# Recent Progress by the EDGES Global 21-cm Experiment

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# EDGES

## Experiment to Detect the Global EoR Signature

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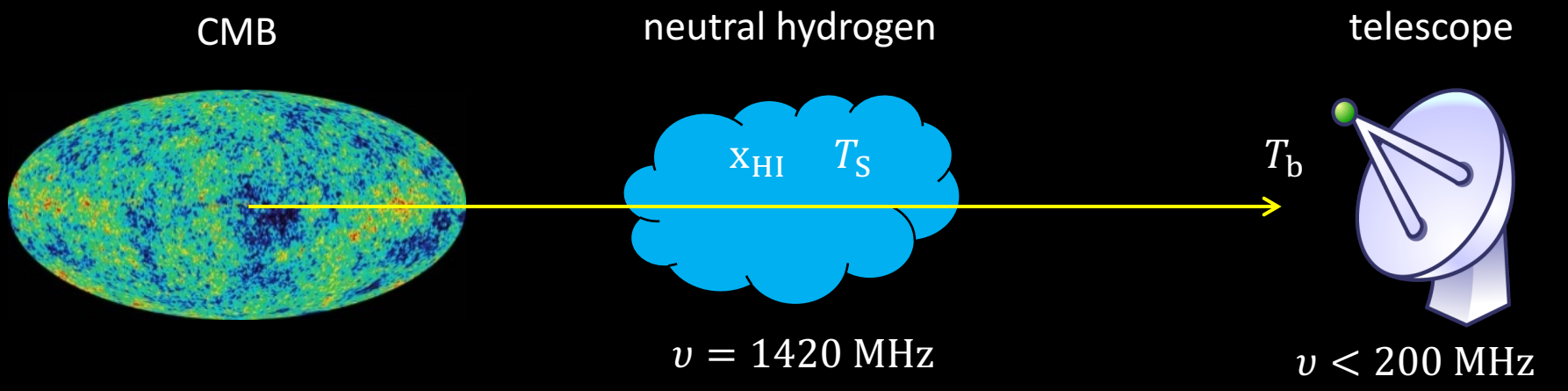
# 21-cm Cosmology



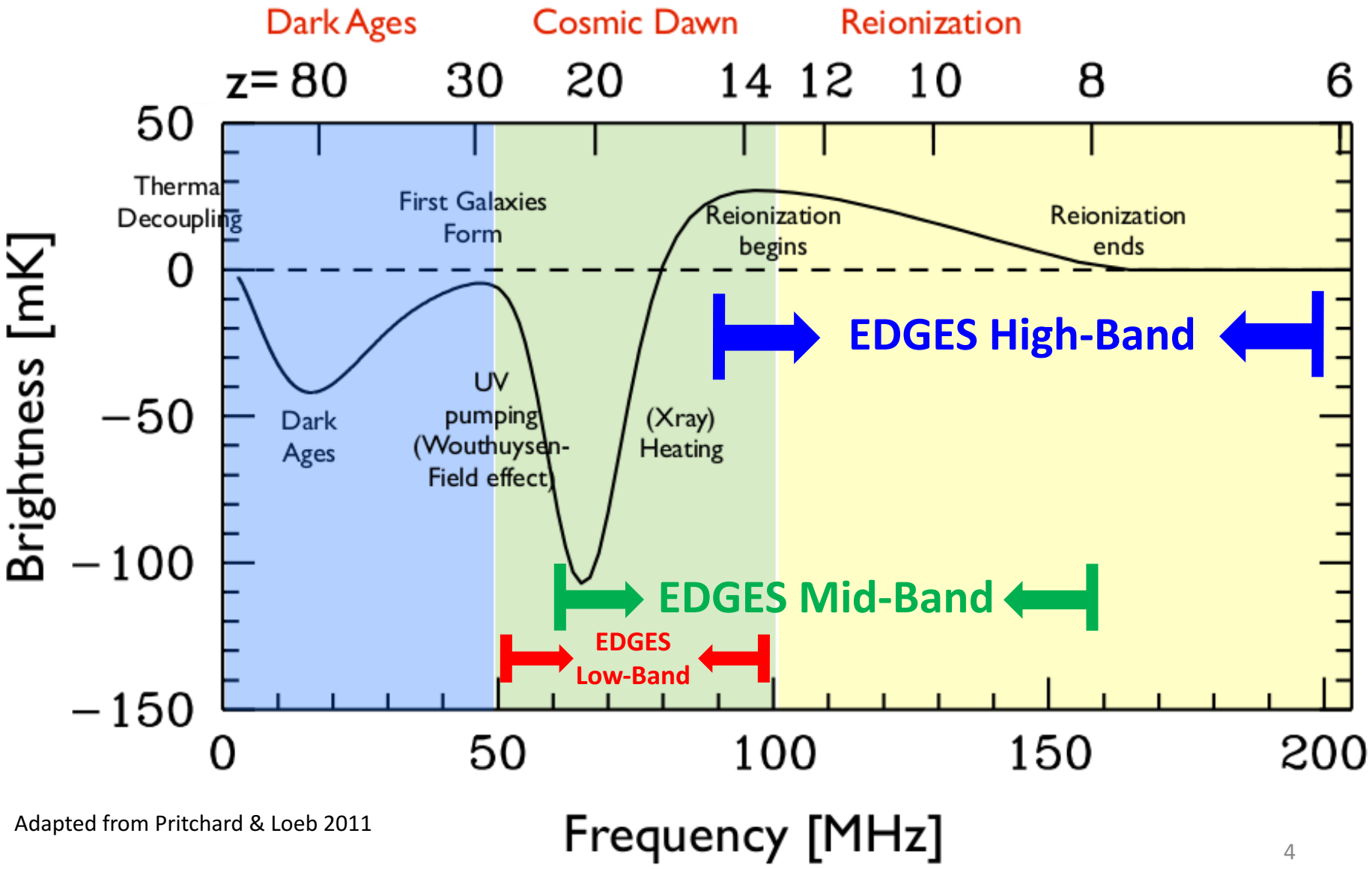

## Average Cosmological Brightness Temperature

$$T_b(\theta, z) \approx 28\,\mathrm{mK} \cdot (1+\delta) \cdot \sqrt{\frac{1+z}{10}} \cdot x_{HI} \cdot \left(\frac{T_S - T_{CMB}}{T_S}\right)$$

fraction of neutral hydrogen

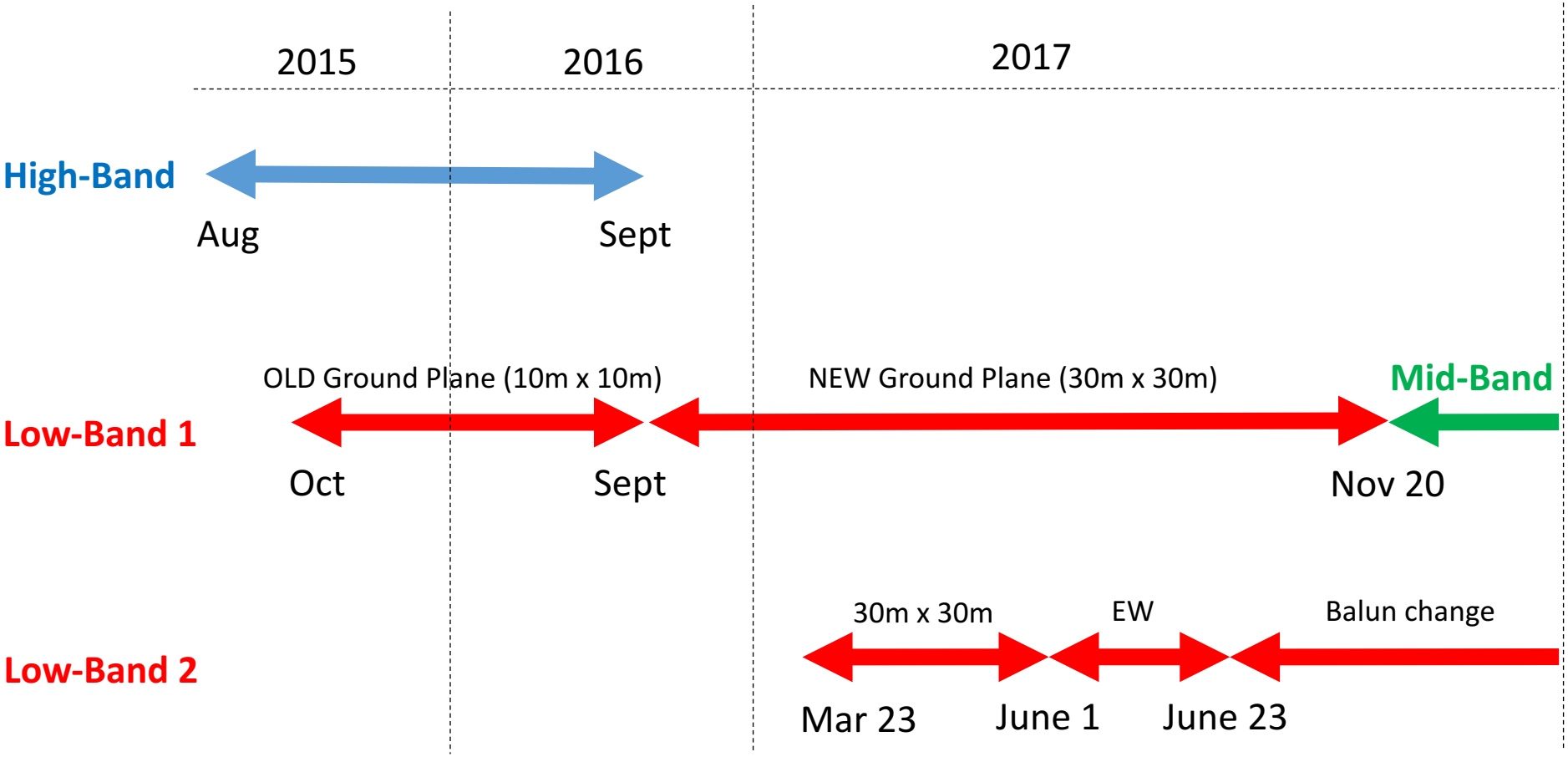
spin temperature

# Three EDGES Instruments




Adapted from Pritchard & Loeb 2011

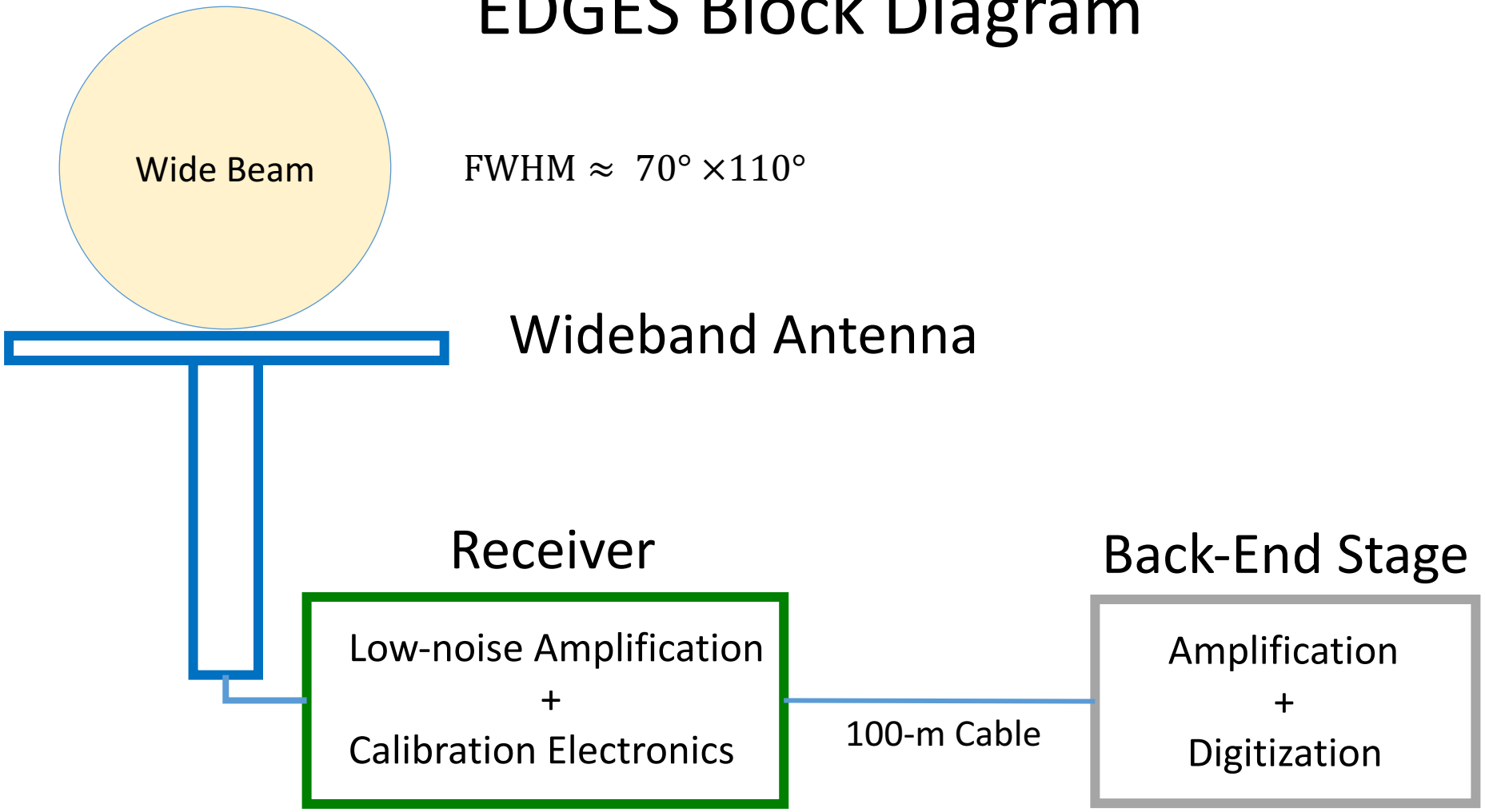
# Current EDGES Instruments



# Location


EDGES
MRO
Northern Territory
Queensland
Australia
Western Australia
South Australia
Perth
Adelaide
Great Australian Bight
Brisbane
Gold Coast
New South Wales
Sydney
Australian Capital Territory
Victoria
Melbourne
Map data ©2014 GBRMPA, Google

# EDGES Block Diagram

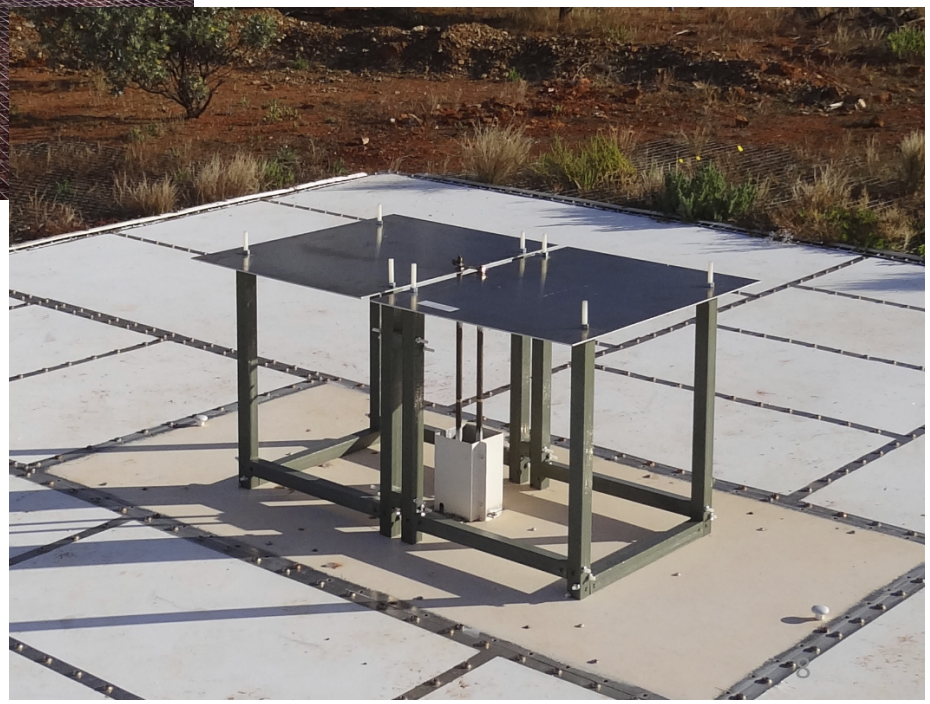



**Details in:**

Mozdzen et al. (2016)

Monsalve et al. (2017)

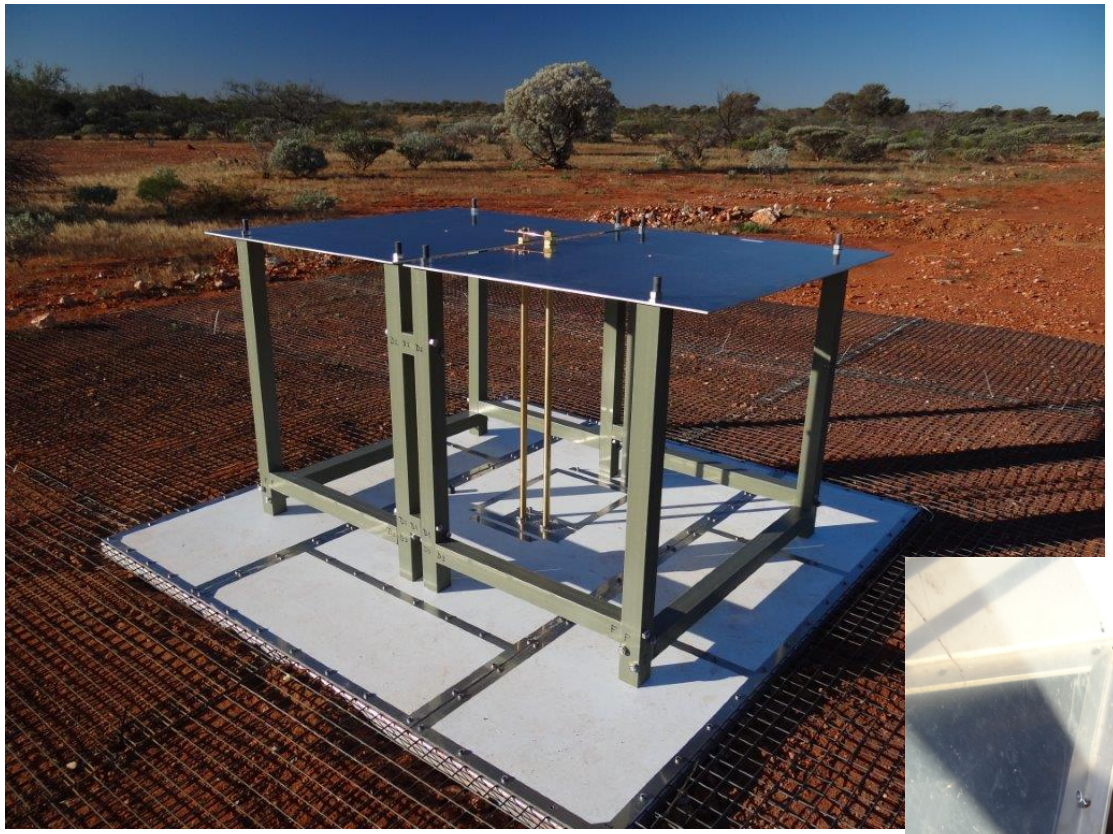
# EDGES High-Band



**Ground plane:**
**10m x 10m**

**Antenna size:**
**1m long / 0.5m high**

# EDGES Low-Band



**Original Ground plane:**
**10m x 10m**

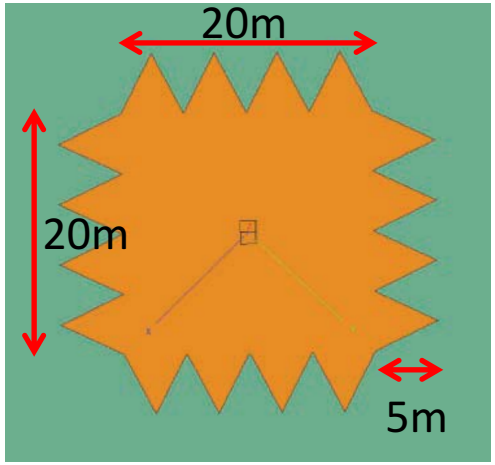
**Antenna size:**
**2m long / 1m high**

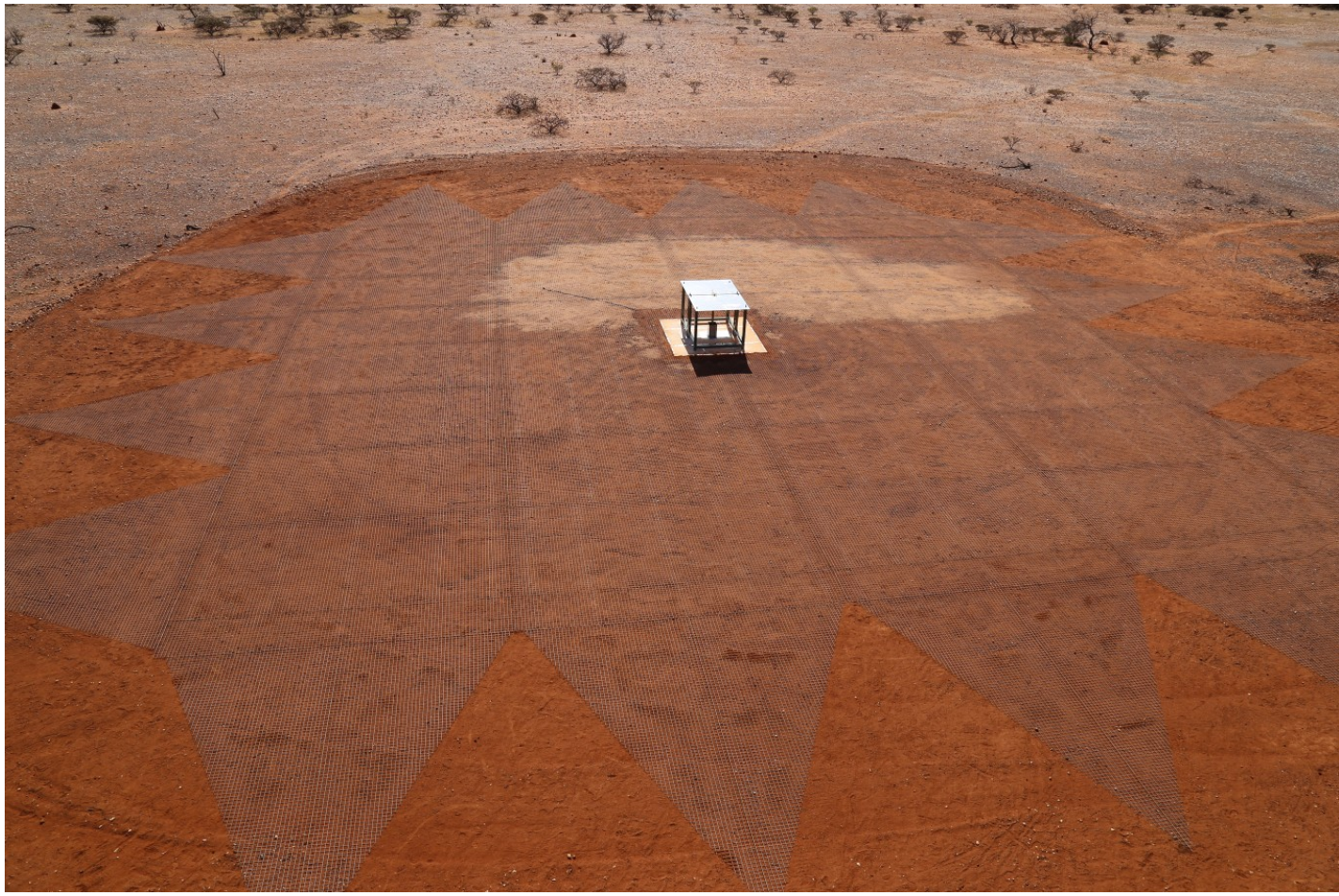
# EDGES Mid-Band

**Antenna size:**
**1.9m long / 0.8m high**

# Low/Mid-Band Ground Plane

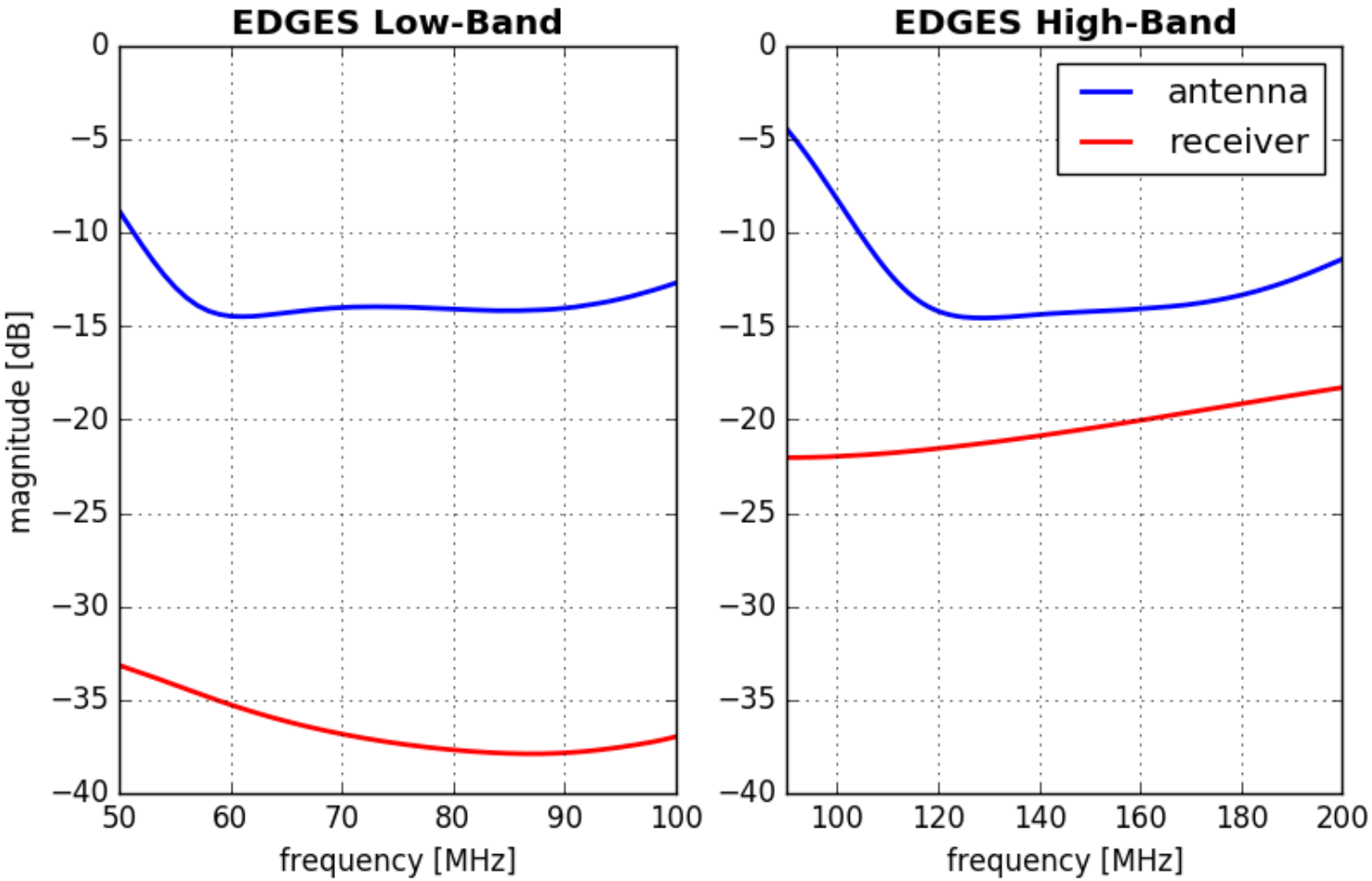
**Extended Ground Plane:**
**Central Square: 20m x 20m**
**16 Triangles: 5m-long**



# Reflection Coefficients

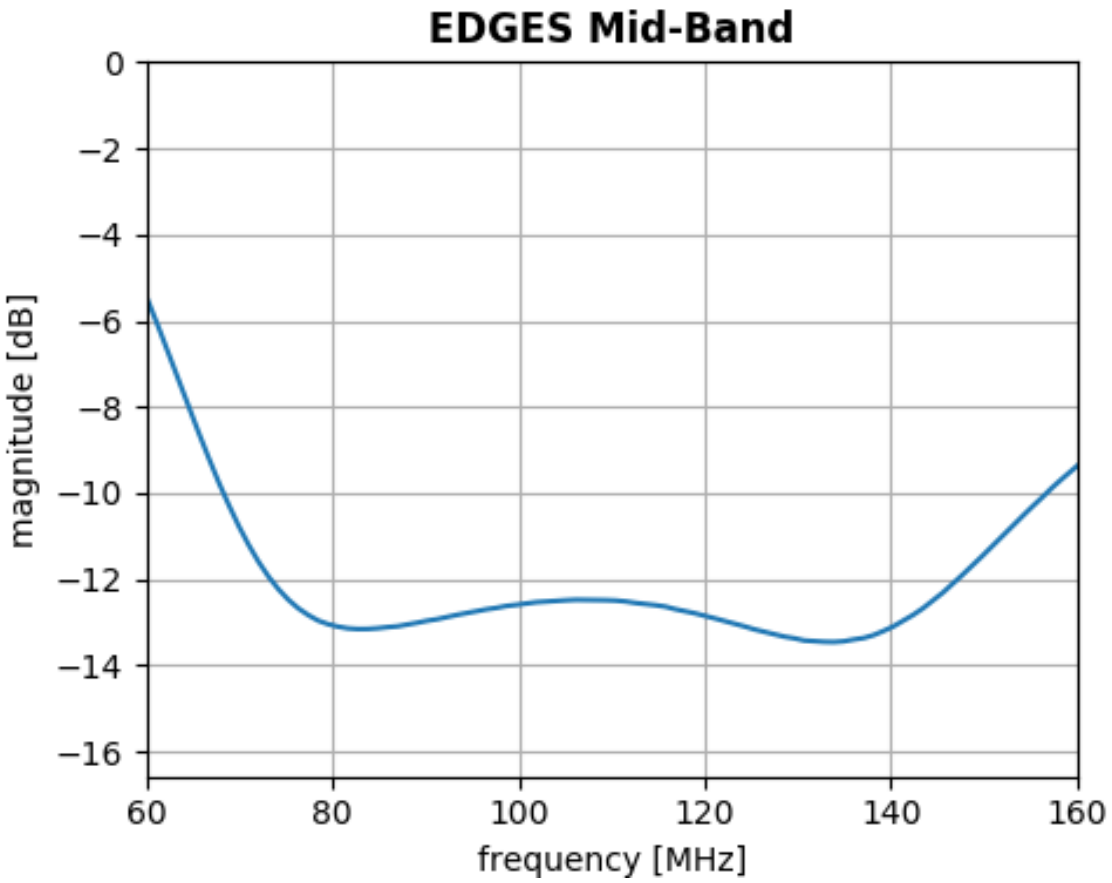
z=27 z=13 z=15 z=6



# Reflection Coefficients

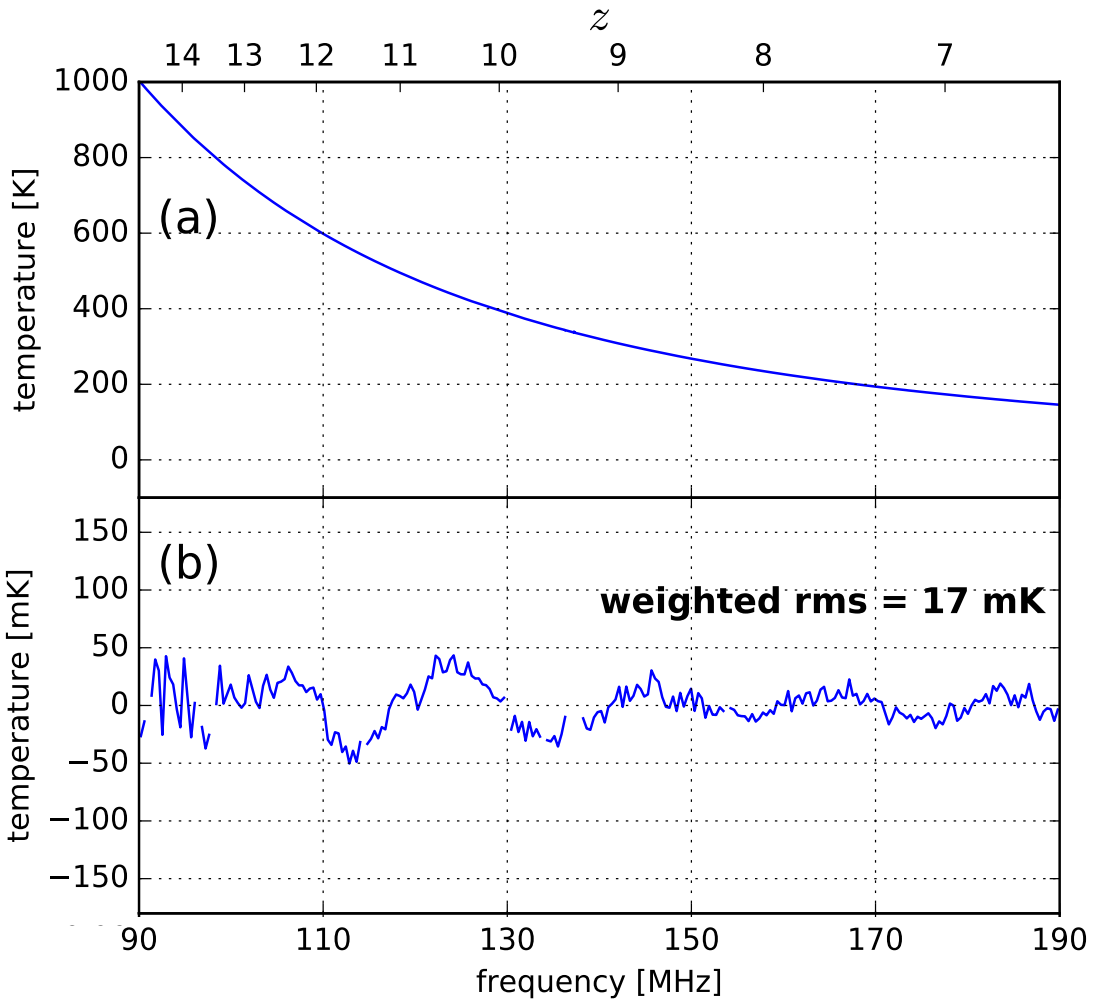
z = 22

z = 8

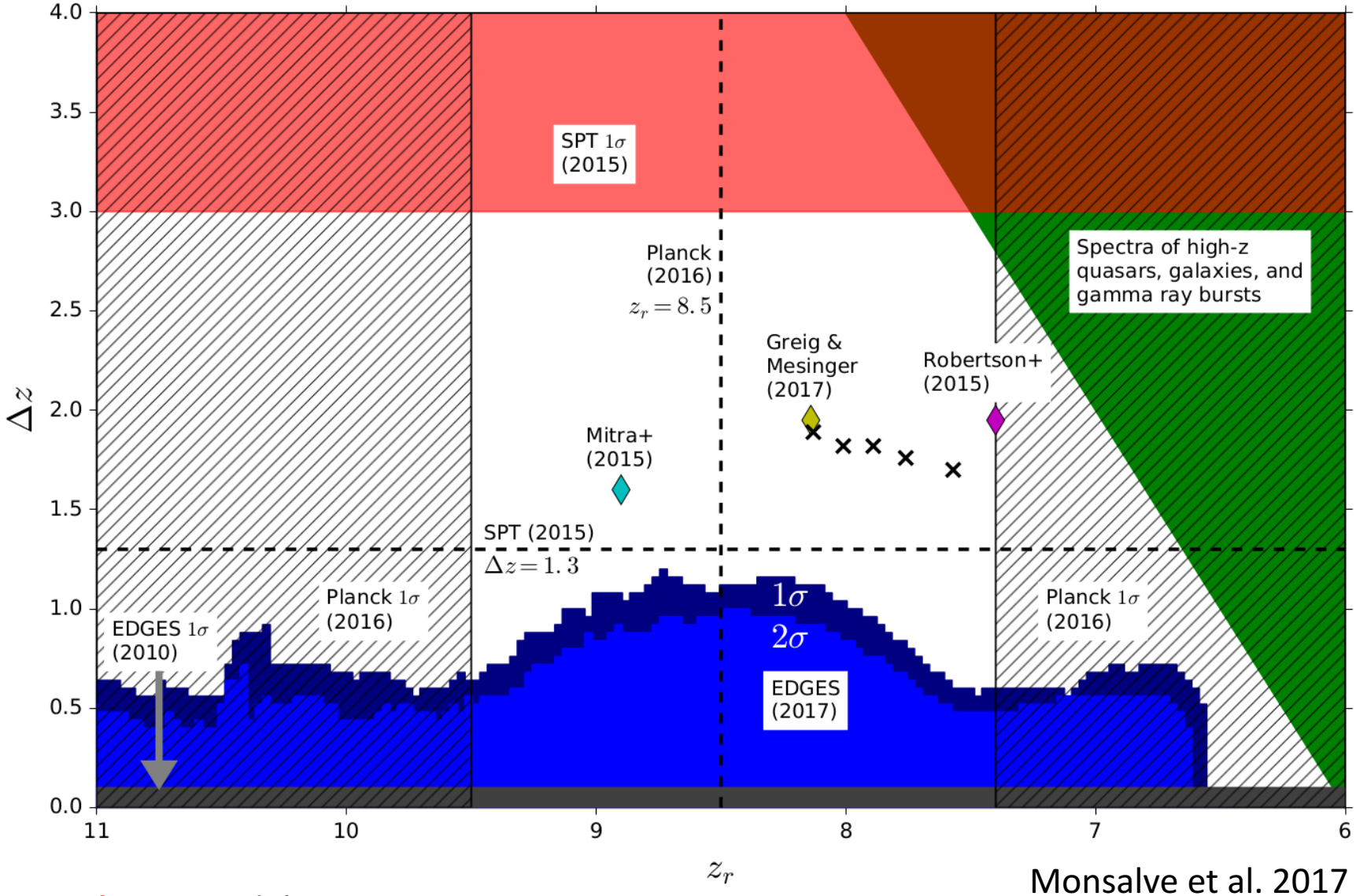


# High-Band Integrated Spectrum

- Residuals to 5-term polynomial.
- Average of 40 days of nighttime.
- Up to 6-hr average per day.
- Low foregrounds.



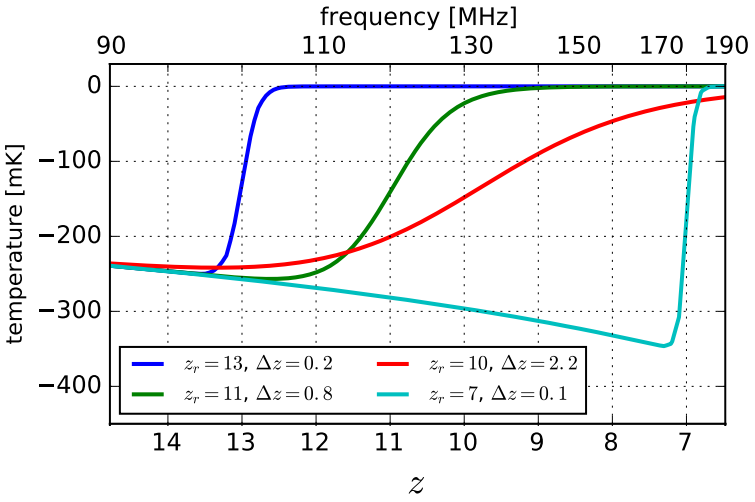
# EoR Constraints for $T_S \gg T_{\mathrm{CMB}}$

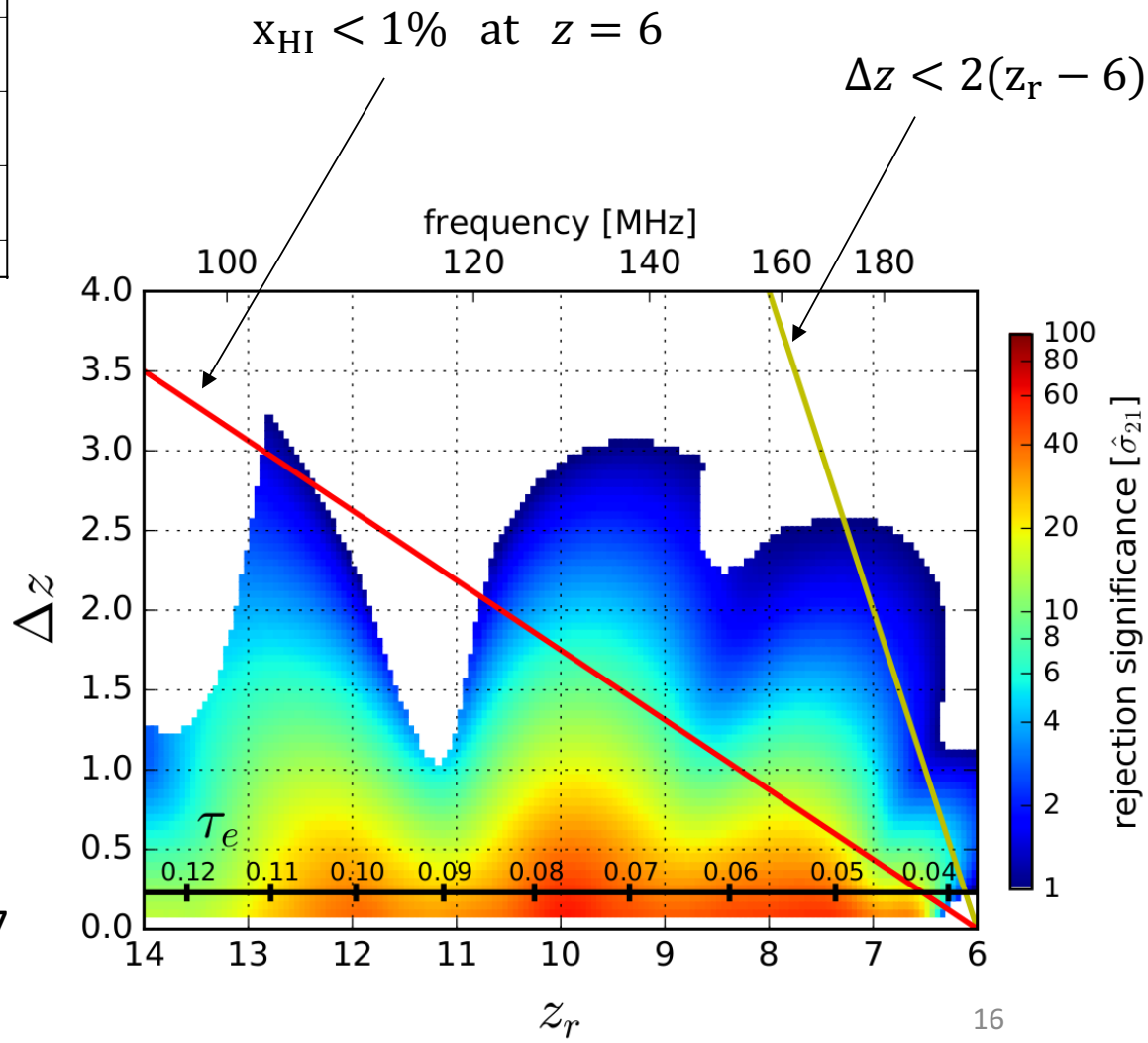



Monsalve et al. 2017

- **Tanh** EoR model.
- Fitting **foreground** coefficients plus amplitude for **EoR model**.

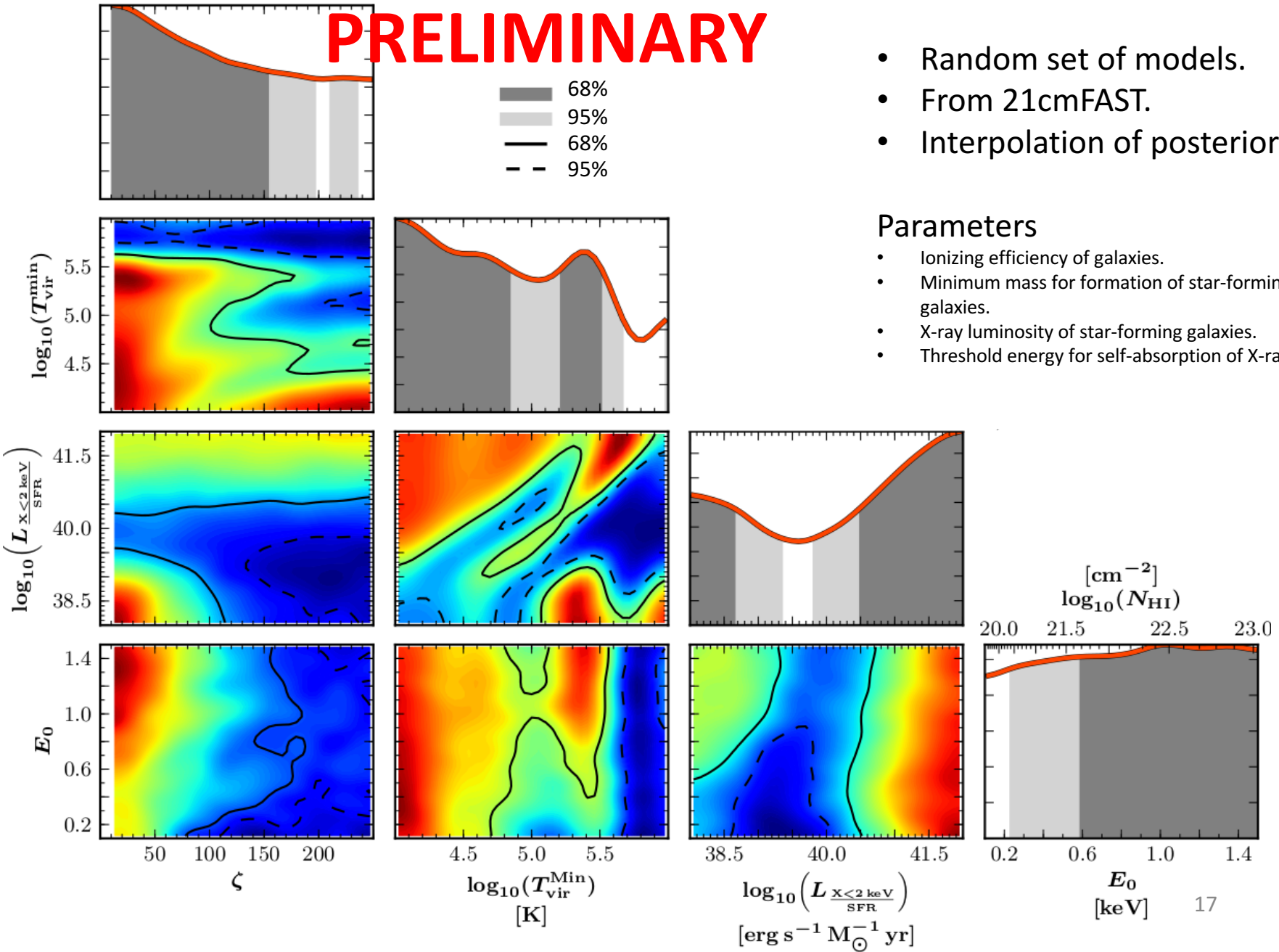
# EoR Constraints for Cold IGM




Monsalve et al. 2017

# High-Band Astrophysical Constraints: Monsalve, Greig, et al. (in prep)



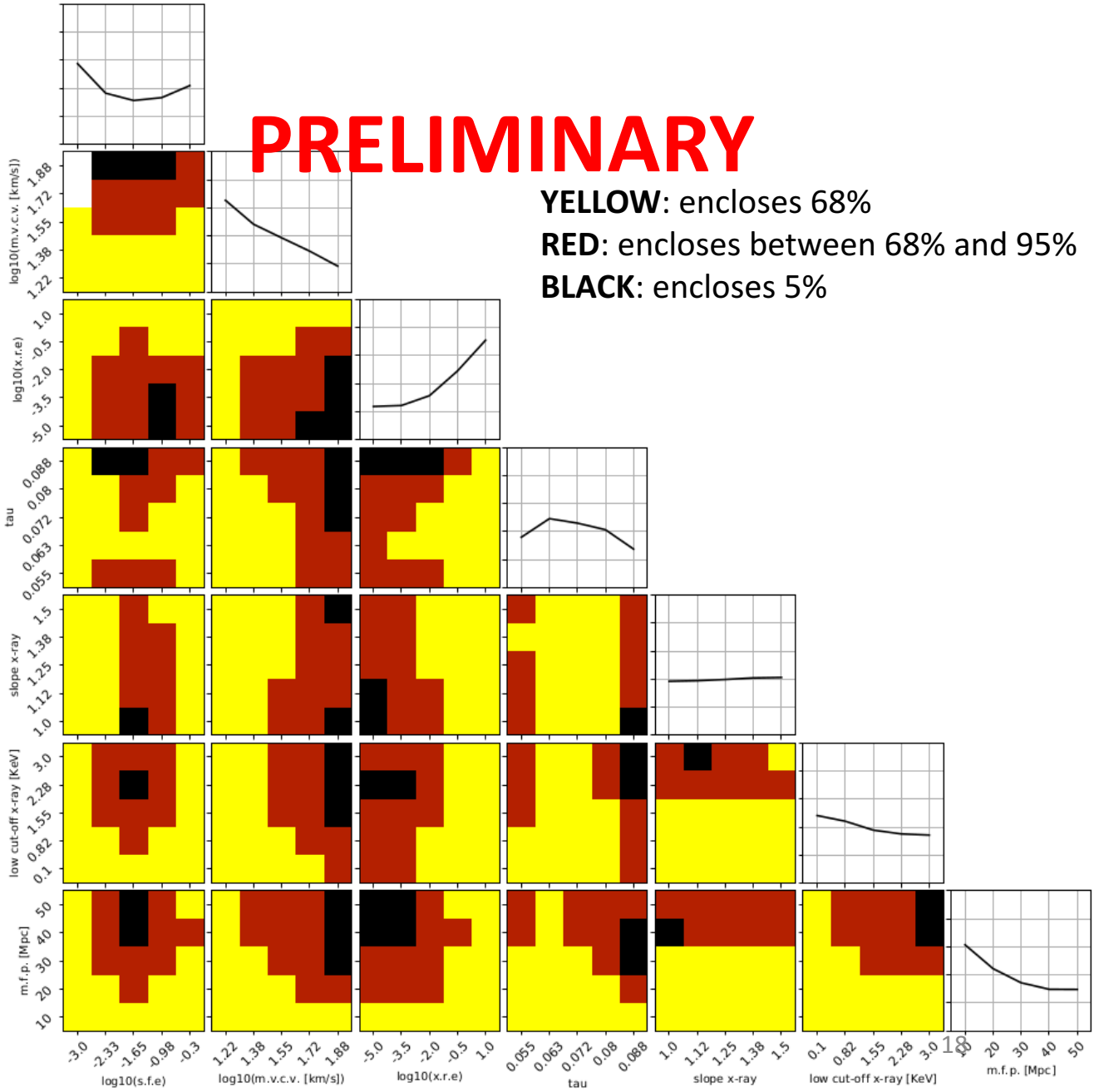

- Random set of models.
- From 21cmFAST.
- Interpolation of posteriors.

## Parameters

- Ionizing efficiency of galaxies.
- Minimum mass for formation of star-forming galaxies.
- X-ray luminosity of star-forming galaxies.
- Threshold energy for self-absorption of X-rays.

# **High-Band** Astrophysical Constraints: Monsalve, Fialkov, et al. (in prep)

- Higher resolution available.
- Semi-numerical models.
- Custom interpolation of models.
- Regular grid sampling.
- No interpolation of posteriors.

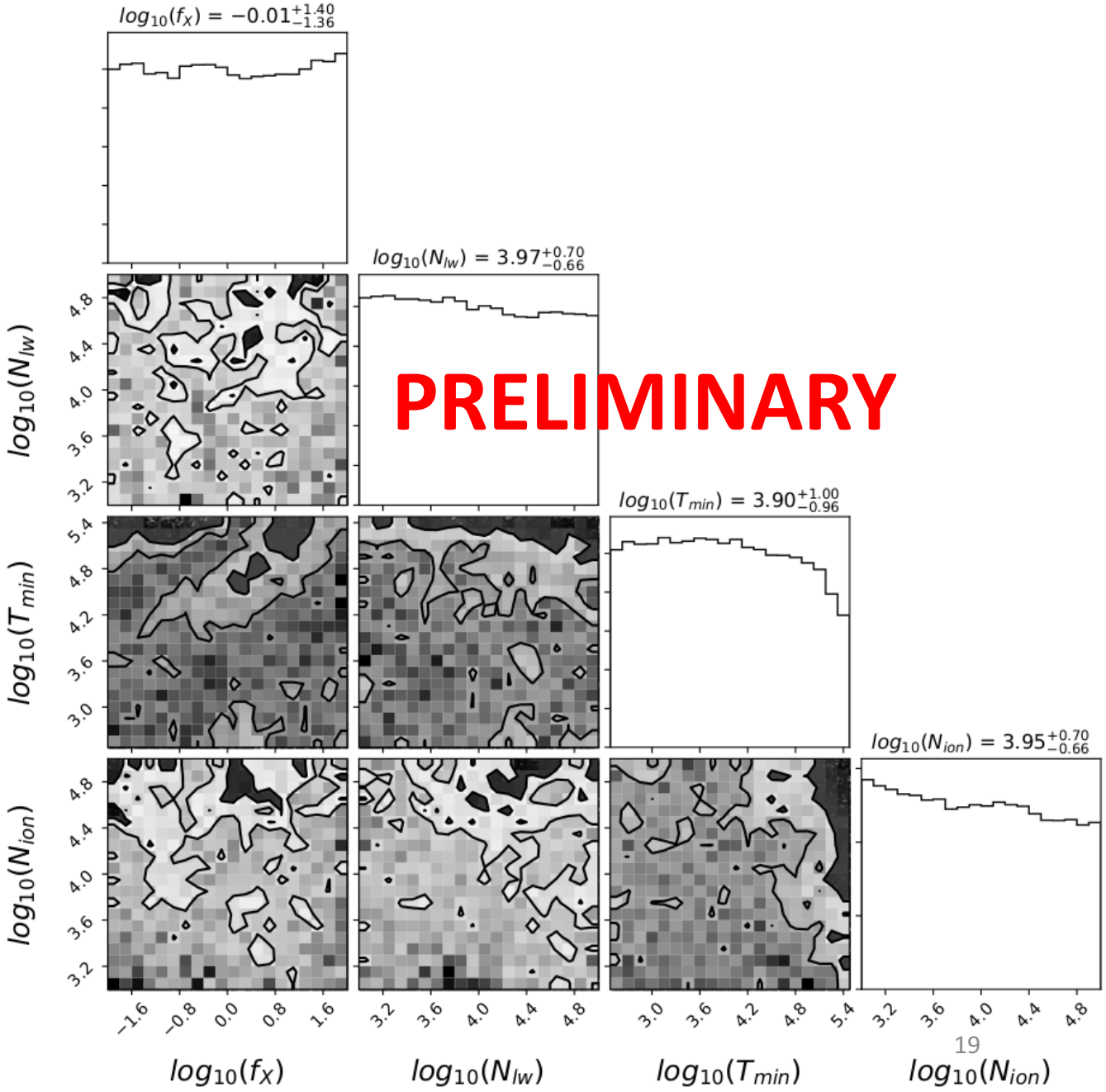


# **High-Band** Astrophysical Constraints: Monsalve, Mirocha, et al. (in prep)

- ARES models (Mirocha et al.) + Emupy interpolation (Kern et al.)
- MCMC sampling.

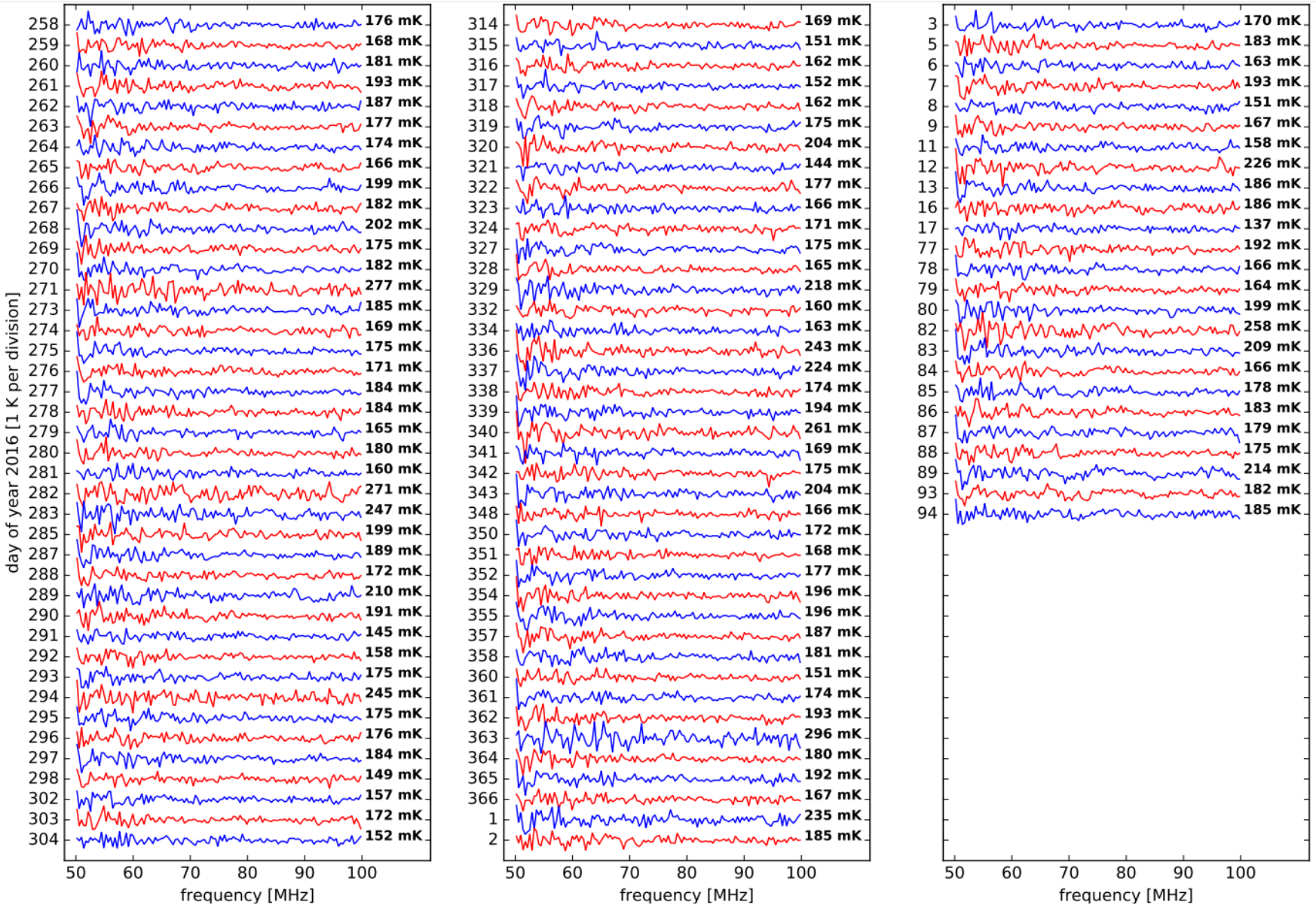
Three approaches have **similar but different** models and parameters.

Good for model and parameter **comparisons**.

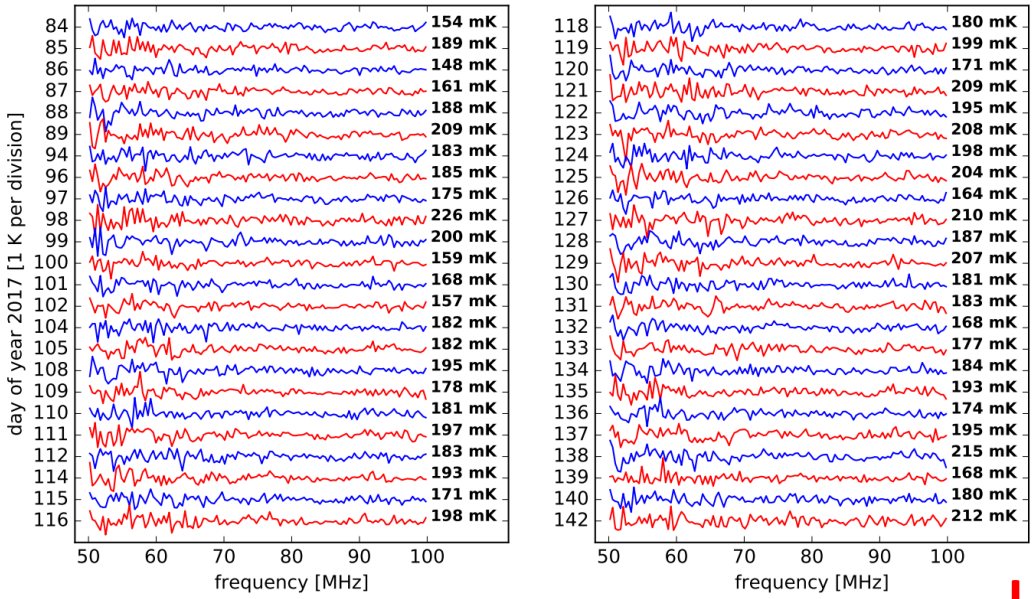


# Some Low-Band Data

# **Low-Band 1** Residuals: Extended Ground Plane

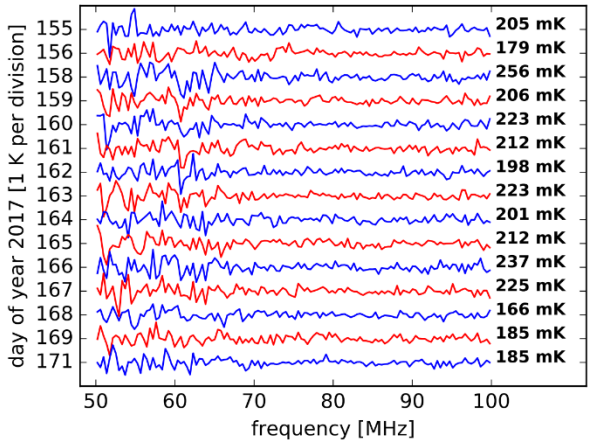


# **Low-Band 2** Residuals: N-S antenna

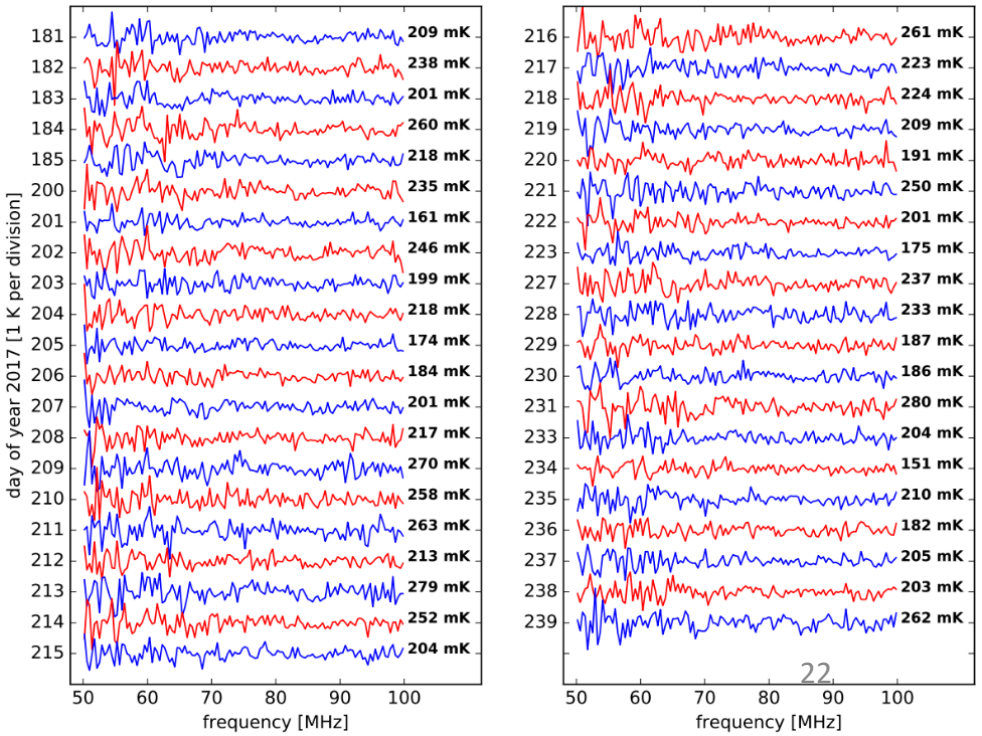



- Both Low-Band systems have **different passband**.
- After integration, persistent residuals **common to both Low-Band systems**.
- Exploring source of residuals.

# **Low-Band 2** Residuals: E-W antenna




# **Low-Band 2** Residuals: Balun change



# Conclusion

1. Current-generation instruments observing in **three bands**.
   Nominally, **50-100** MHz, **60-160** MHz, and **90-190** MHz.

2. With **High-Band**, initial constraints on phenomenological parameters.
   Rejecting Tanh EoR durations $\Delta z \lesssim 1$ **for saturated IGM**, and $\Delta z \lesssim 3$ **for cold IGM**.

3. With **High-Band**, currently constraining astrophysical parameters.
   Working with **Greig** et al., **Fialkov** et al., **Mirocha** et al.

4. Two **Low-Band** instruments, persistent residuals **common to both instruments**.
   Exploring source of residuals.

5. **Mid-Band** with significantly **different passband**, deployed for further cross-checks.

# Thank You

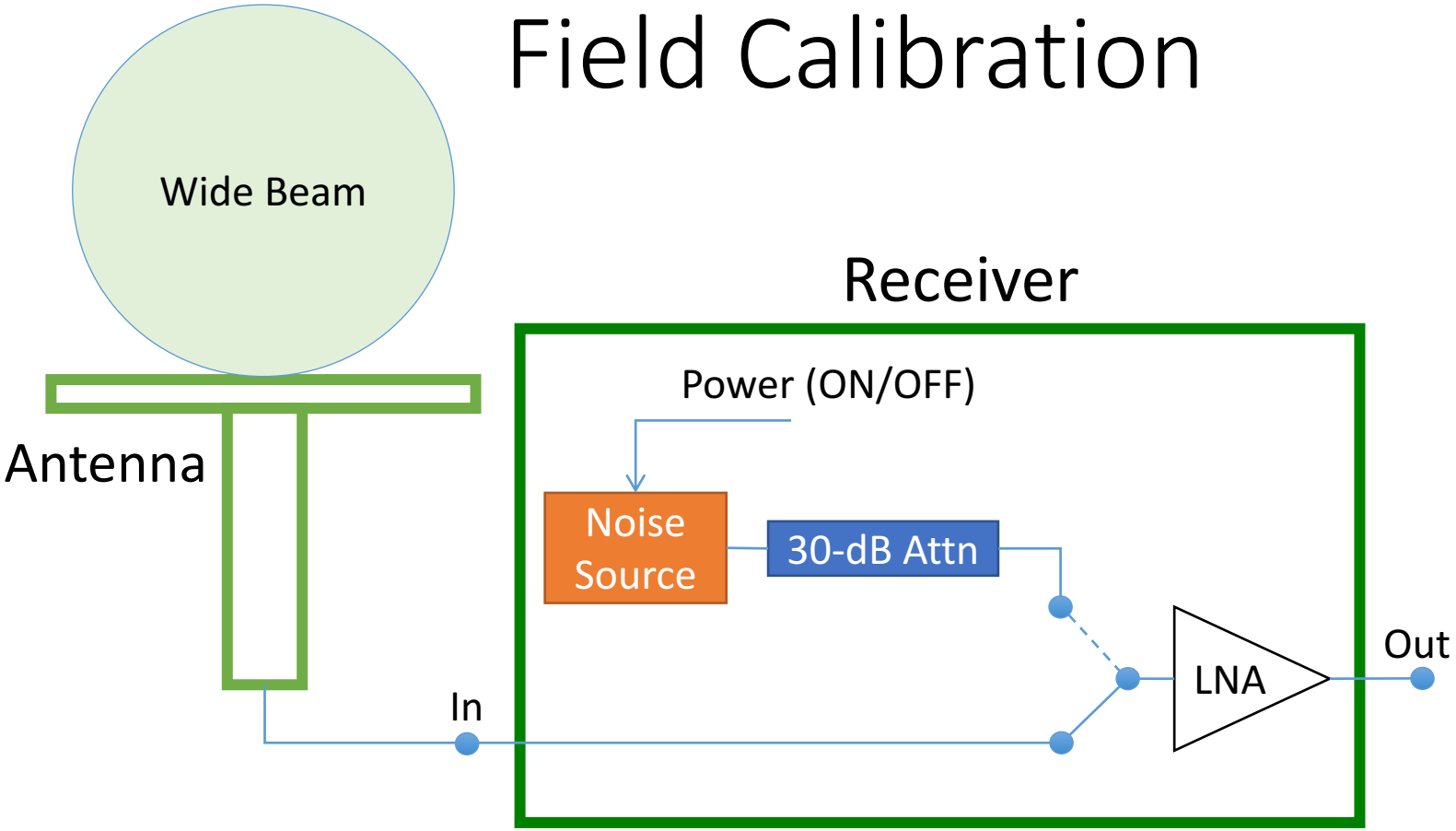
# Extra Slides

# Instrumental Calibration

Calibration involves removing the following effects:

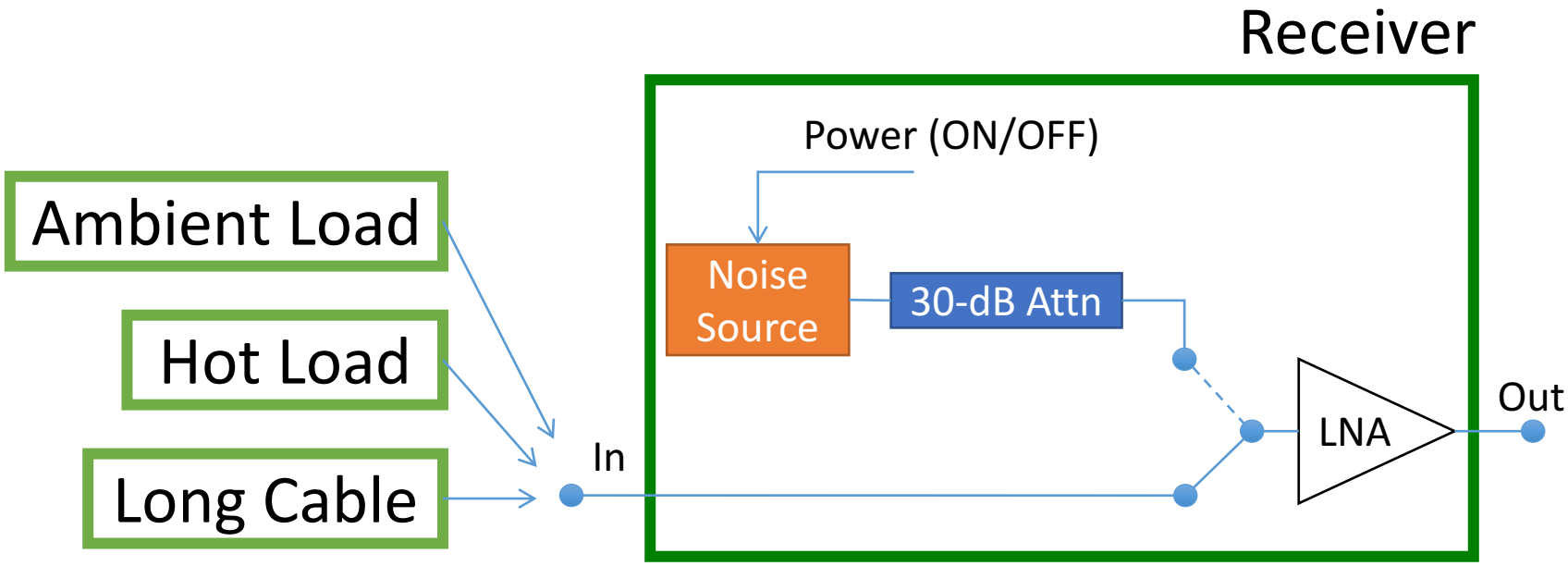
1) Receiver gain and offset.
2) Impedance mismatch between receiver and the antenna.
3) Antenna and ground losses.
4) Frequency-dependence of the antenna beam.

# Field Calibration




$$T^{*}_{\text{ant}} = T_{\text{NS}} \frac{(P_{\text{ant}} - P_{\text{L}})}{(P_{\text{L+NS}} - P_{\text{L}})} + T_{\text{L}},$$

# Absolute Lab Calibration

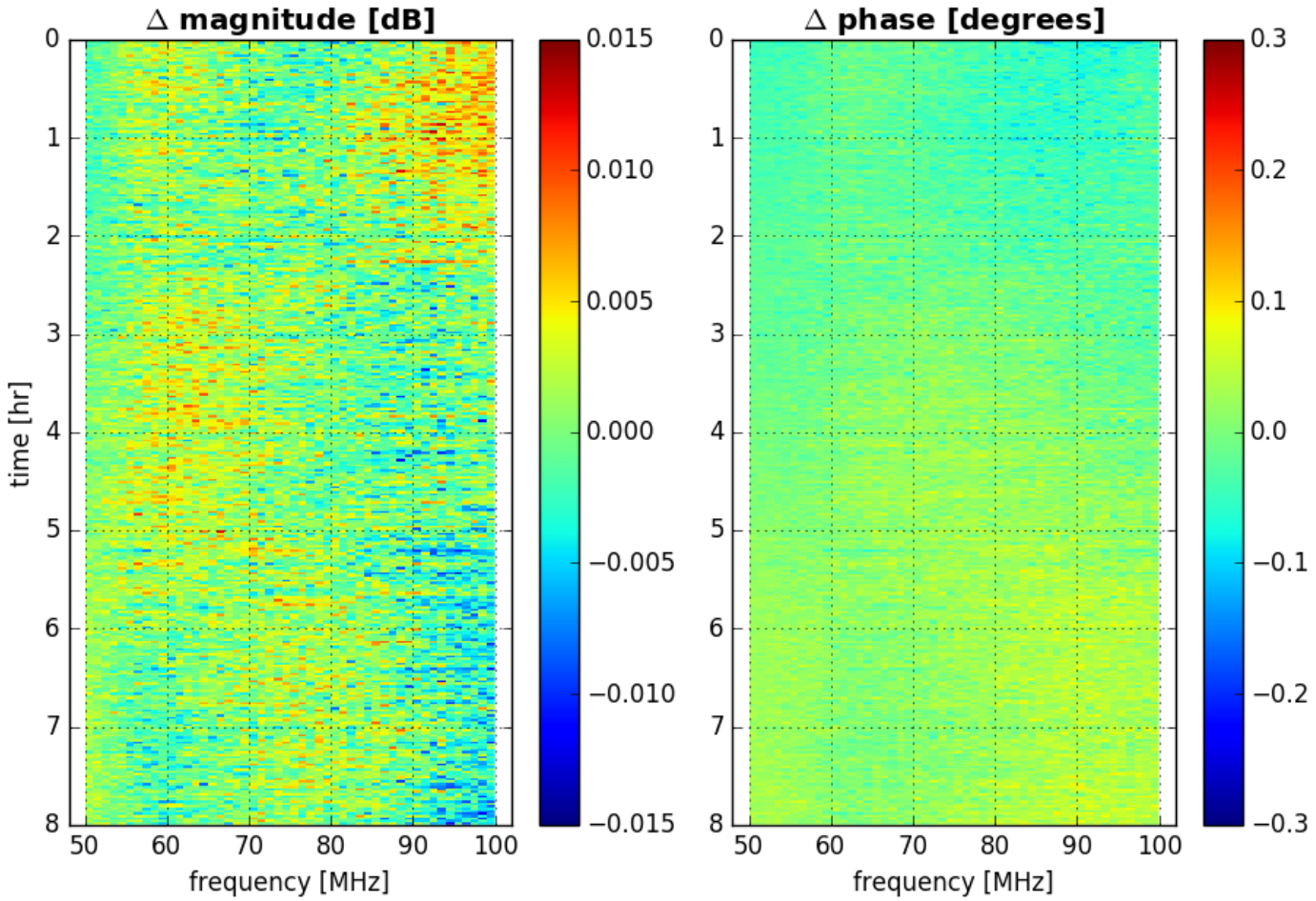



$$T_{ant}^{L} = (C_1\, T_{ant}^{*} + C_2)K_B - T_U K_U - T_C K_C - T_S K_S$$

$K_B, K_U, K_C, K_S$ Encode reflections between antenna and receiver

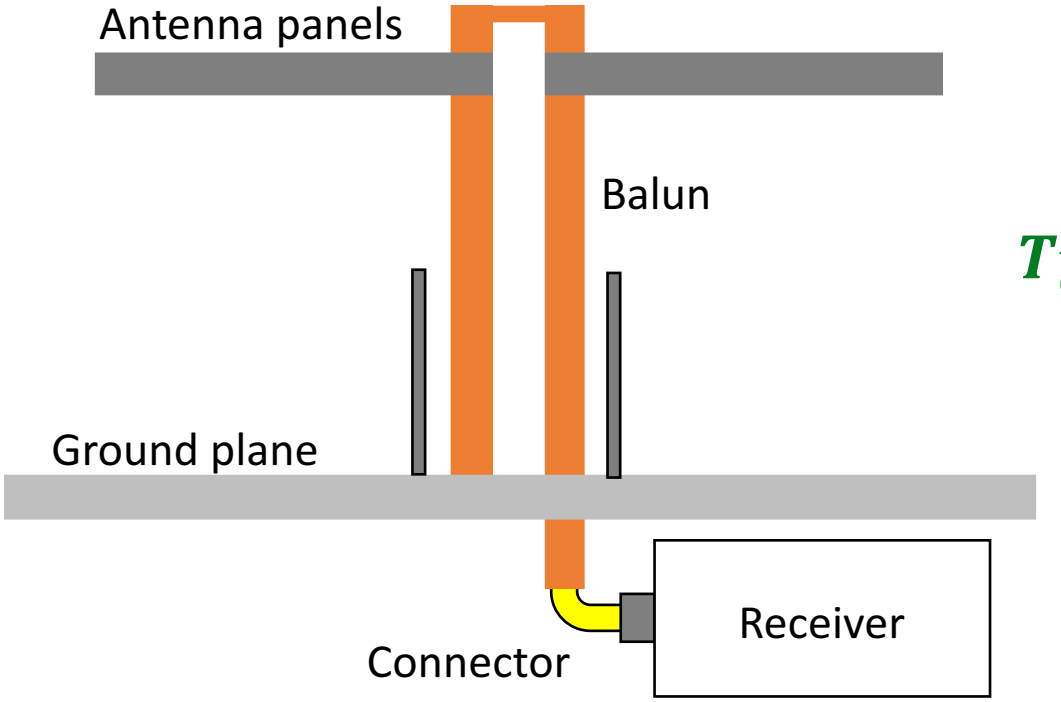
$C_1, C_2, T_U, T_C, T_S$ Calibration quantities obtained from lab measurements

# Antenna Reflection Stability



# Antenna Efficiency

SIDE VIEW




$$T_{ant}^{L} = L\,T_{ant} + (1 - L)T_{amb}$$

# Beam chromaticity

$$T_{\text{ant}}(\upsilon) = \int T_{\text{sky}}(\upsilon, \Omega) \cdot B(\upsilon, \Omega) \cdot d\Omega$$

$$T_{\text{sky}} = \frac{T_{\text{ant}}}{B_{\text{factor}}}$$

Simulated Beam $B(\upsilon, \Omega)$

$$B_{\text{factor}}(\nu) = \frac{\int_{\Omega} T_{\text{sky}}(150\text{MHz}, \Omega) B(\nu, \Omega) \text{d}\Omega}{\int_{\Omega} T_{\text{sky}}(150\text{MHz}, \Omega) B(150\text{MHz}, \Omega) \text{d}\Omega}$$