Recent Progress by the EDGES Global 21-cm Experiment

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EDGES

Experiment to Detect the Global EoR Signature

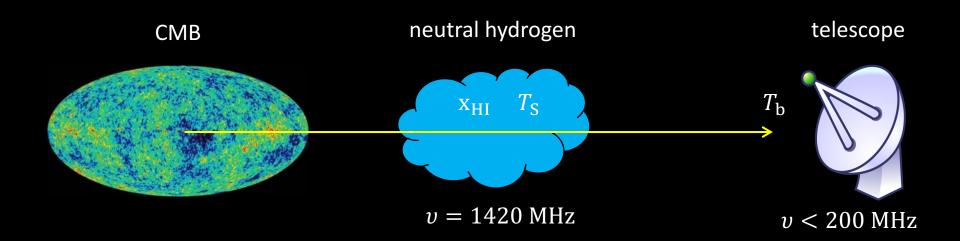
Prof. Judd Bowman (PI) Dr. Alan Rogers Dr. Raul Monsalve Dr. Thomas Mozdzen Ms. Nivedita Mahesh







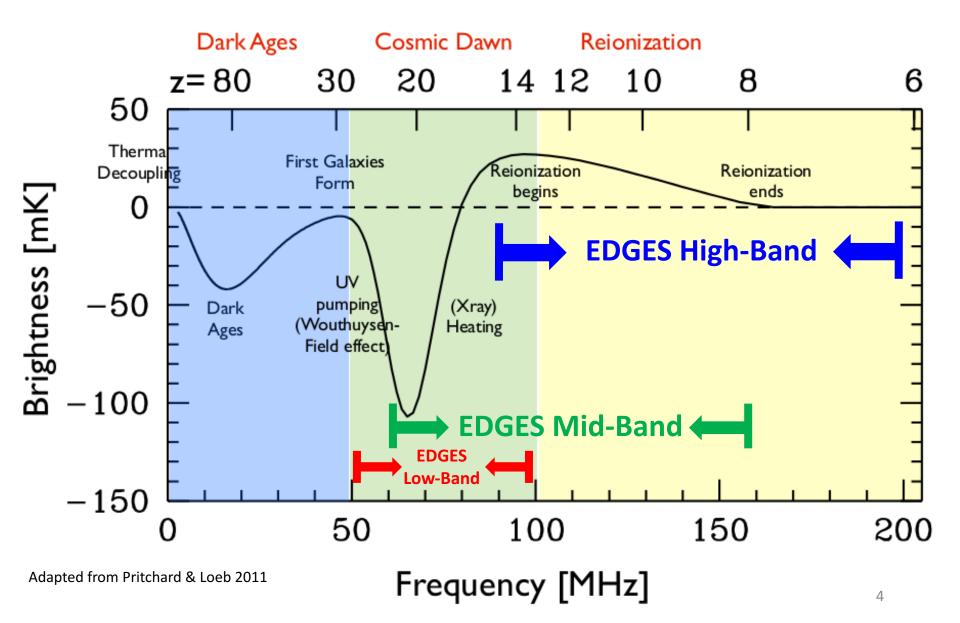
21-cm Cosmology



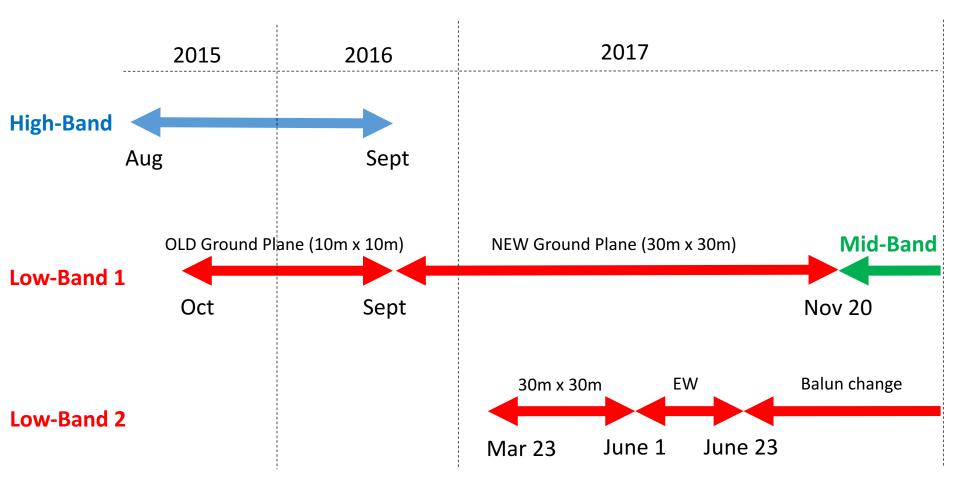
Average Cosmological Brightness Temperature $T_b(\theta, z) \approx 28 \text{ mK} \cdot (1 + \delta) \cdot \sqrt{\frac{1+z}{10}} \cdot x_{\text{HI}} \cdot \left(\frac{T_{\text{S}} - T_{\text{CMB}}}{T_{\text{S}}}\right)$ fraction spin of neutral temperature

hydrogen

Three EDGES Instruments

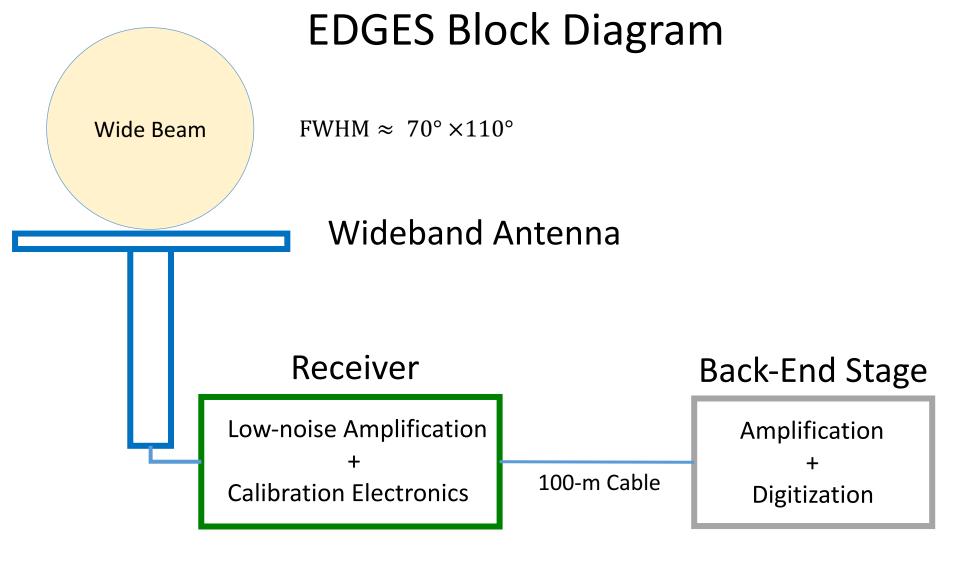


Current EDGES Instruments



Location





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



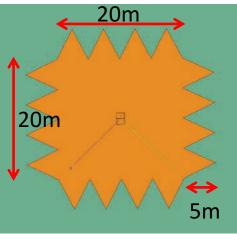
EDGES Mid-Band



Antenna size: 1.9m long / 0.8m high

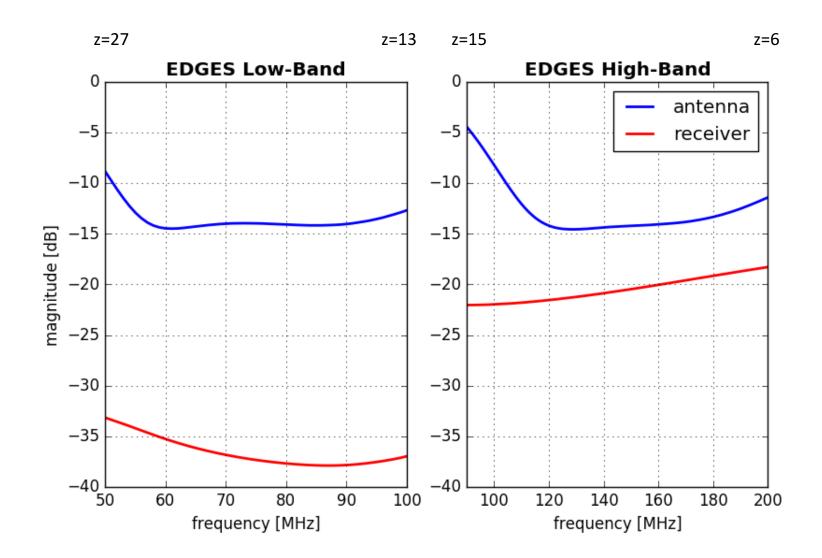
Low/Mid-Band Ground Plane

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

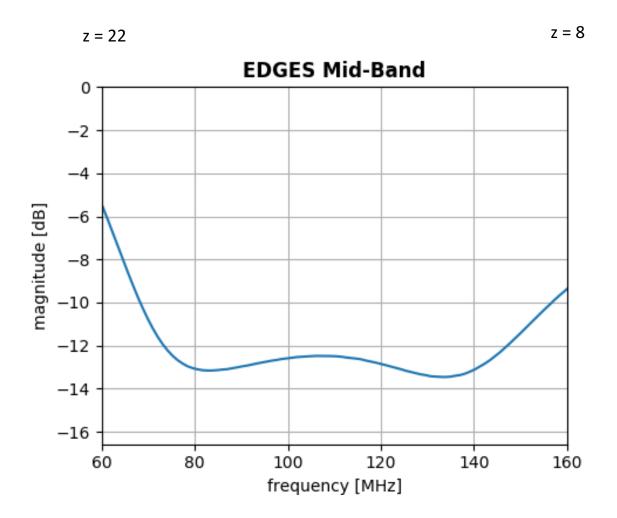




Reflection Coefficients



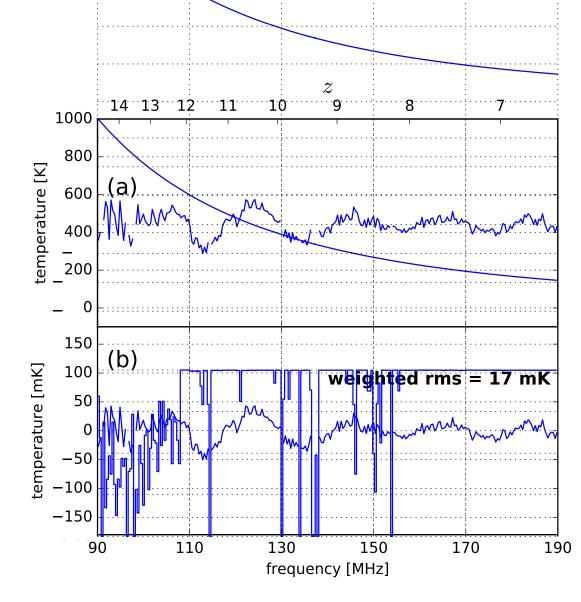
Reflection Coefficients



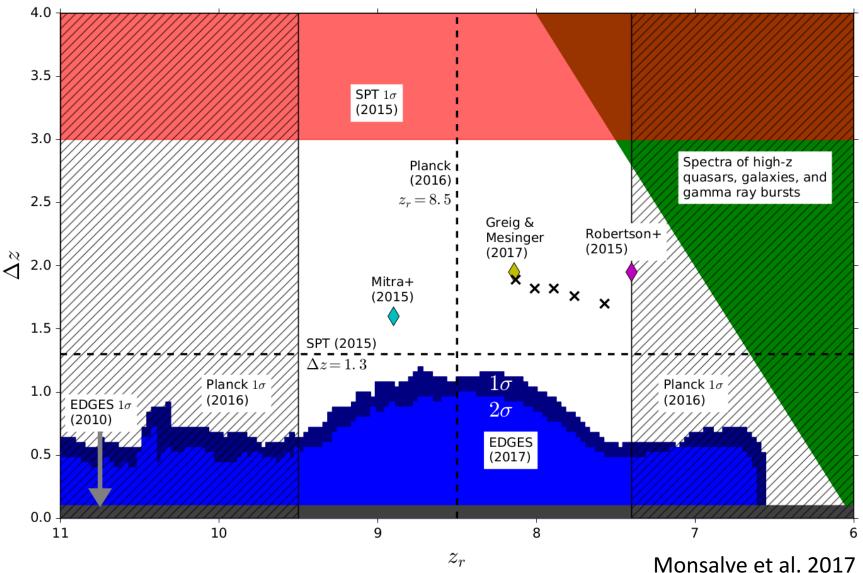
13

High-Band Integrated Spectrum

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

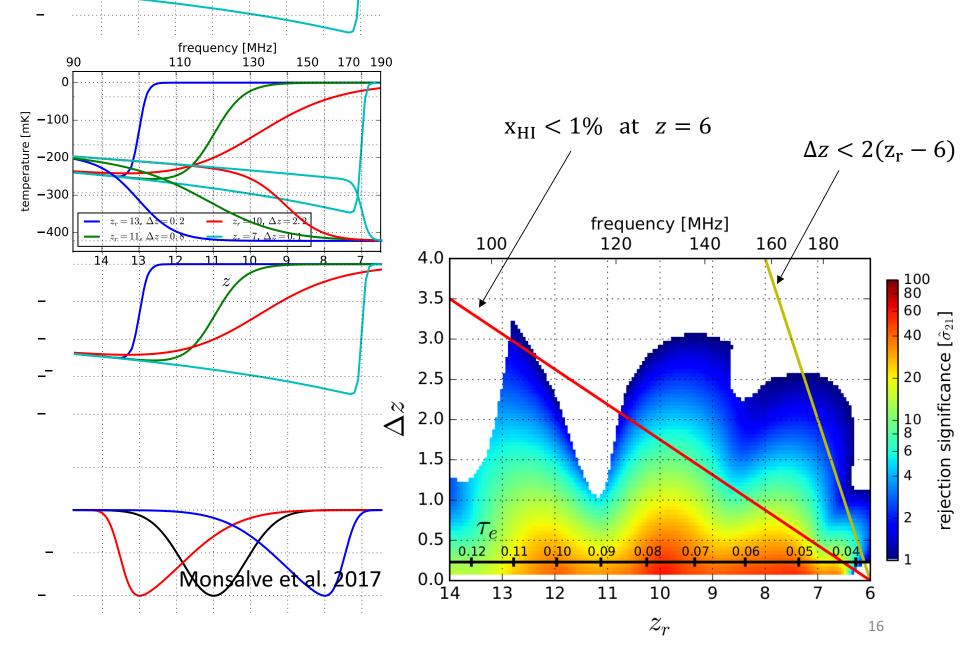


EoR Constraints for $T_S \gg T_{CMB}$

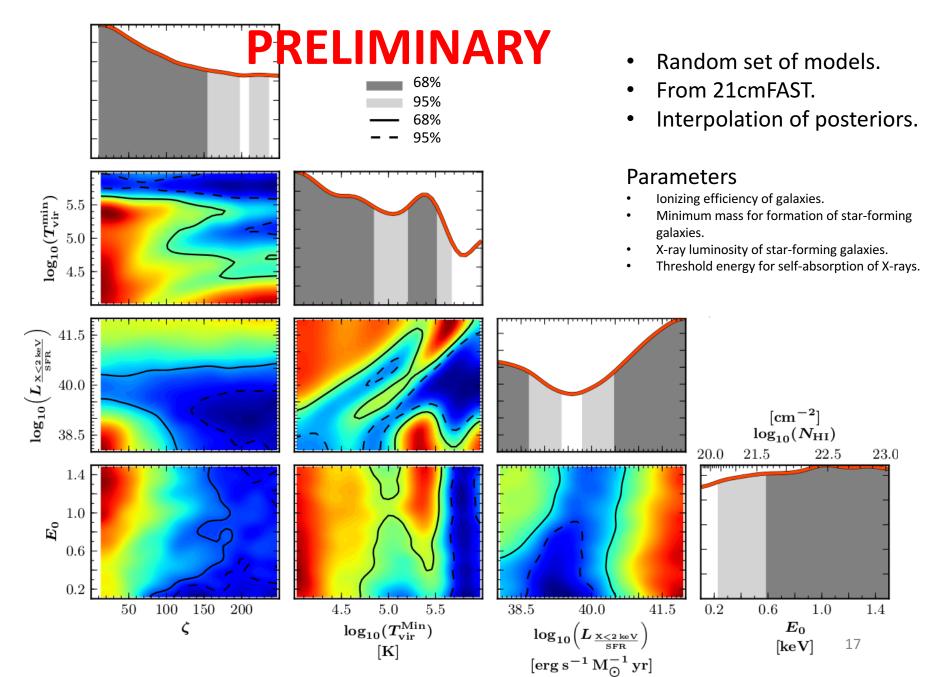


- Tanh EoR model.
- Fitting **foreground** coefficients plus amplitude for **EoR model**.

EOR Constraints for Cold IGM



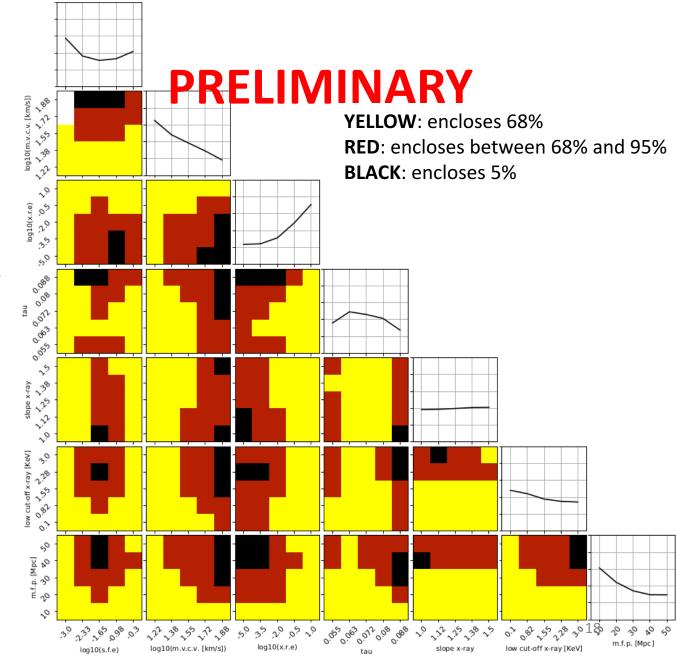
High-Band Astrophysical Constraints: Monsalve, Greig, et al. (in prep)



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



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



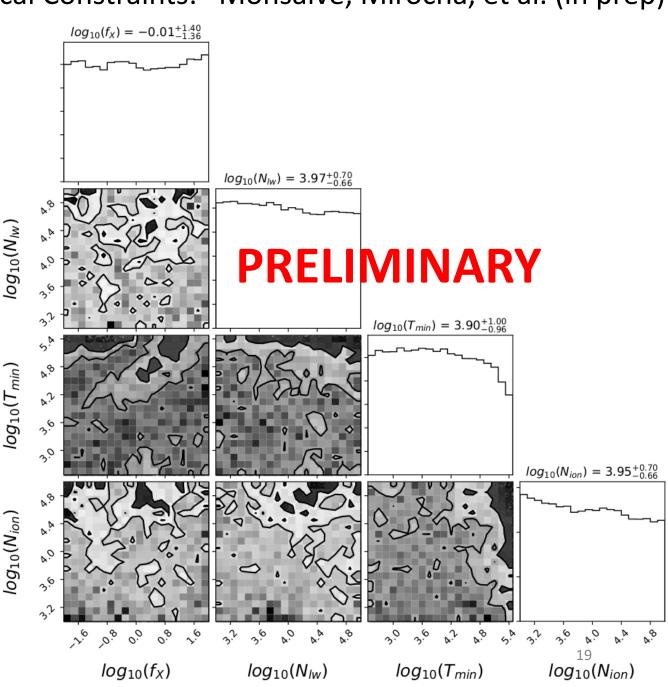
High-Band Astrophysical Constraints: Monsalve, Mirocha, et al. (in prep)

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

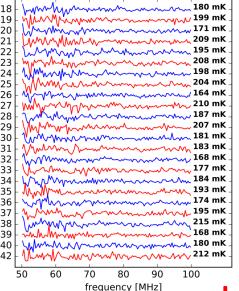
Low-Band 1 Residuals: Extended Ground Plane

		-	
258	- Mynymmyn 176 mK_	314	169 mK_
259	- W MM 168 mK	315	With Mark 151 mK_
260	- Why MM 181 mK	316	With min 162 mK_
261	- WWW. Mummin 193 mK_	317	how my 152 mK_
262	- Mr. 187 mK_	318	MAMMAN 162 mK
263	- 1. 177 mK_	319	MMymm 175 mK_
264	- MMM	320	1000 204 mK
265	- Jum a house and 166 mK_	321	144 mK_
266	- 1 M. M. Mun 199 mK_	322	My Mm mm 177 mK
267	. M. m. 182 mK_	323	166 mK_
268	- M. 202 mK_	324	1/m/ 171 mK_
269	- MMMmmmmmm 175 mK_	327	175 mK_
270	- WWW. 182 mK_	328	M.M. 165 mK_
_ 271	Why My my Mar why 277 mK	329	MMMMMMMMMMM 218 mK_
E 273	- M.M.M. 185 mK_	332 -	(mm 160 mK_
uoisivip 273	how 169 mK	334 -	MM
275	- [175 mK_	336	MMm 243 mK
ษ 276	- WMM	337 -	1000 224 mK
a 277	- M	338 -	//////////////////////////////////////
¥ 278	- h MM m 184 mK_	339 -	WM www. 194 mK_
I 270	- ////////////////////////////////////	340	Multimum 261 mK
0	- W.M. 180 mK_	341	169 mK_
280 7 7 281	- MMMMMMMM 160 mK_	342	Muhumm 175 mK_
ัษ 282	- WM WM MM M 271 mK	343 -	Mmmmmmm 204 mK_
785 year 283	- MM Mmmmmmmm 247 mK	348 -	166 mK_
ъ 285	199 mK_	350 -	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
A 287	- M. 189 mK	351	100 168 mK
Ö 288	- M. M. 172 mK	352 -	My Muhamman 177 mK_
289	- MMM MM 210 mK	354	Munhamming 196 mK
290	1 May Mul 191 mK	355 -	4 Mm 196 mK_
291	- WWWWWWWWWWWW 145 mK	357	(MM 187 mK
292	- mm 158 mK	358 -	181 mK_
293	- W	360	M.M. 151 mK_
294	- MMMMMMMMMMM 245 mK	361	174 mK_
295	- Why Monson 175 mK	362	h Mul my 193 mK
296	- Mummmmm 176 mK	363 -	mmmmmm 296 mK
297	- M. 184 mK	364	100 mm 180 mK
298	- Mymmmmm 149 mK	365 -	192 mk
302	- WM	366	WMM 167 mK
303	MMMmmmmm 172 mK	1	MMmmmmm Mr 235 mK
304	- ym////////////////////////////////////	2 -	WMwymmmmm 185 mK_
		Ļ	
	50 60 70 80 90 100	5	50 60 70 80 90 100
	frequency [MHz]		frequency [MHz]

3- Manum	170 mK
5- WWWMmmmm	183 mK
6- MMmmmm	163 mK
7 - Jummmmmmm	193 mK
	151 mK
8- mmmmm	167 mK
9- W Marmon	158 mK
11 - Marman	
12 - Mymmm	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
13- 13- 13- Marine	186 mK_
16 - Mmmmmm	~~~~~ 186 mK_
17 - manning	137 mK
77 - Munnon	192 mK_
78- Langermann	166 mK_
79- land man man	164 mK
80- Marthourson	199 mK_
82 - MMMMMMM	258 mK
83-	209 mK
84 - 1000	166 mK
85 - mmm	178 mK
	183 mK
86 - Munum	179 mK
87 - 4	
88- WMM - 88	175 mK_
89- Minning	~~~~~~ 214 mK_
93 - Churching	182 mK_
94 - him home man	185 mK_
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50 60 70 80	90 100
frequency	[MHz]

Low-Band 2 Residuals: N-S antenna

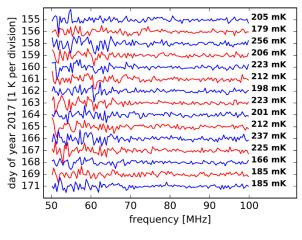
484 of year 2017 [1 K per division] 494 of year 2017 [1 K per division] 405 066 86 86 411 101 101 101 1114 115 116	50		70		154 r 189 r 189 r 188 r 188 r 188 r 209 r 183 r 200 r 159 r 200 r 159 r 168 r 200 r 159 r 188 r 189 r 180 r 180 r 195 r 181 r 193 r 171 r 198 r 100	nK nnK nnK nnK nnK nnK nnK nnK nnK nnK	118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 142 50
	50	00		ency [N	100		50

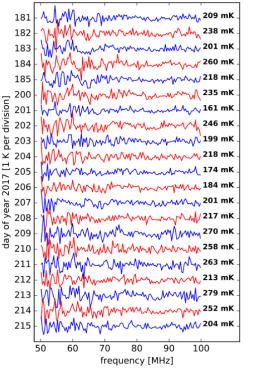


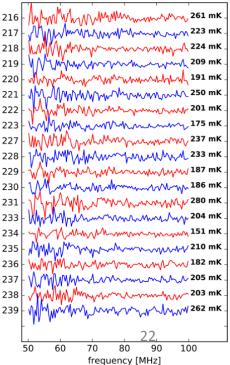
- Both Low-Band systems have different passband.
- After integration, persistent residuals common to both Low-Band systems.
- Exploring source of residuals.

Low-Band 2 Residuals: Balun change

Low-Band 2 Residuals: E-W antenna







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.

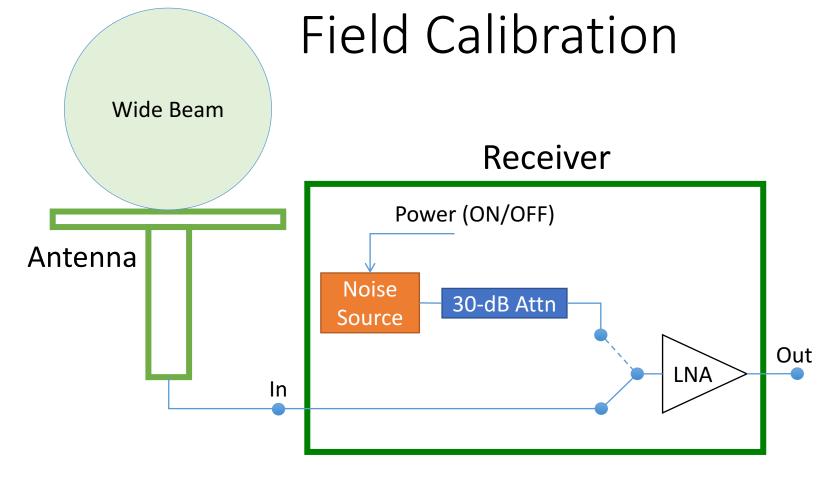
Thank You

Extra Slides

Instrumental Calibration

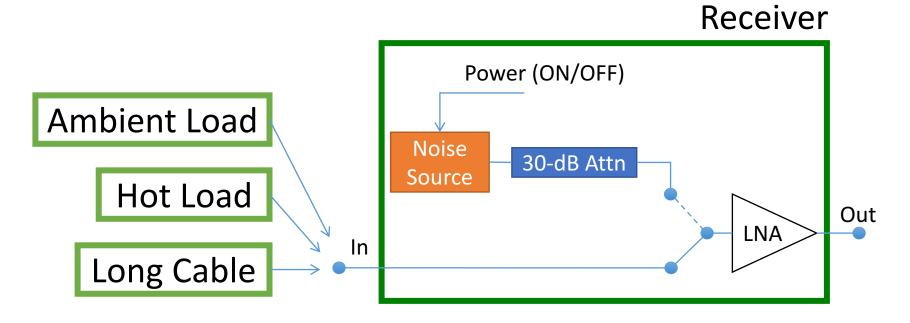
Calibration involves removing the following effects:

- 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.



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

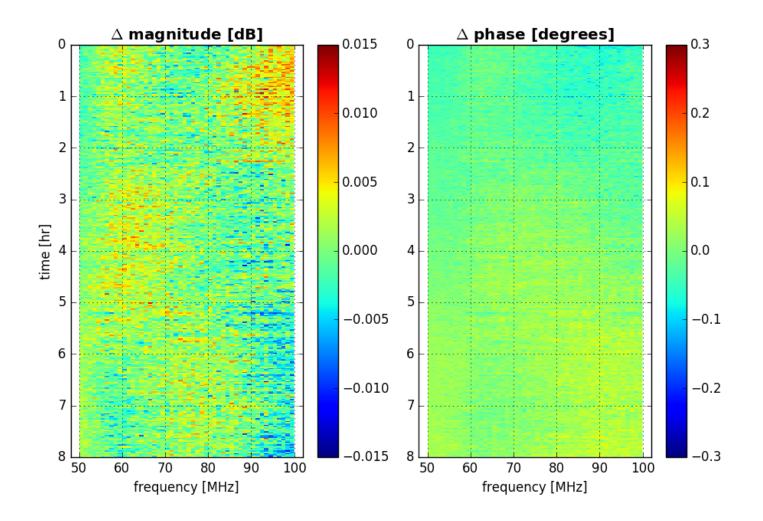
Absolute Lab Calibration



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

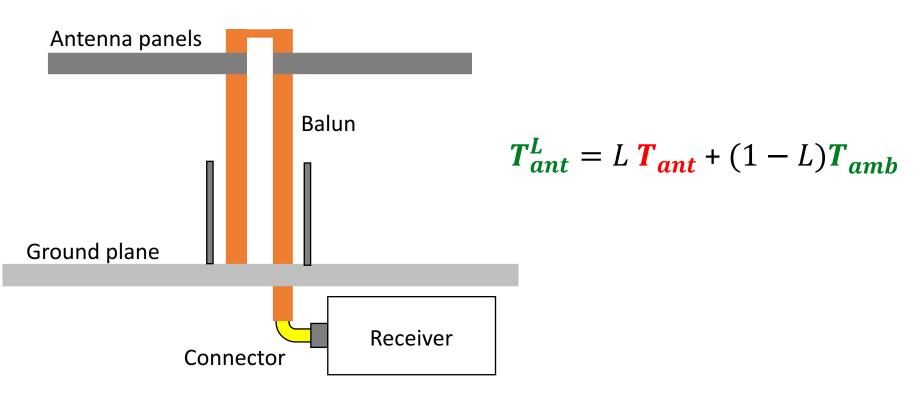
 K_B, K_U, K_C, K_S Encode reflections between antenna and receiver C_1, C_2, T_U, T_C, T_S Calibration quantities obtained from lab measurements

Antenna Reflection Stability



Antenna Efficiency

SIDE VIEW



Beam chromaticity

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

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

Simulated Beam $B(v, \Omega)$

