Systematics Considerations for Probing the Pre-Reionization Power Spectrum

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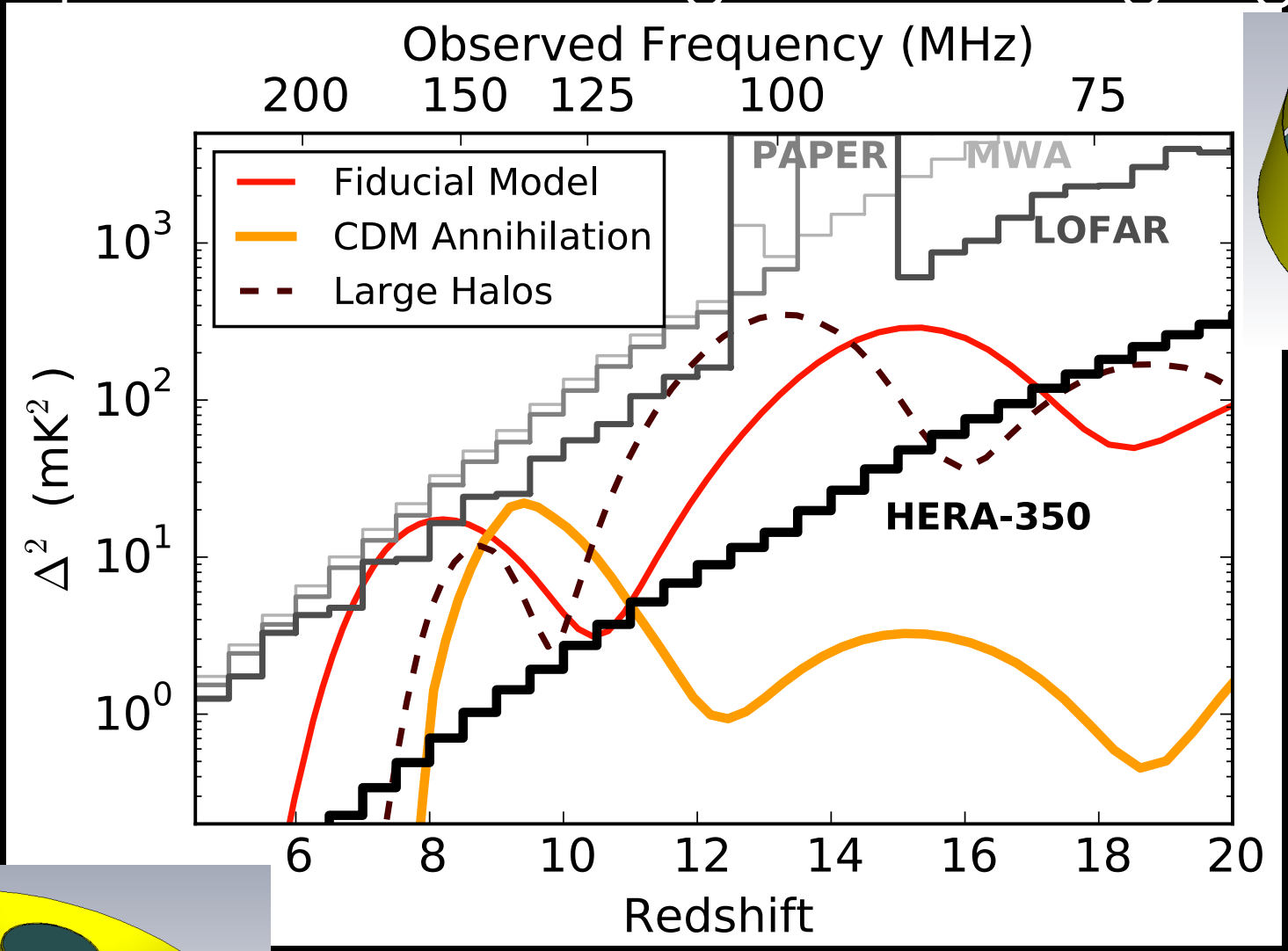
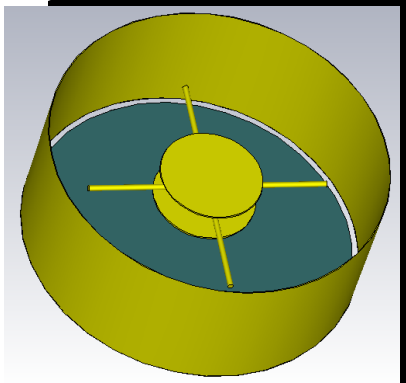
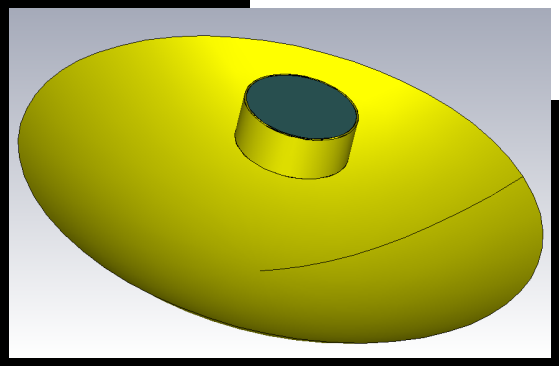
The next ten years; in principal HERA-III is capable of detecting the heating signal.





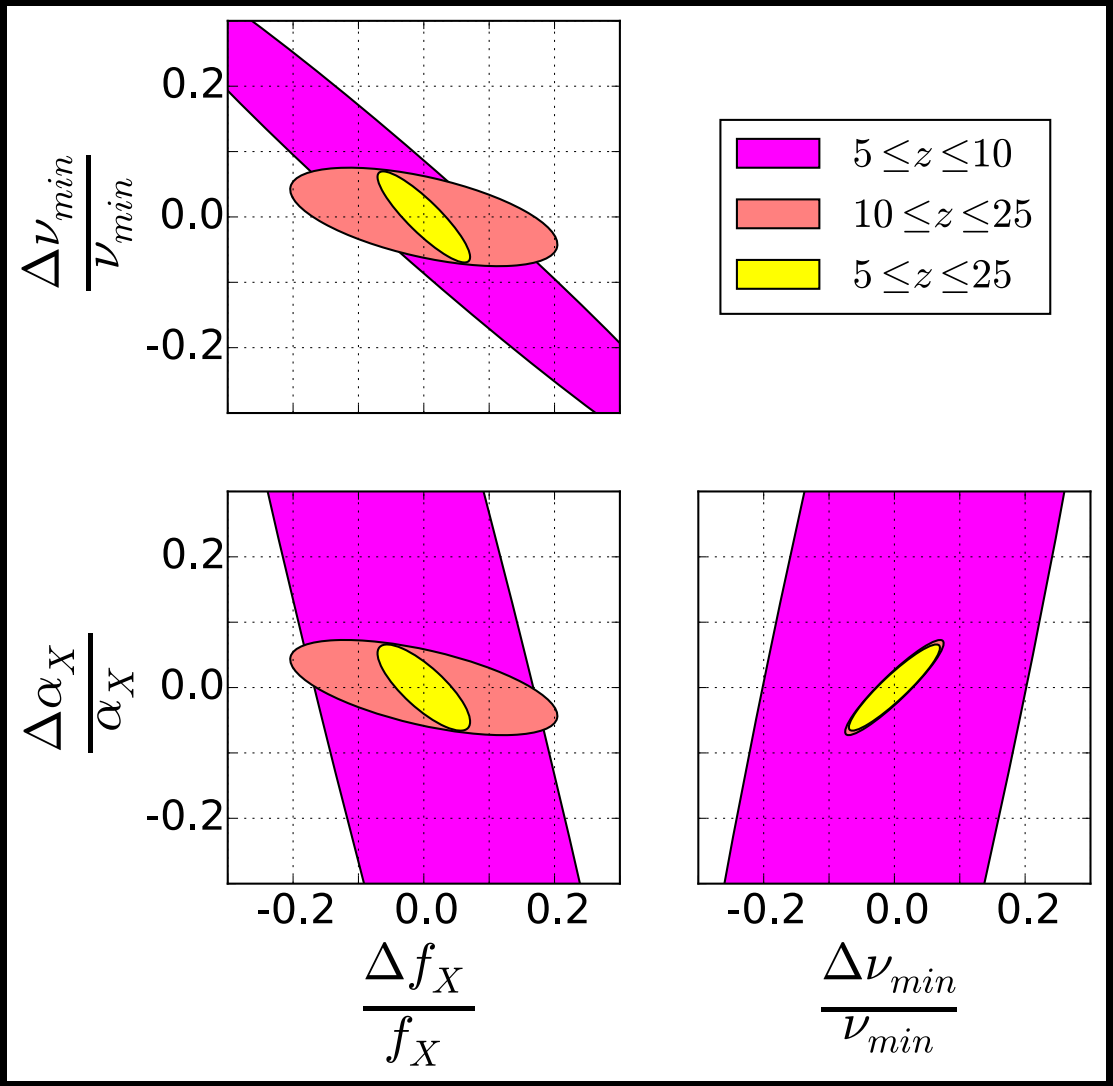


We are currently developing a specialized feed for the heating epoch in case broadband feed is not possible.

HERA-350 will deliver ~6% constraints on the spectral properties of early X-ray sources

Reionization Redshifts

Heating + Reionization Redshifts



95% confidence ellipses

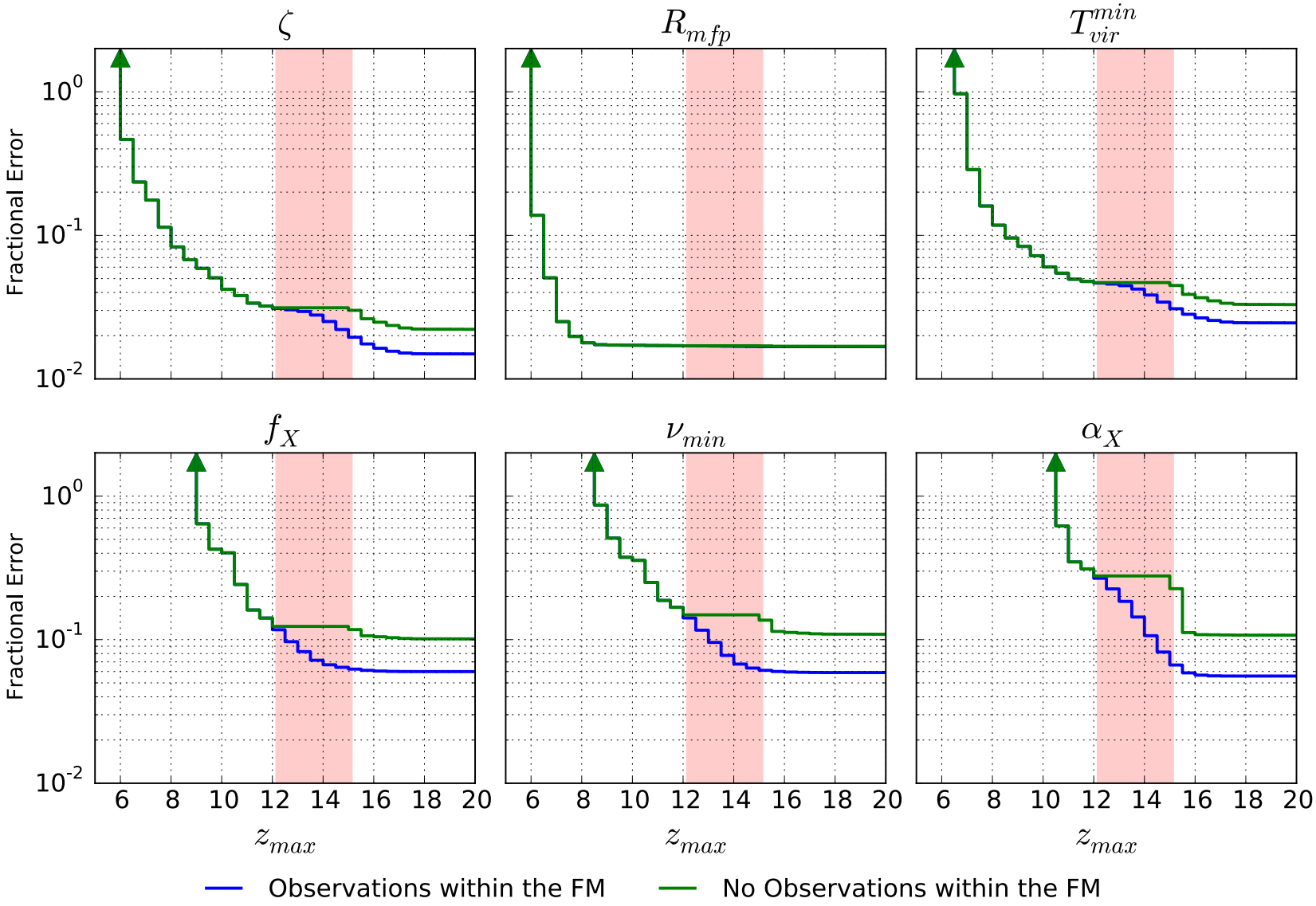
AEW+ 2015, MNRAS

New Ground for HERA-III

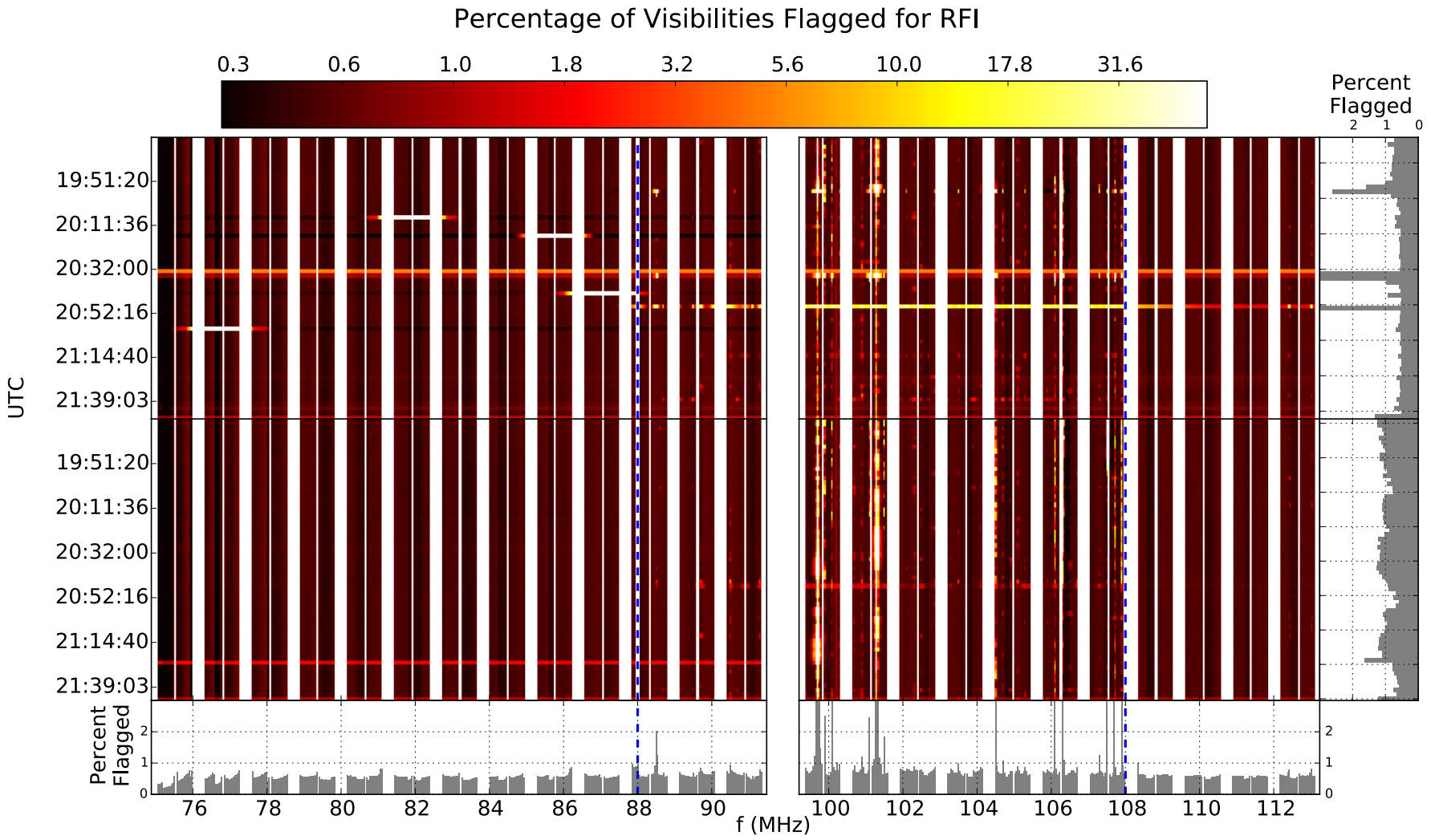
- Scenarios with vigorous heating (Cold Dark Matter)
- Higher order statistics at pre-reionization redshifts
- More Modes-> Better Model Constraints and Better Models.
- Lyman-alpha coupling.
- The dark ages?

Systematic Challenges for Pre-Reionization Measurements

RFI: Excising the FM band does not hurt us too much.



FM in the MRO accessible after three hours



AEW+2016

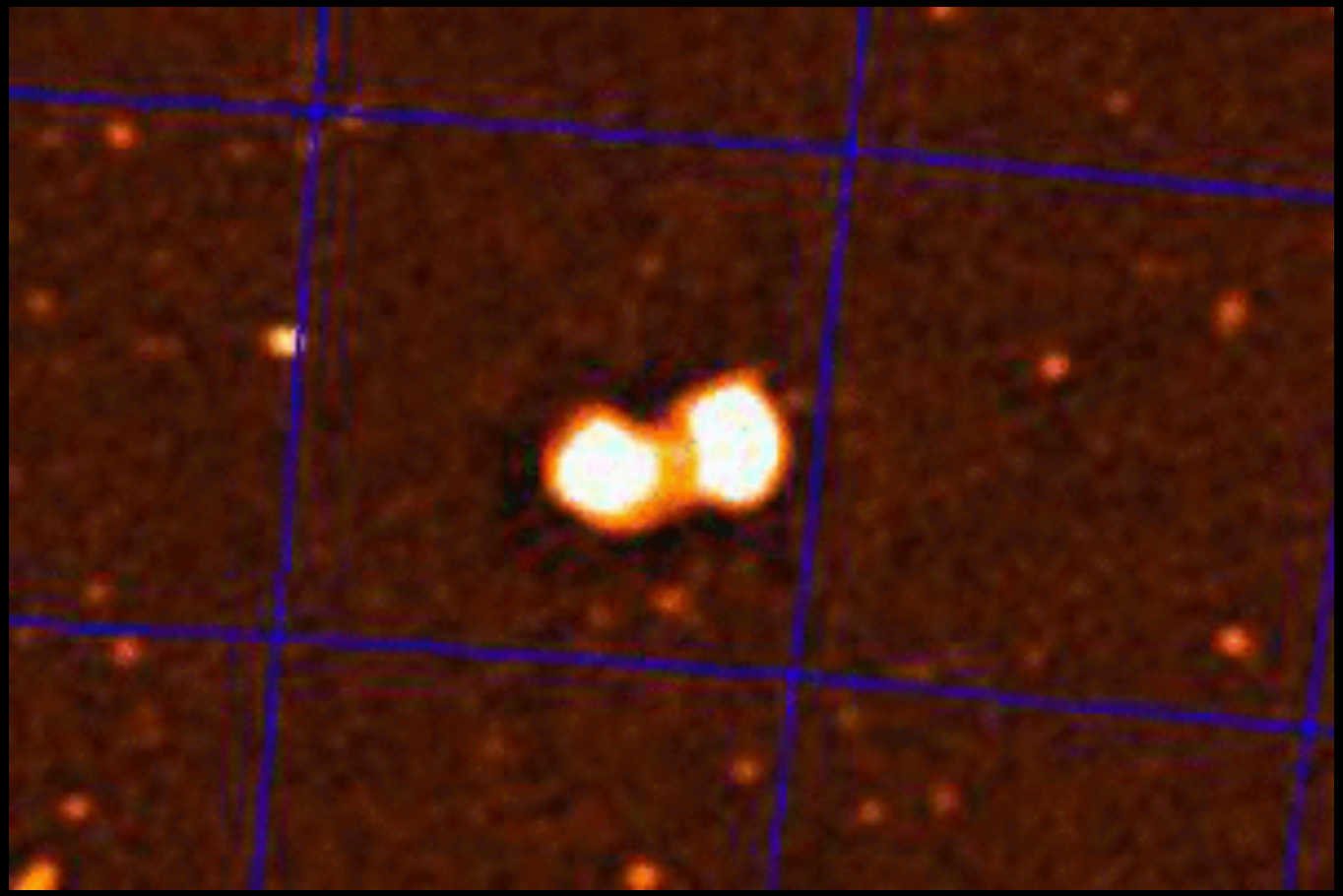
So far, we have been able to produce power spectra (3-hours) within the FM band (Murchison Radio Observatory)

Will FM power affect outside channels?

If so, is it possible to filter a discrete band?

Will working inside of the FM may require finer channelization (like LOFAR)?

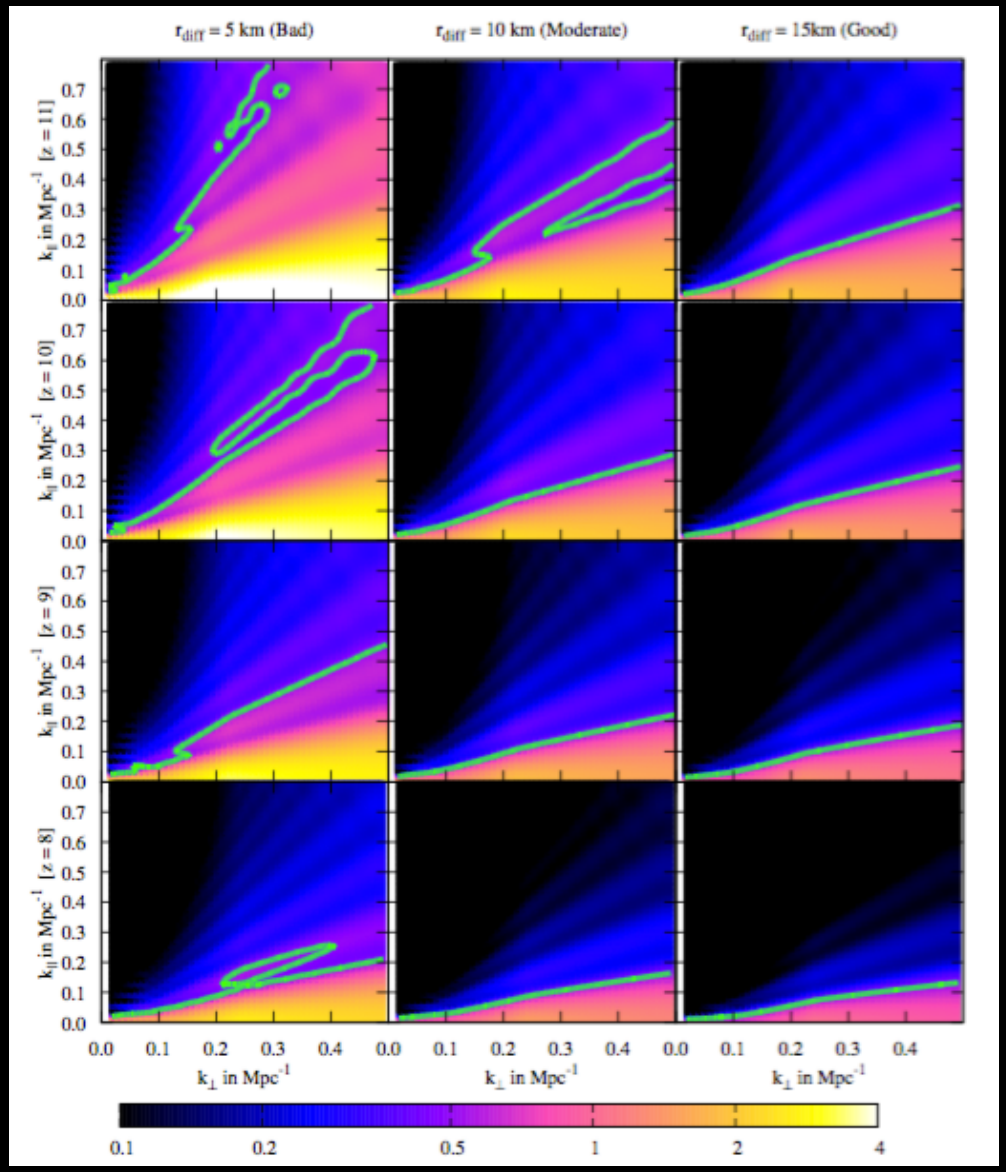
The Ionosphere



Refraction and Scintillation both are more severe at low frequency!

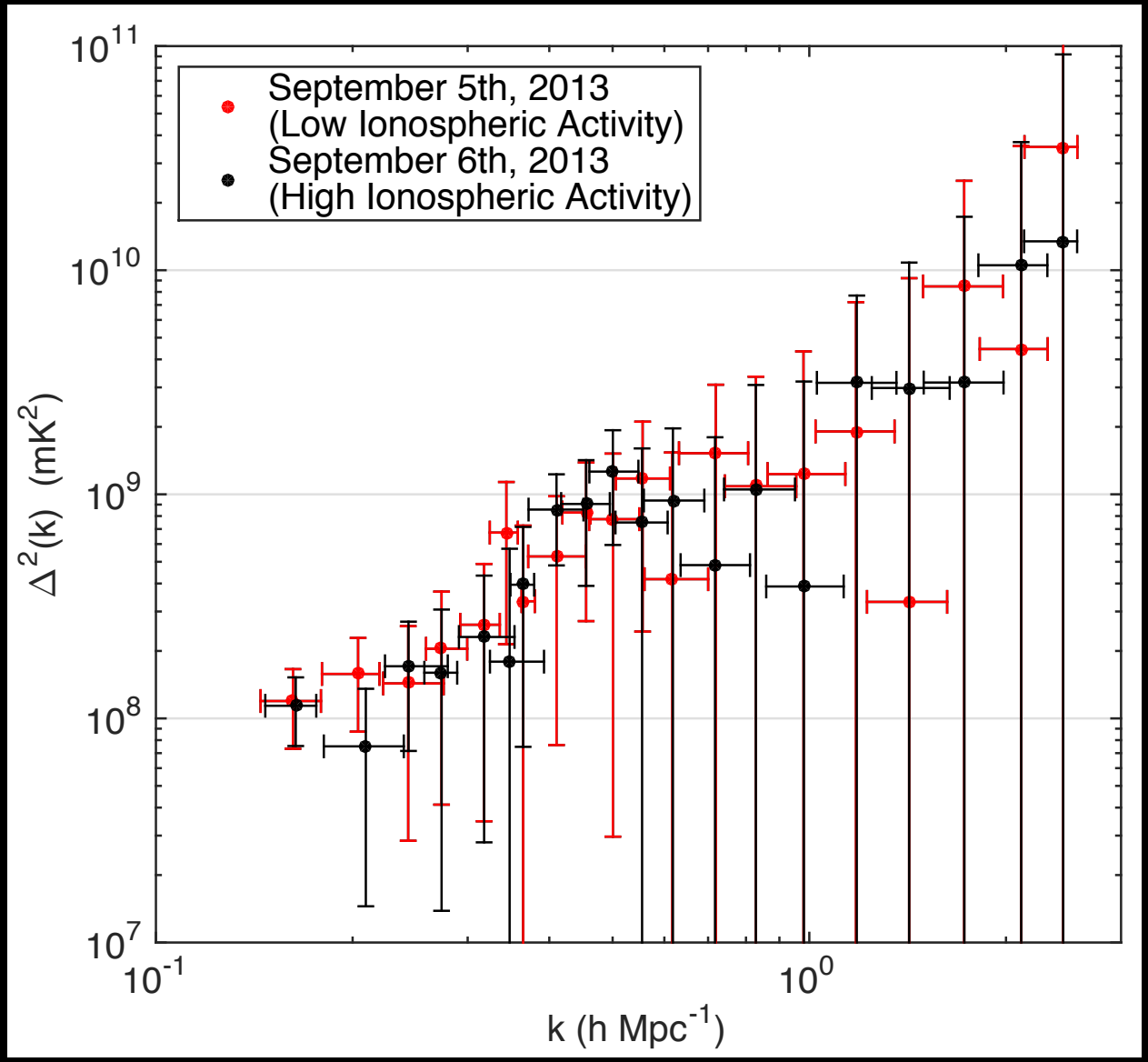
AEW+MNRAS Accepted

Ionospheric Scintillation and Refraction is contained within the wedge.



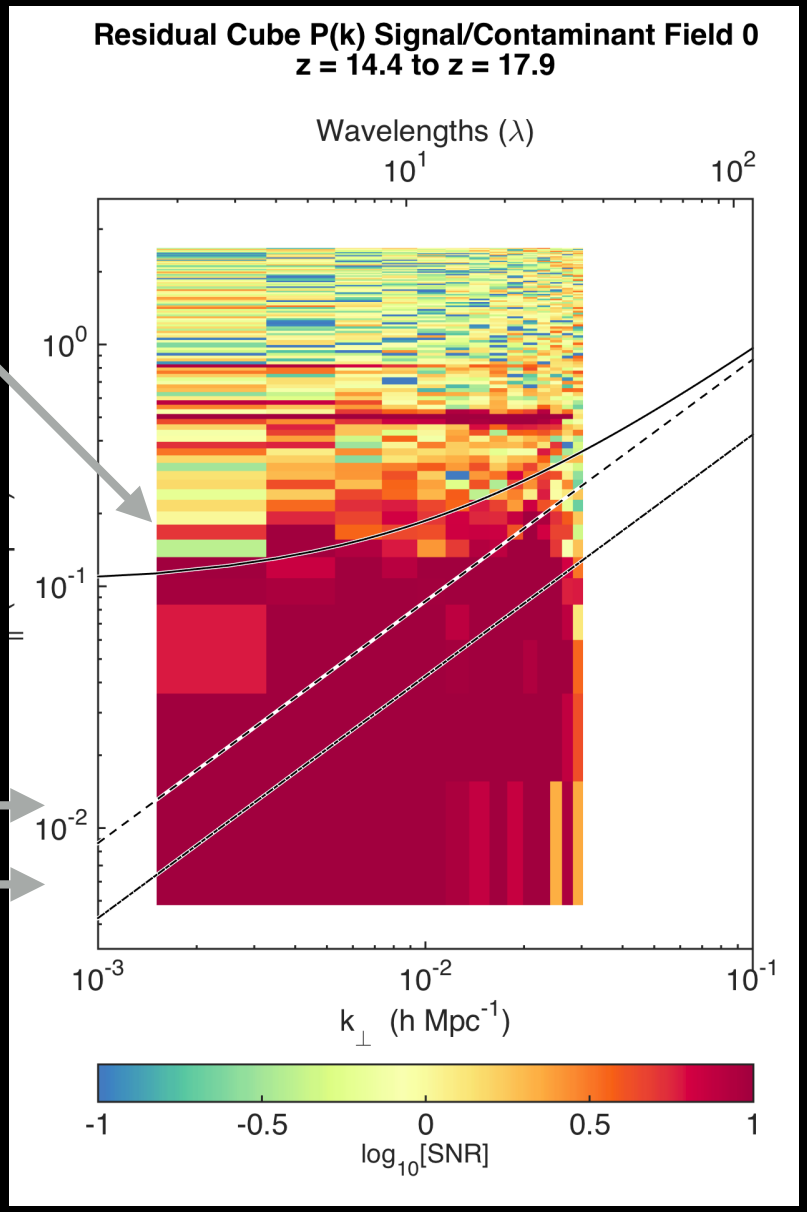
Vedantham and Koopmans 2015
V,K 2016

Power Spectrum Comparison Between Nights



As with the EoR, Instrumental Spectral Structure needs to be controlled for EoX and the Epoch of the First Stars.

First attempt: Ratio of Power to Error: z=15-18



Wedge+0.1hMpc^{-1}

Horizon

First Null

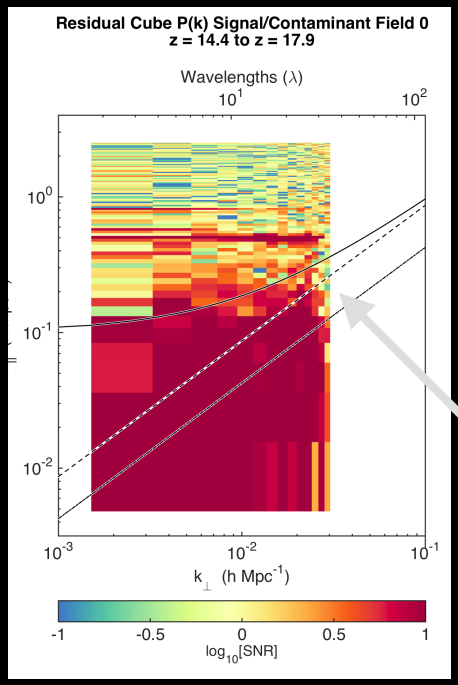
Small LoS Scales

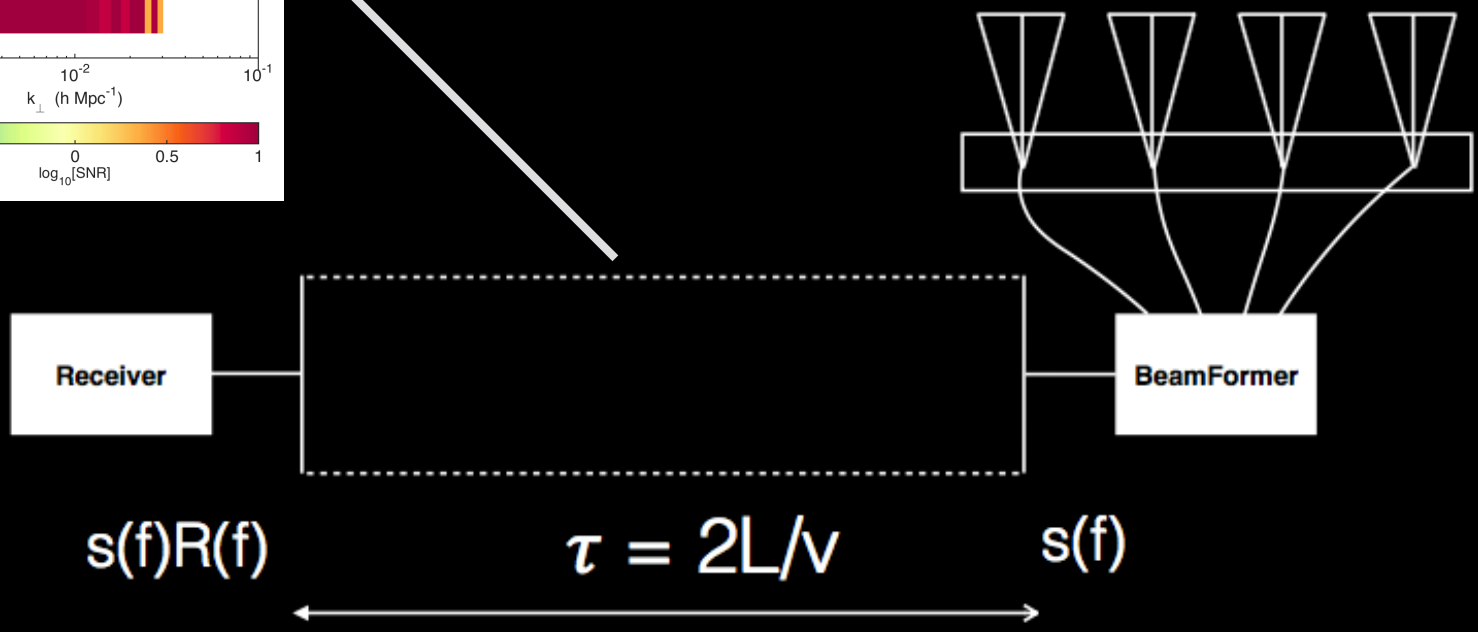
Ideally, the region below "wedge" Should be free of decections

Large LoS Scales

X-ray Epoch Power Spectrum

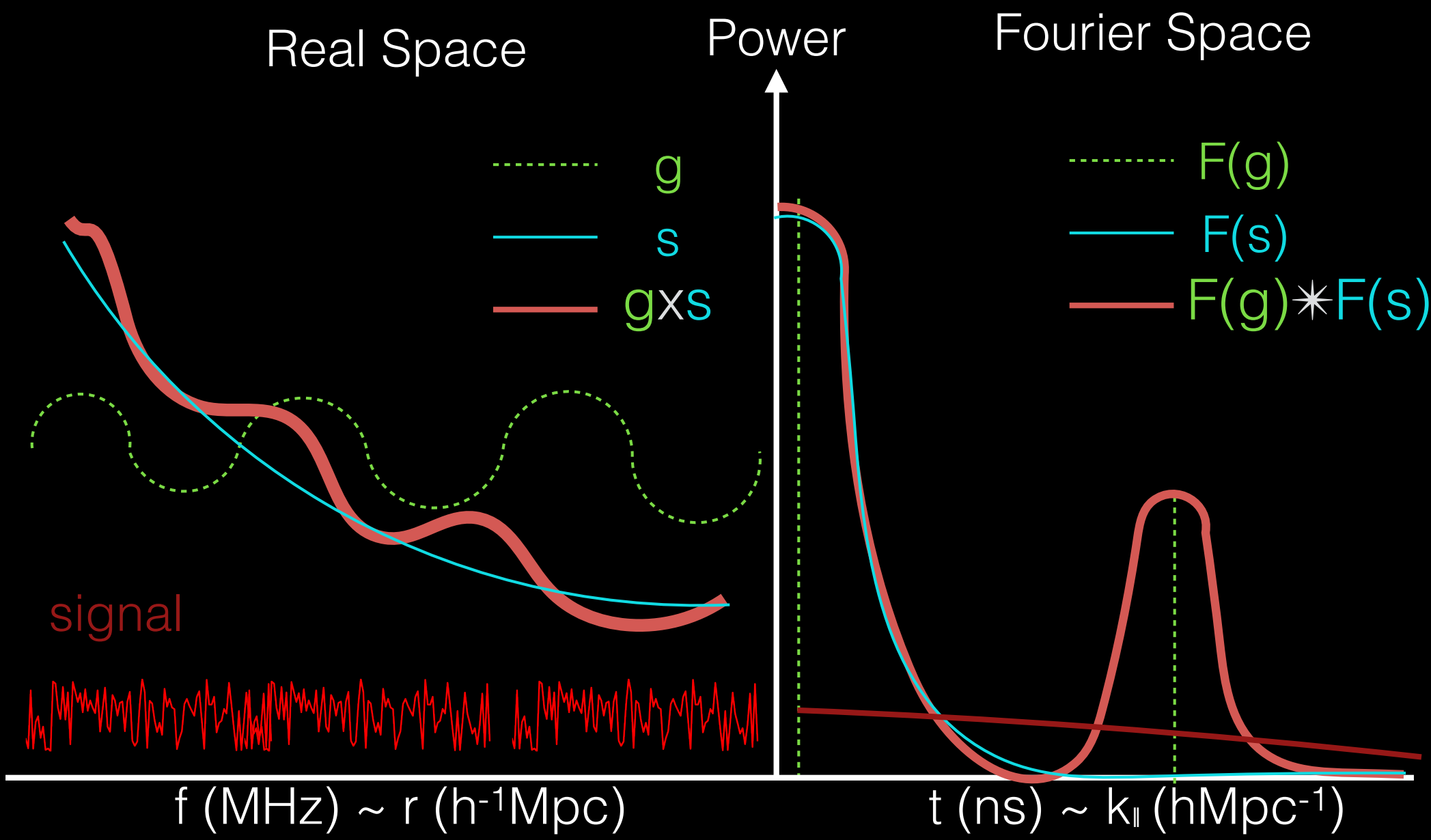
First attempt: Ratio of Power to Error: z=15-18



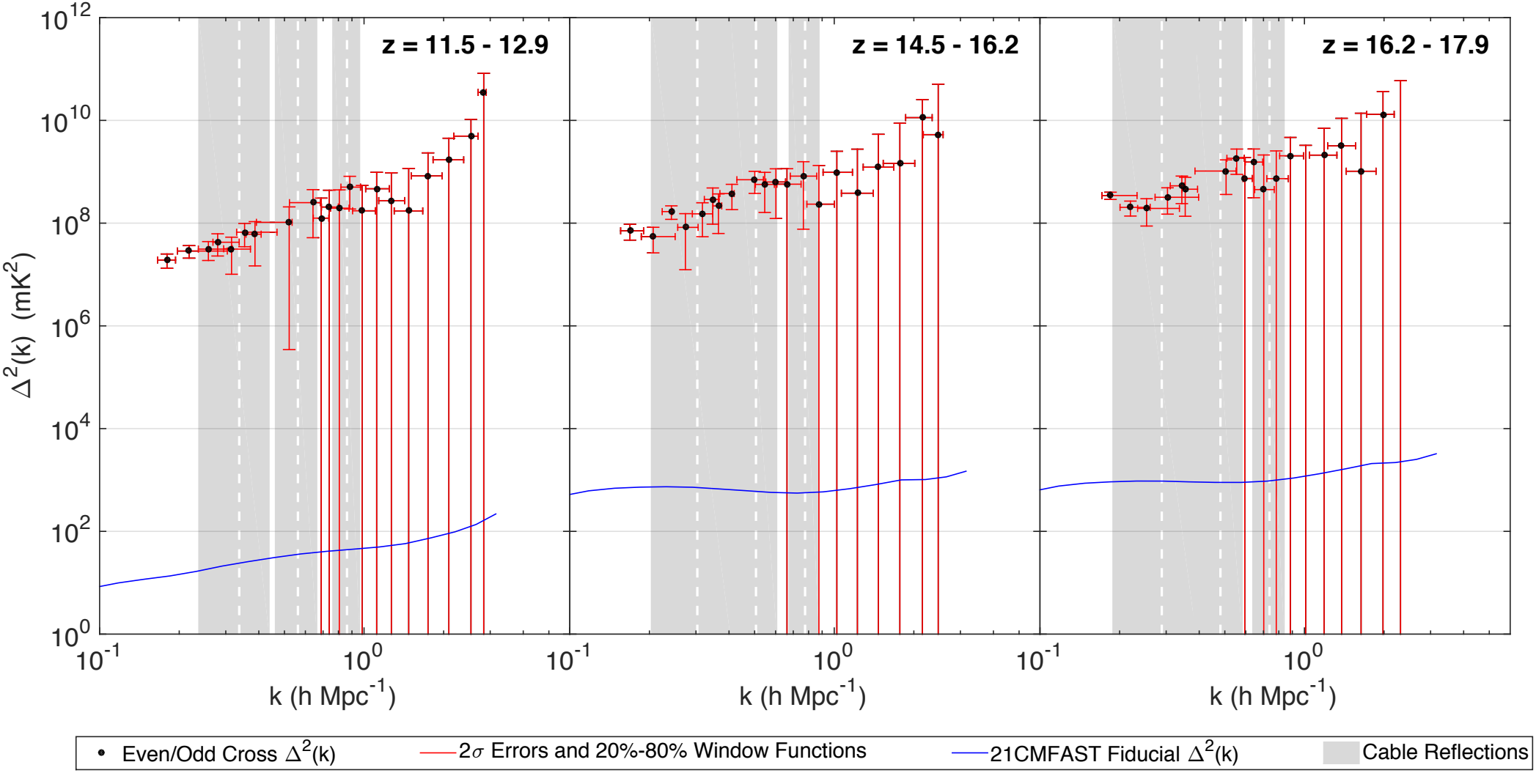


AEW+MNRAS

The Effect of uncalibrated Cable Reflections



1d power spectra limited by intrinsic spectral structure

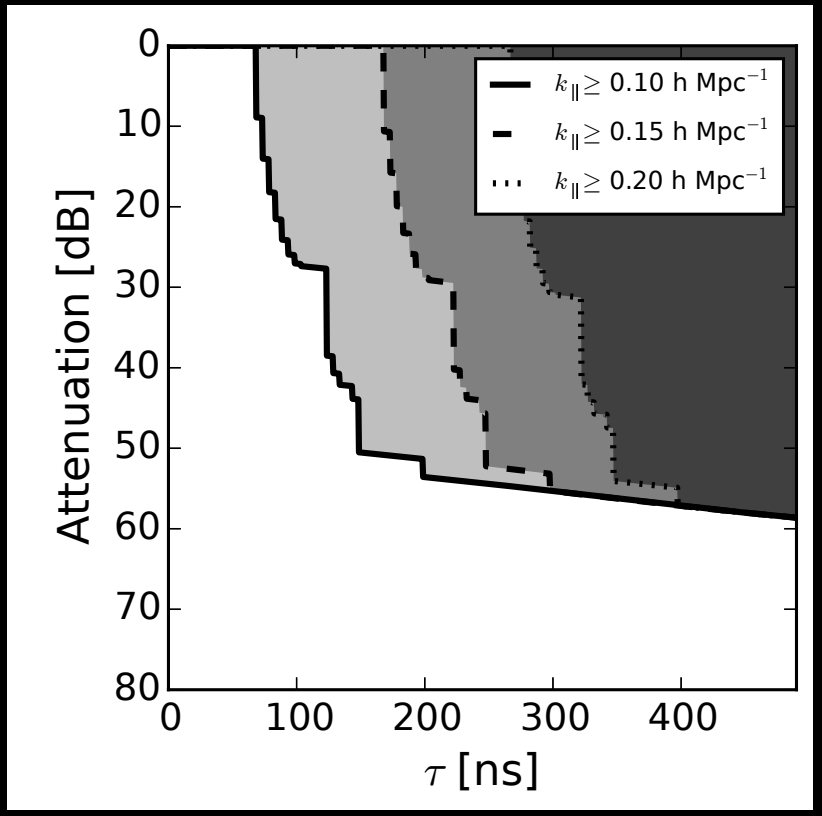


AEW+MNRAS Accepted

- Ensure that the bandpass of the Antenna is Smooth
- And if not, ensure that calibration can remove un-smooth features.

How Smooth?

Delay Specification for EoR Studies



Thyagarajan+ 2016
Ewall-Wice+2016
Patra+ in prep.

-50dB at 250 ns for k=0.15 h/Mpc

Spec for X-ray heating

- Signal x sqrt(10)
- Foregrounds x 10

-55dB

Delay Spec for EoX

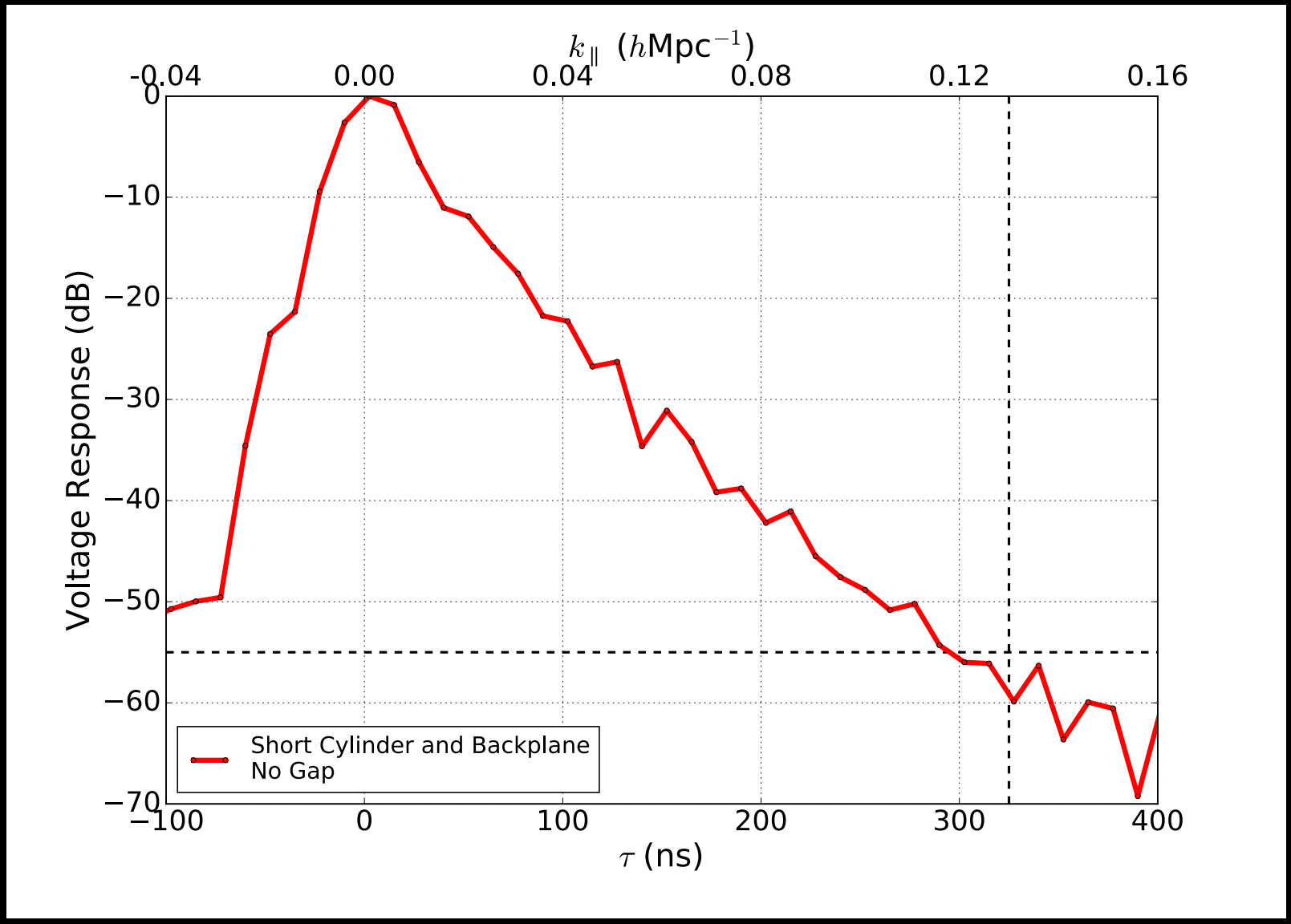
A fixed frequency scale (delay)
corresponds to a larger coming scale

$$k_{\parallel} \propto (1+z)^{-1/2}\tau$$

- tau * sqrt[(15+1)/(8+1)] = tau * 1.3

=> -55dB at 325 ns

Simulated Delay Performance for a Low Frequency HERA Feed (50-130MHz)



What about Lyman-Alpha Coupling?

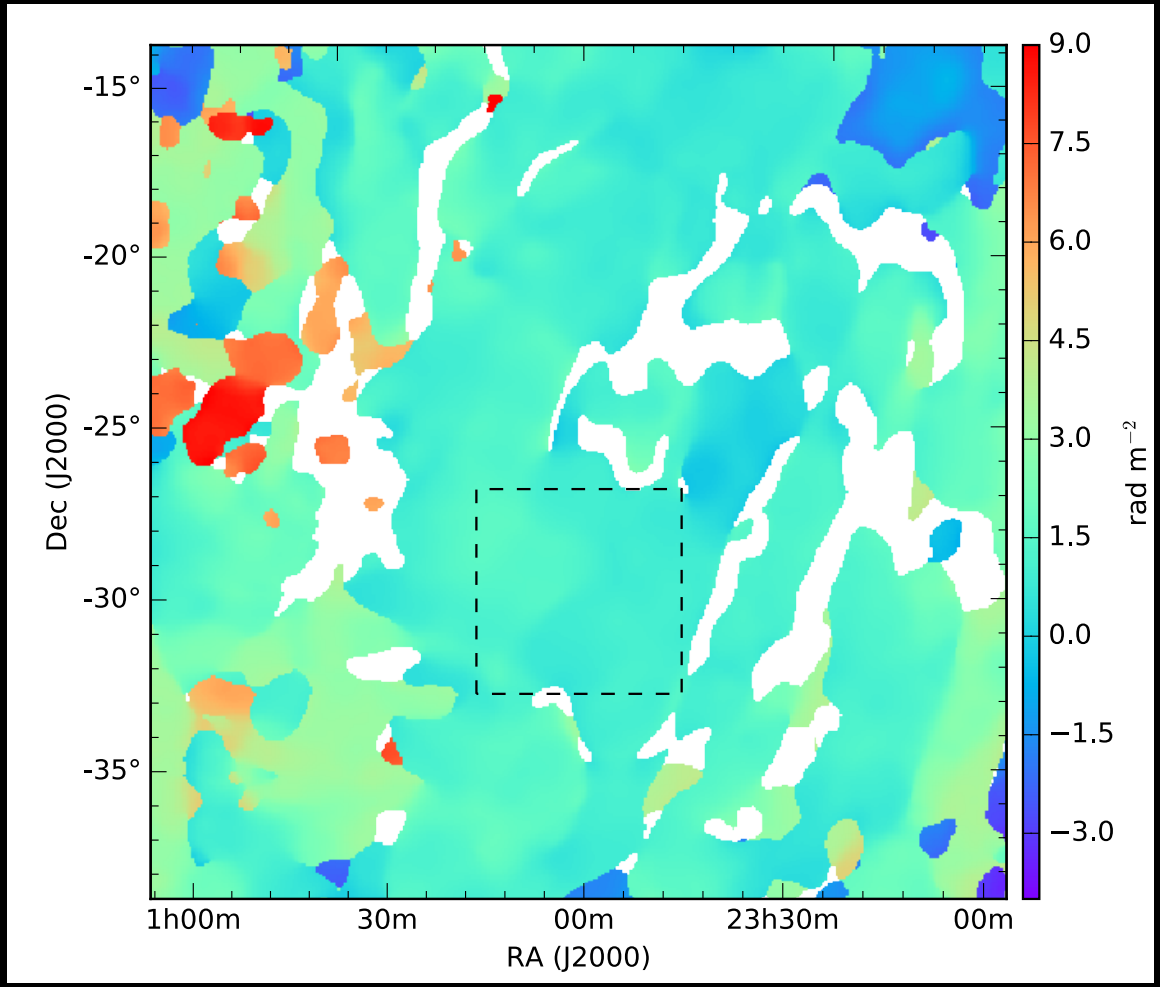
- Signal x sqrt(5)
- Foregrounds x 10
- tau * sqrt[(20+1)/(8+1)] = tau * 1.53

-56.5dB at 382.5ns

We should consider digitization at each Antenna to minimize cable reflections.

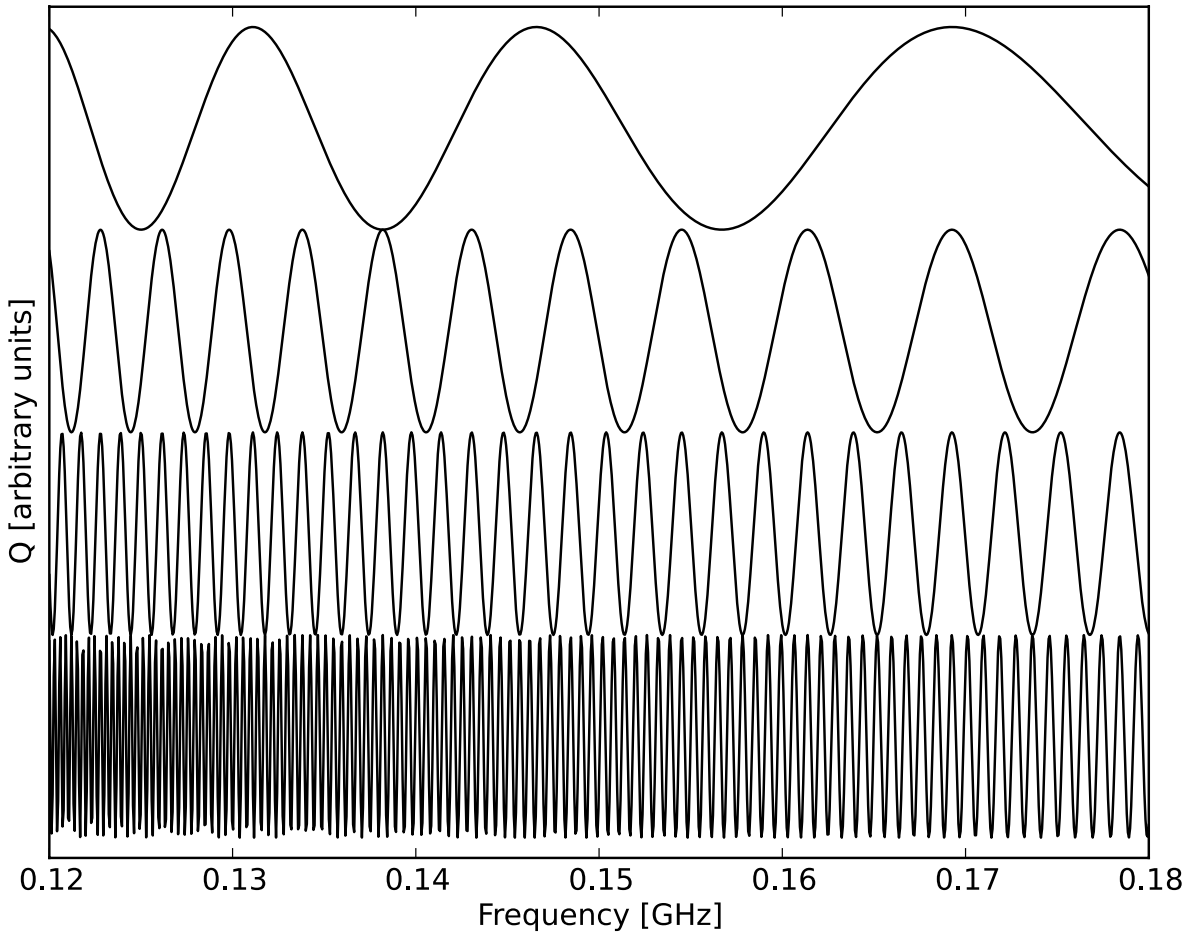
Significant Polarization Challenge at Low Frequencies?

- Lenc+ 2016: 10% polarized diffuse structures at low rotation measure.
- EoR antennas aim for ~10^-3 Polarization Mismatch spec at 150MHz
- No Equivalent Measurements exist <100MHz



Lenc+ 2016

Chromaticity from Faraday Rotation



RM=3/m^2

RM=10/m^2

RM=30/m^2

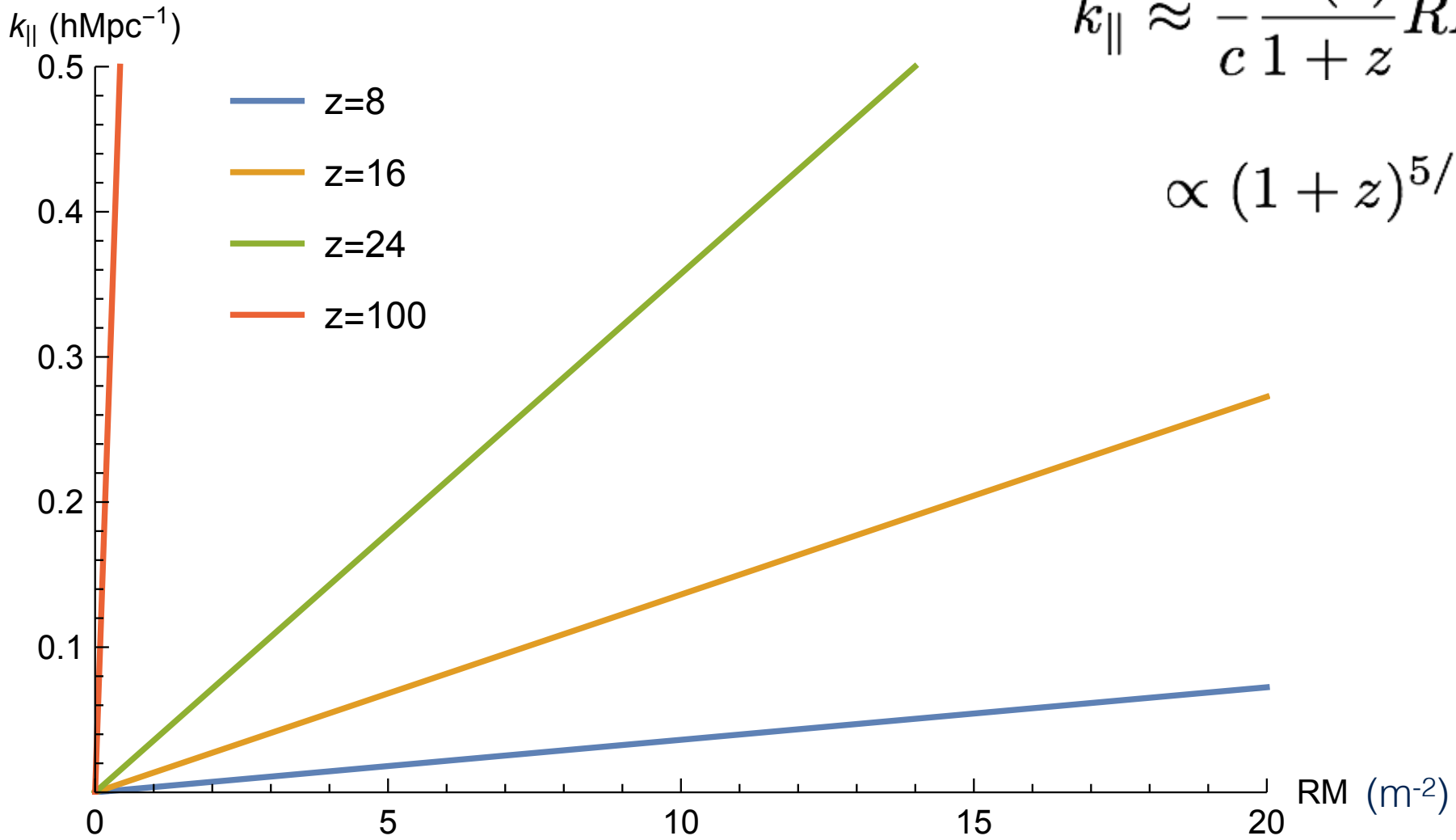
RM=100/m^2

Moore+2013

For Higher Redshift, Fixed Rotation Measures map to Larger $k_{||}$ (Moore+ 2014,2015)

$$k_{||} \approx \frac{2}{c}\frac{H(z)}{1+z} RM \lambda^2$$

$$\propto (1+z)^{5/2}$$



Missing Ingredients

1. Polarized Fractions at low frequency
2. How much will depolarization help?

Summary

- RFI and the Ionosphere are additional challenges but do not appear to be insurmountable (above the ionosphere cutoff).
- Delay-Specs for Pre-Reionization feed are more stringent but also at higher delays.
- Polarization: Potentially a very severe problem at z>~20

Discussion Questions

- Will FM Power contaminate additional channels?
- If so, is it possible to filter a discrete band?
- Will working inside of the FM require finer channelization than EoR?
- Should we digitize at the antennas?
- What degree of polarization correction is possible?
- What complimentary signals can be cross correlated before reionization?
  - 21cm Forest?
  - X-ray background?