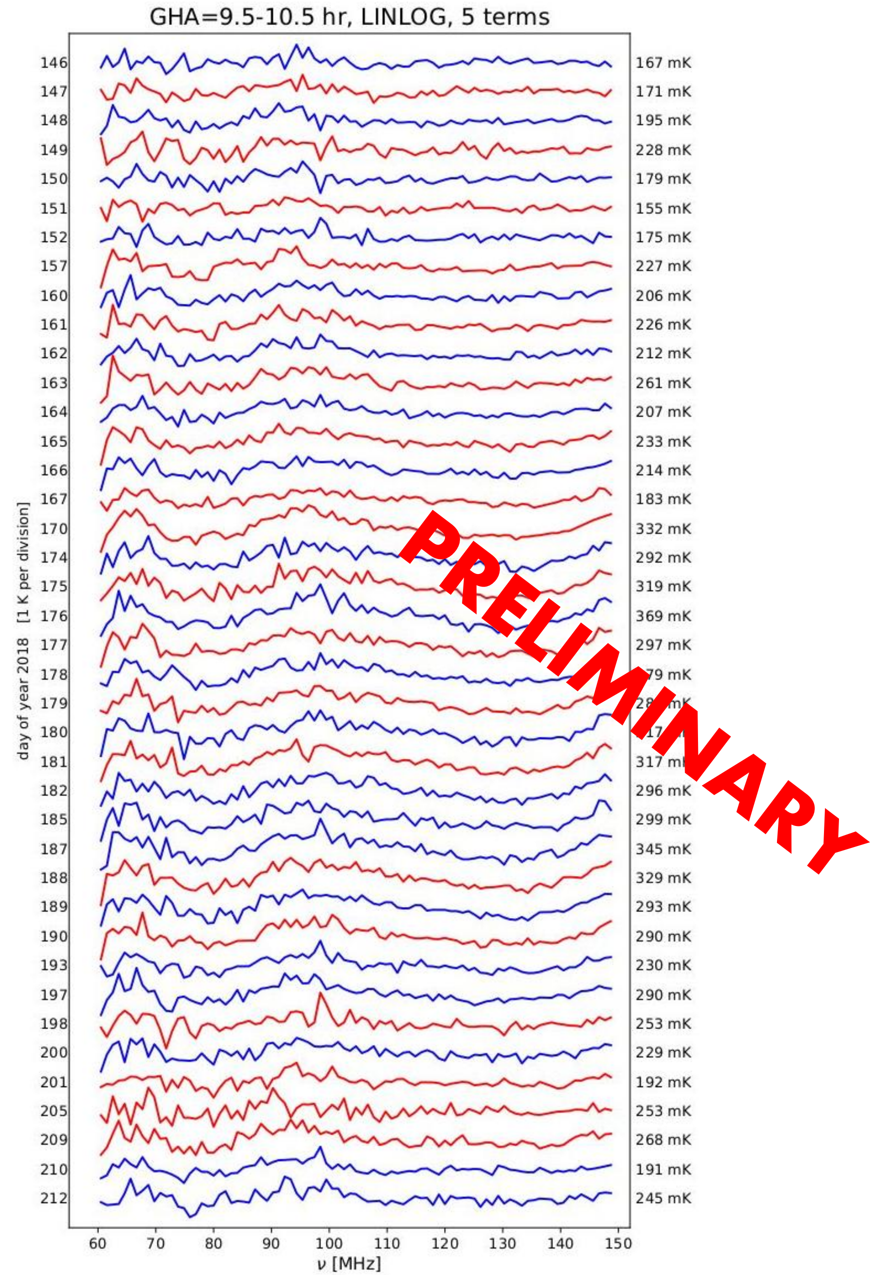
Guzman 45 MHz map (Guzman et al 2011)



Monsalve et al (2019, in preparation)

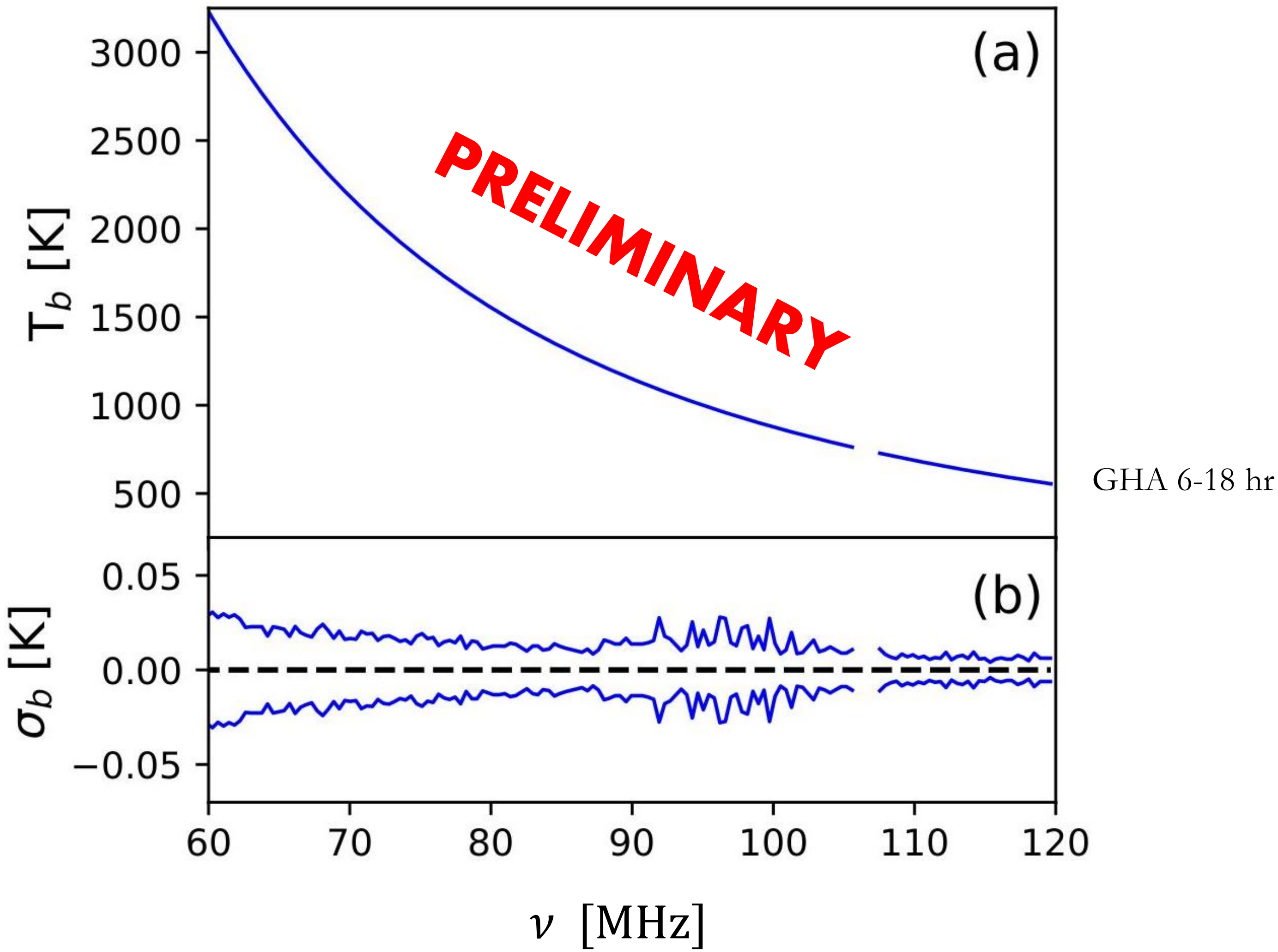
Sample of Daily **Mid-Band** Residuals for 1hr Integrations

May-August 2018



Monsalve et al (2019, in preparation)

Integrated **Mid-Band** Spectrum



Monsalve et al (2019, in preparation)

Model of the Spectrum

$$m(\nu) = m_{21}(\nu) + m_{\mathrm{fg}}(\nu)$$

Absorption Model: "Flattened Gaussian"

$$m_{21}(\nu) = -\boldsymbol{A} \left(\frac{1 - e^{-\boldsymbol{\tau}\, e^{B}}}{1 - e^{-\boldsymbol{\tau}}} \right)$$

$$B = \frac{4\,(\nu - \boldsymbol{\nu_0})^2}{\boldsymbol{w}^2} \quad \ln\left[-\left(\frac{1}{\boldsymbol{\tau}}\right) \ln\left(\frac{1 + e^{-\boldsymbol{\tau}}}{2}\right) \right]$$

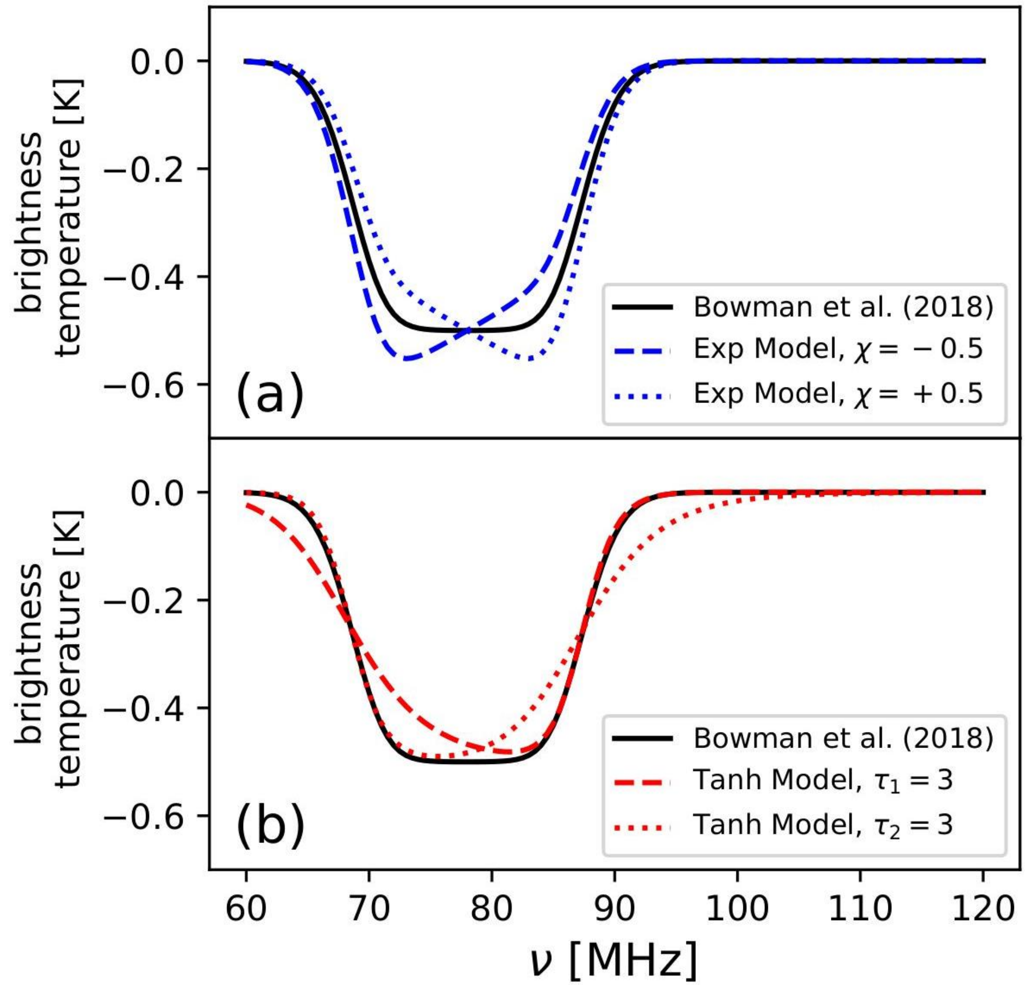
$\boldsymbol{A}$: absorption amplitude

$\boldsymbol{\nu_0}$: center frequency

$\boldsymbol{w}$: width

$\boldsymbol{\tau}$: flattening parameter

Extended "Flattened Gaussian"



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Foreground Models

PowerLog:

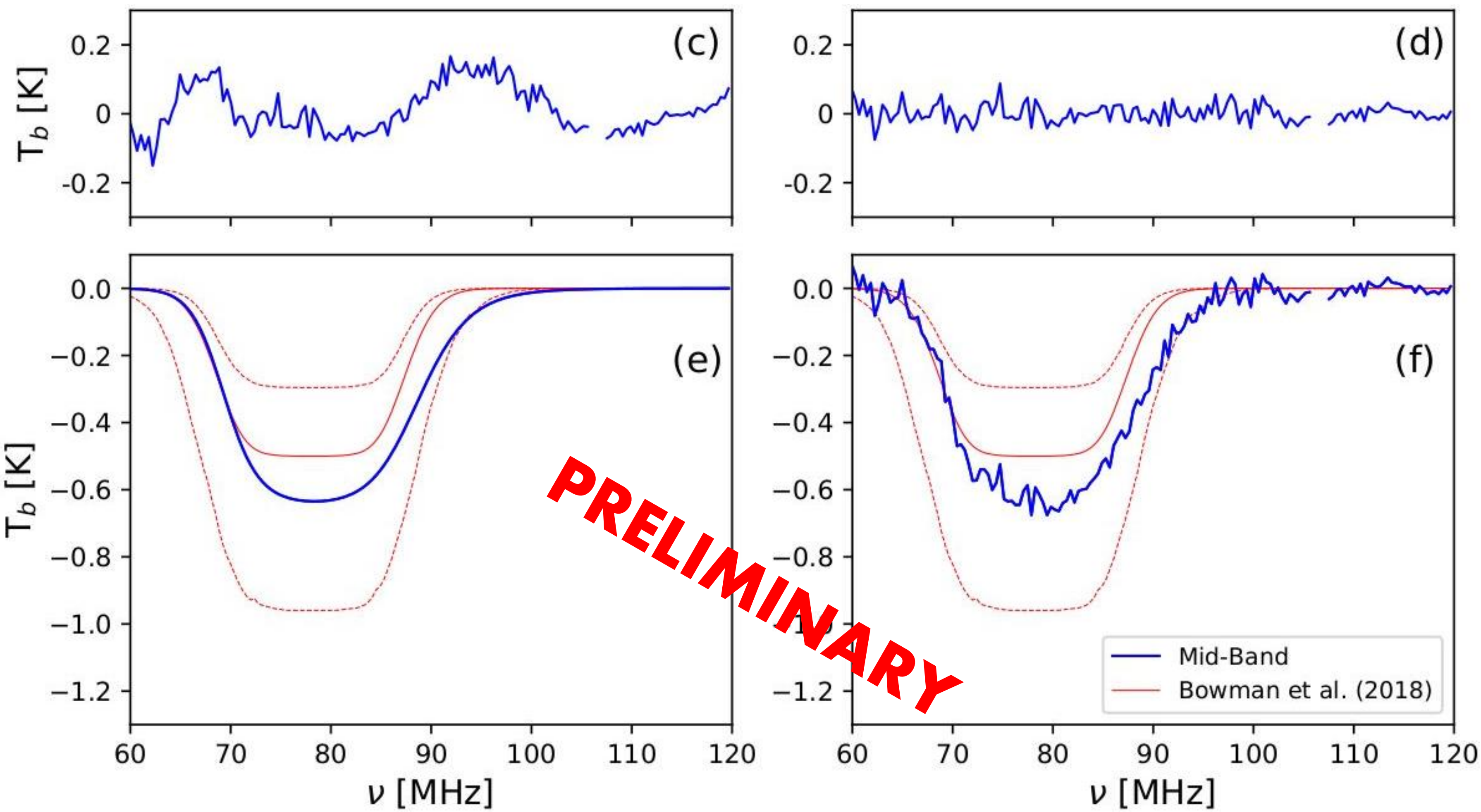
$$m_{\text{fg}}(\nu) = \boldsymbol{a_0} \left(\frac{\nu}{\nu_0}\right)^{\sum_{i=1}^{N_{\text{fg}}-1} \boldsymbol{a_i} \left[log\left(\frac{\nu}{\nu_0}\right)\right]^{i-1}}$$

LinLog Model:

$$m_{\text{fg}}(\nu) = \left(\frac{\nu}{\nu_0}\right)^{-2.5} \sum_{i=0}^{N_{\text{fg}}-1} \boldsymbol{a_i} \left[log\left(\frac{\nu}{\nu_0}\right)\right]^{i}$$

Smooth sets of basis functions that model well, with few terms, the spectrum over wide frequency ranges.

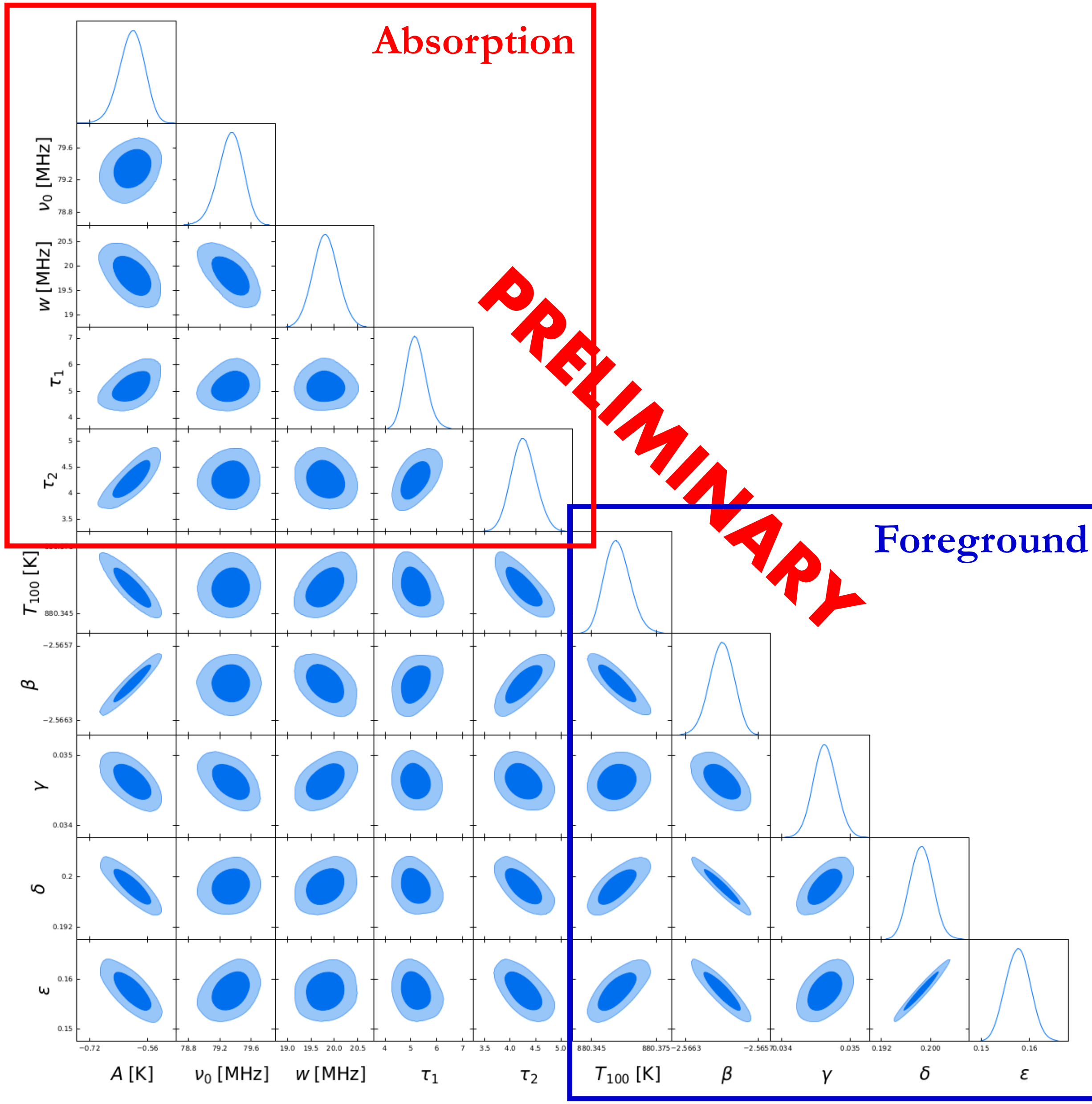
Preliminary **Mid-Band** Results



Monsalve et al (2019, in preparation)

- Not identical but consistent with Bowman et al (2018).
- Rising slope less steep than Bowman et al (2018).

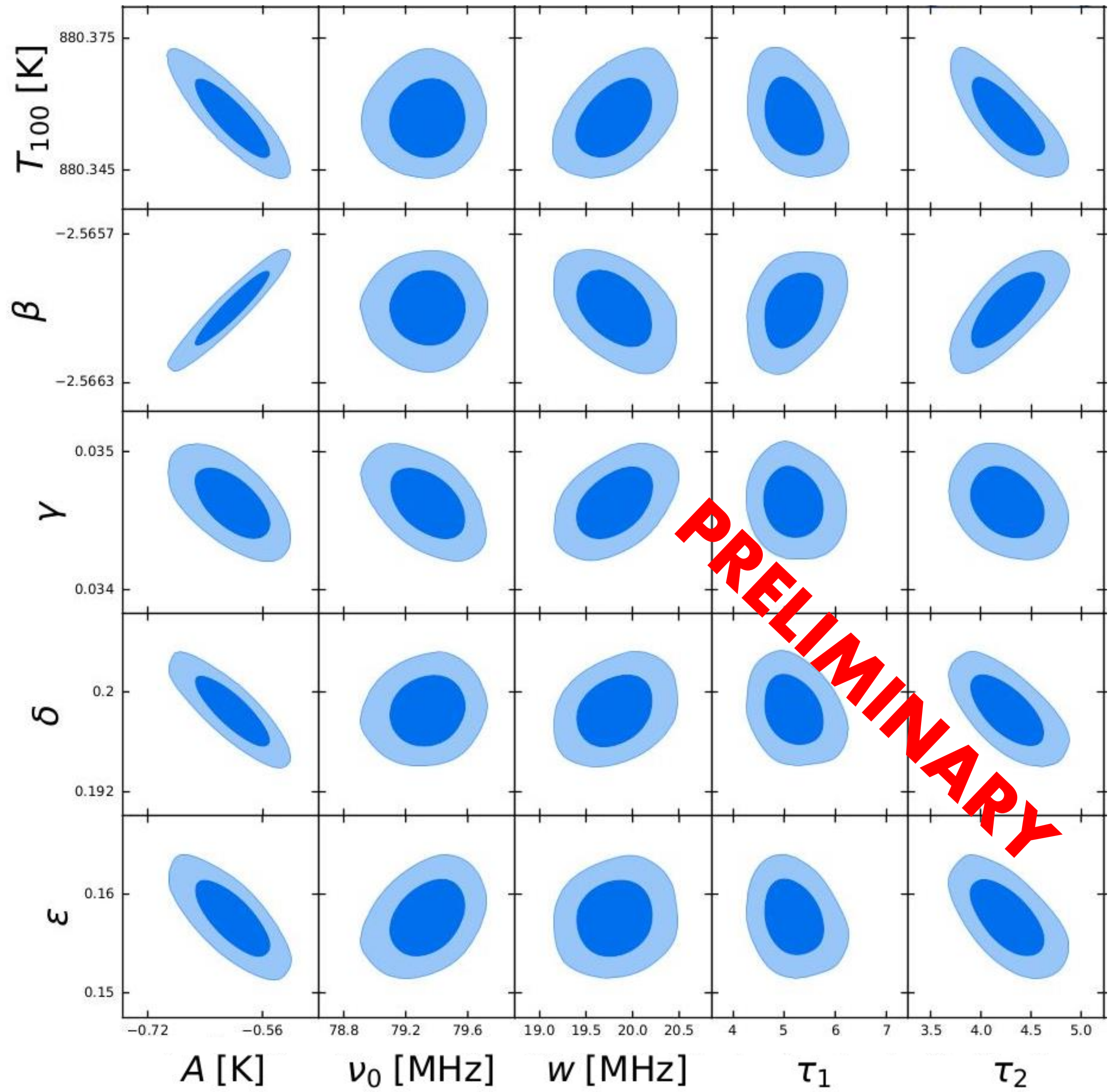
Preliminary Mid-Band Results



- Using Polychord Nested Sampling algorithm
- PowerLog foreground model
- Extended flattened Gaussian

Monsalve et al (2019, in preparation)

Preliminary **Mid-Band** Results



Monsalve et al (2019, in preparation)

Current Efforts

1) Data selection:

- Relatively **small dataset**, with **low-foreground region available during daytime**. Ionosphere and ambient temperature **less stable than at night**. Data selection is important.
- Working on **developing robust filters** that select for analyses the most representative observations.

2) New lab receiver calibration:

- Evaluating the **sensitivity** of the integrated spectrum to the **receiver calibration** solution.
- In **2018** we carried out the nominal receiver calibration, **before observations**.
- In **2019** we carried out a receiver calibration **after observations**.
- **Currently** carrying out a **second receiver calibration after observations**.

3) Beam models:

- To determine correctly the antenna beam chromaticity, the **antenna gain** has to be computed **over the full sphere**, and not only above the horizon.
- The **gain below the horizon is very hard to compute** reliably **when including a realistic model of the soil** below the ground plane.
- Currently computing antenna gain using **different software packages** for comparison.

Summary

- **Nominal analysis** of Mid-Band observations yield an **absorption feature consistent with Bowman et al (2018)**.

- Currently we are:

1) refining the **data selection**,

2) evaluating the **receiver calibration stability**, and the **sensitivity** of the spectrum to small variations, and

3) verifying our **antenna beam model** over the full sphere using **several** software packages.