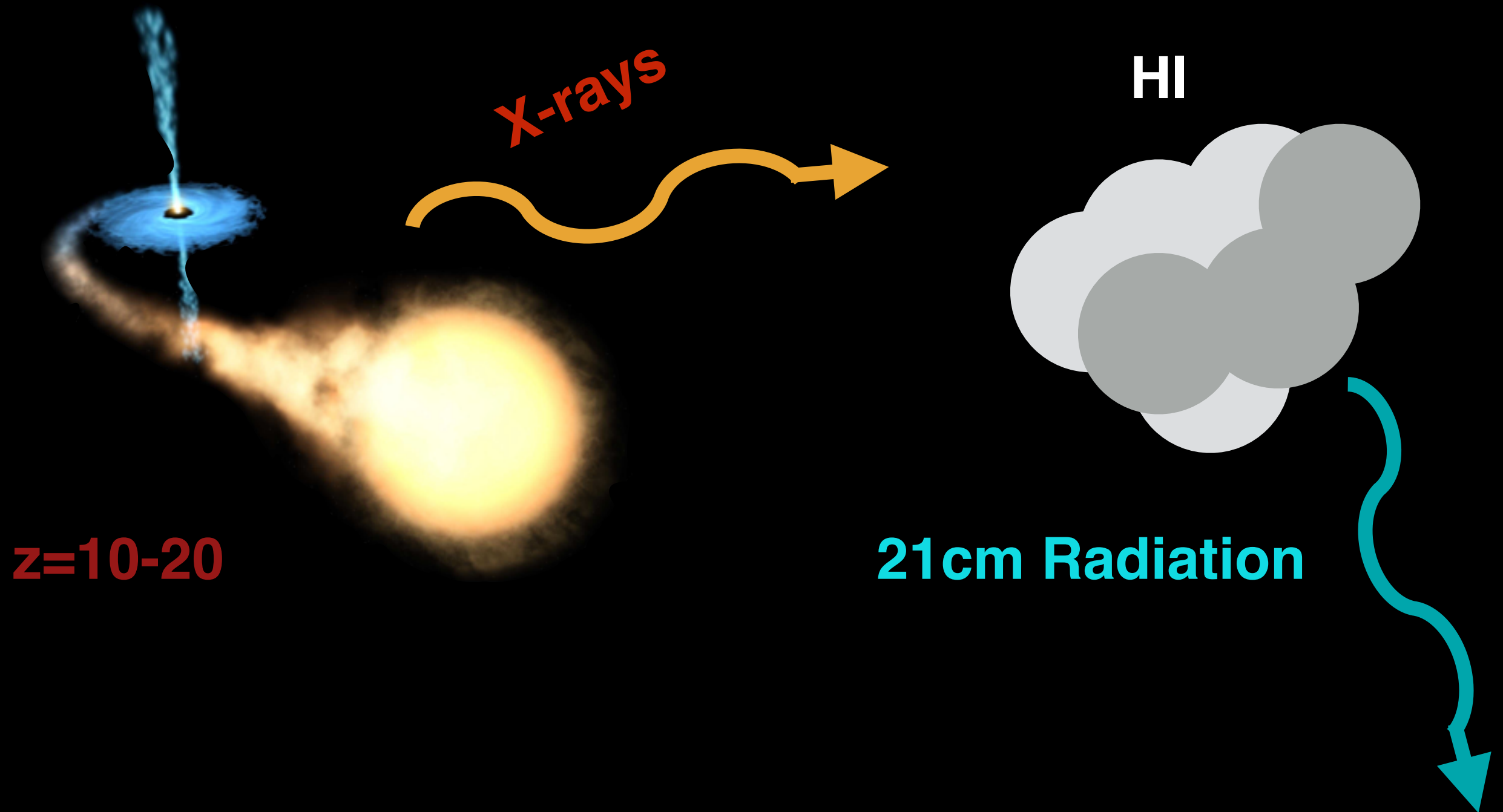


The Epoch of X-ray Heating Power Spectrum: Sensitivity Predictions for HERA and First Limits with the MWA

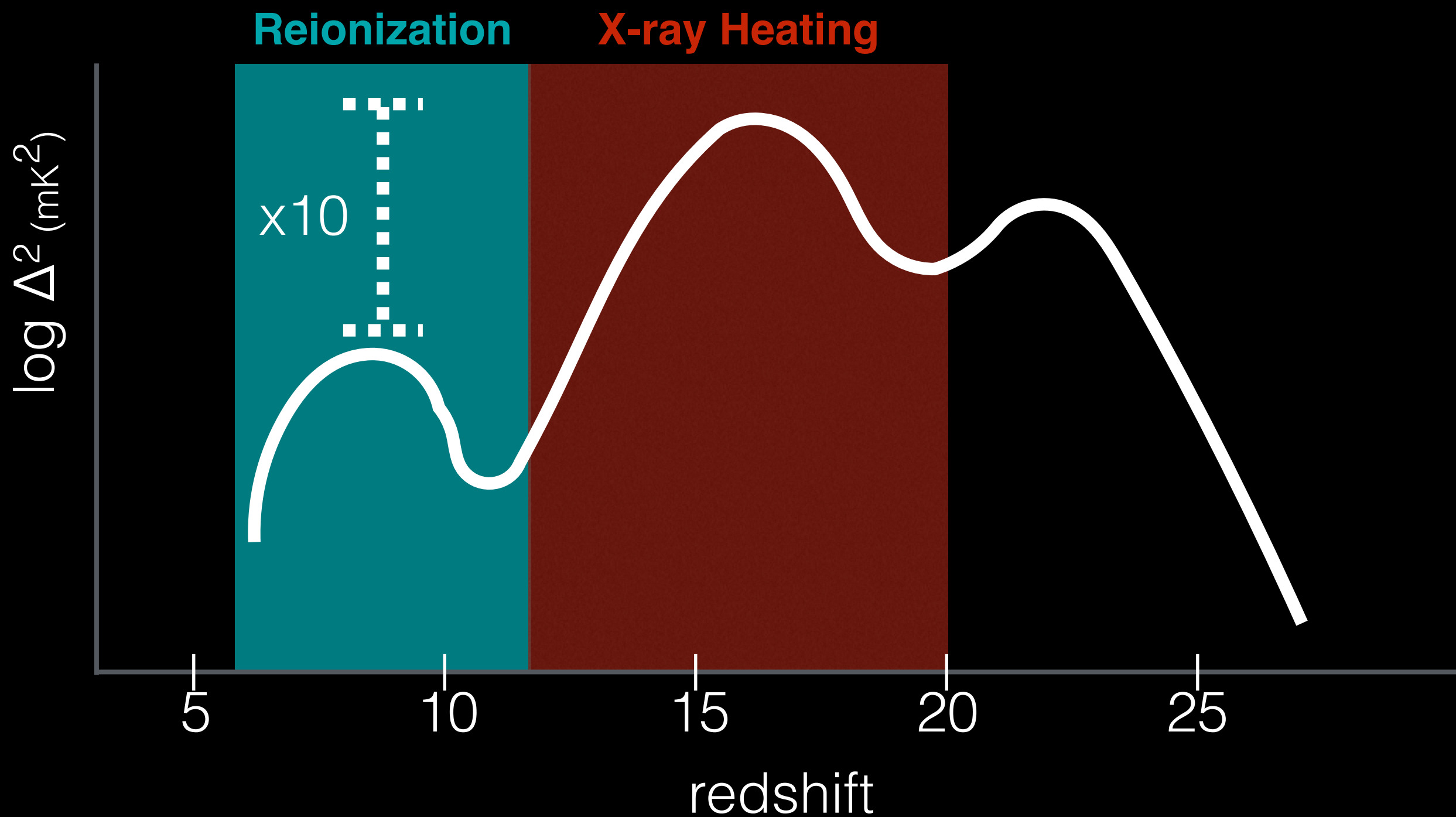
Aaron Ewall-Wice
MIT

Joshua Dillon, Jacqueline Hewitt, Andrei Mesinger, Abraham Neben,
Adrian Liu, Jonathan Pober, Avi Loeb, Max Tegmark, Andre Offringa,
Daniel Jacobs, Nithyanandan Thyagarajan, the MWA and HERA
collaborations.

The Epoch of X-ray Heating



$$\delta T_b \propto x_{HI} \left(1 - \frac{T_{CMB}}{T_s} \right)$$



What can we learn from a next generation Interferometer?

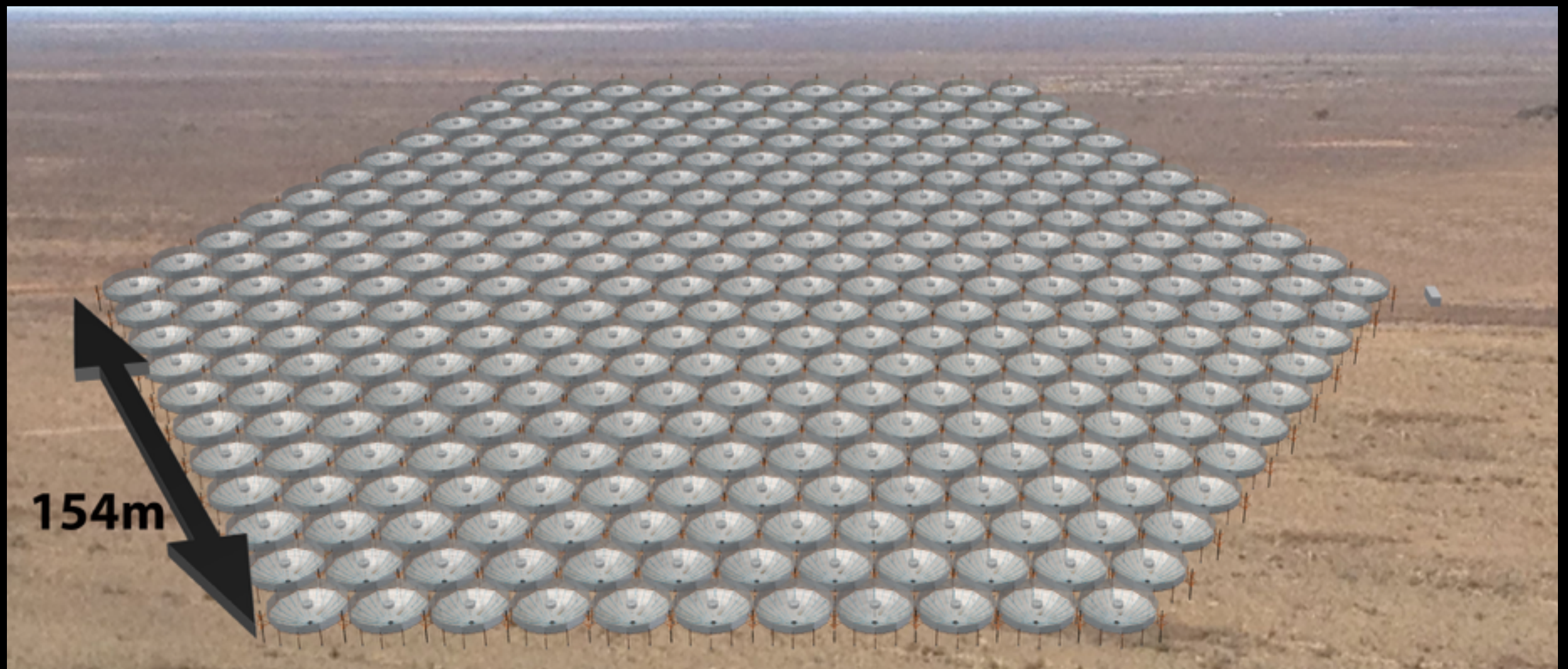
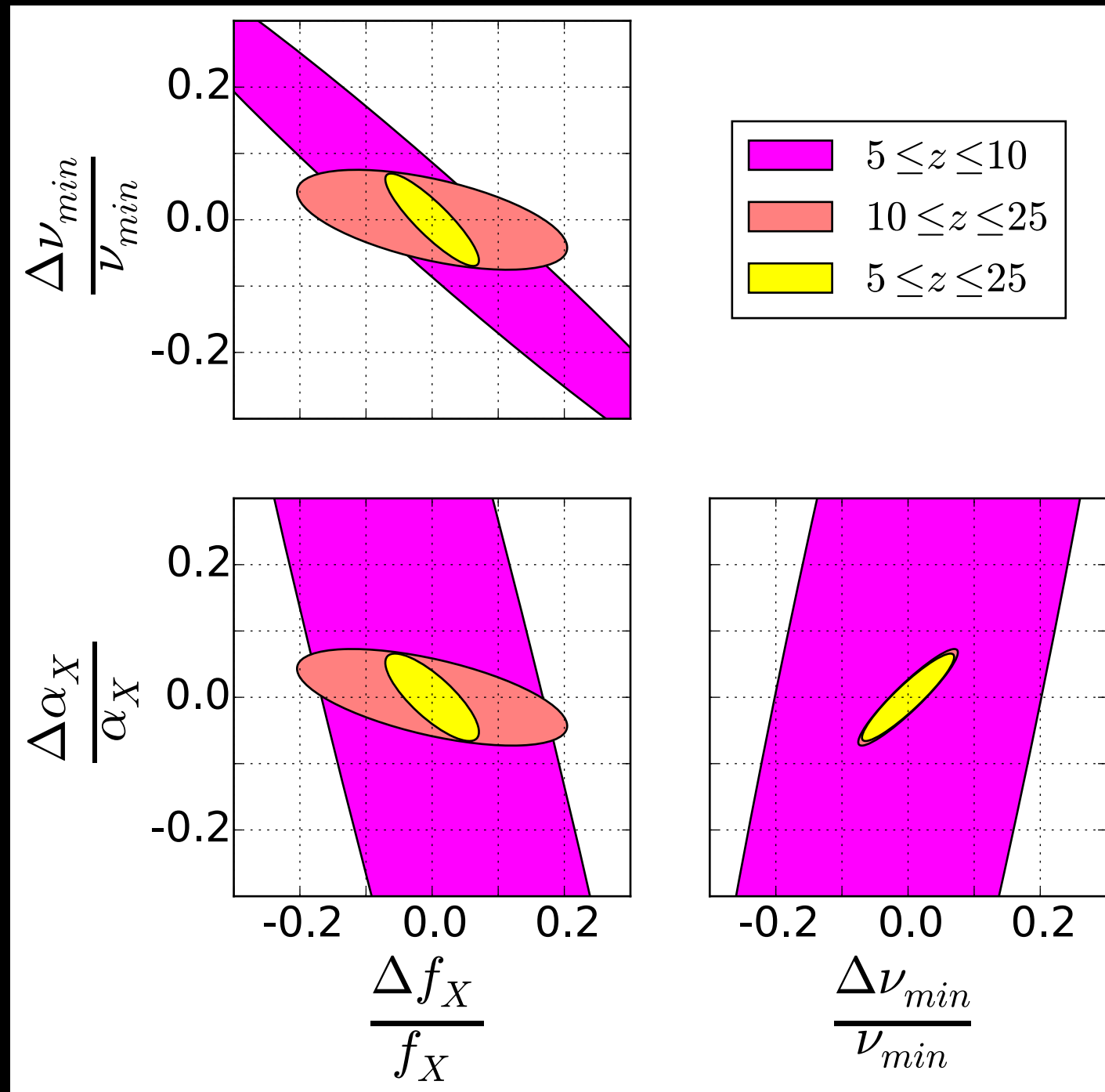


image credit: David DeBoer

HERA-331 will deliver $\sim 6\%$ constraints on the spectral properties of early X-ray sources

Reionization
Redshifts

Heating
+
Reionization
Redshifts



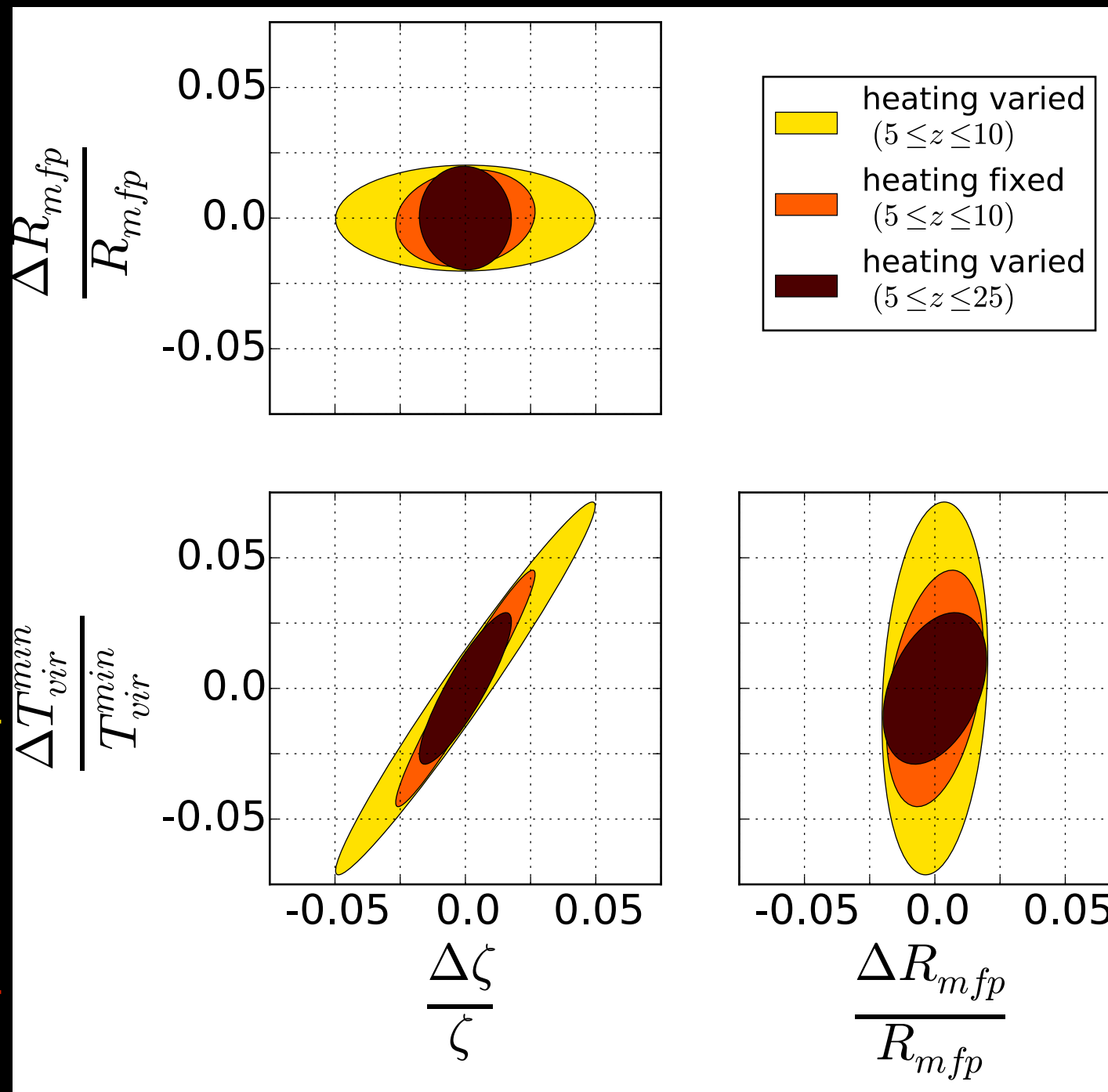
95%
confidence
ellipses

High Redshift Observations will Break Heating-Reionization Degeneracies

Reionization
Redshifts
Heating Fixed

Reionization
Redshifts
Heating Varied

All Redshifts
Heating Varied



95%
confidence
ellipses

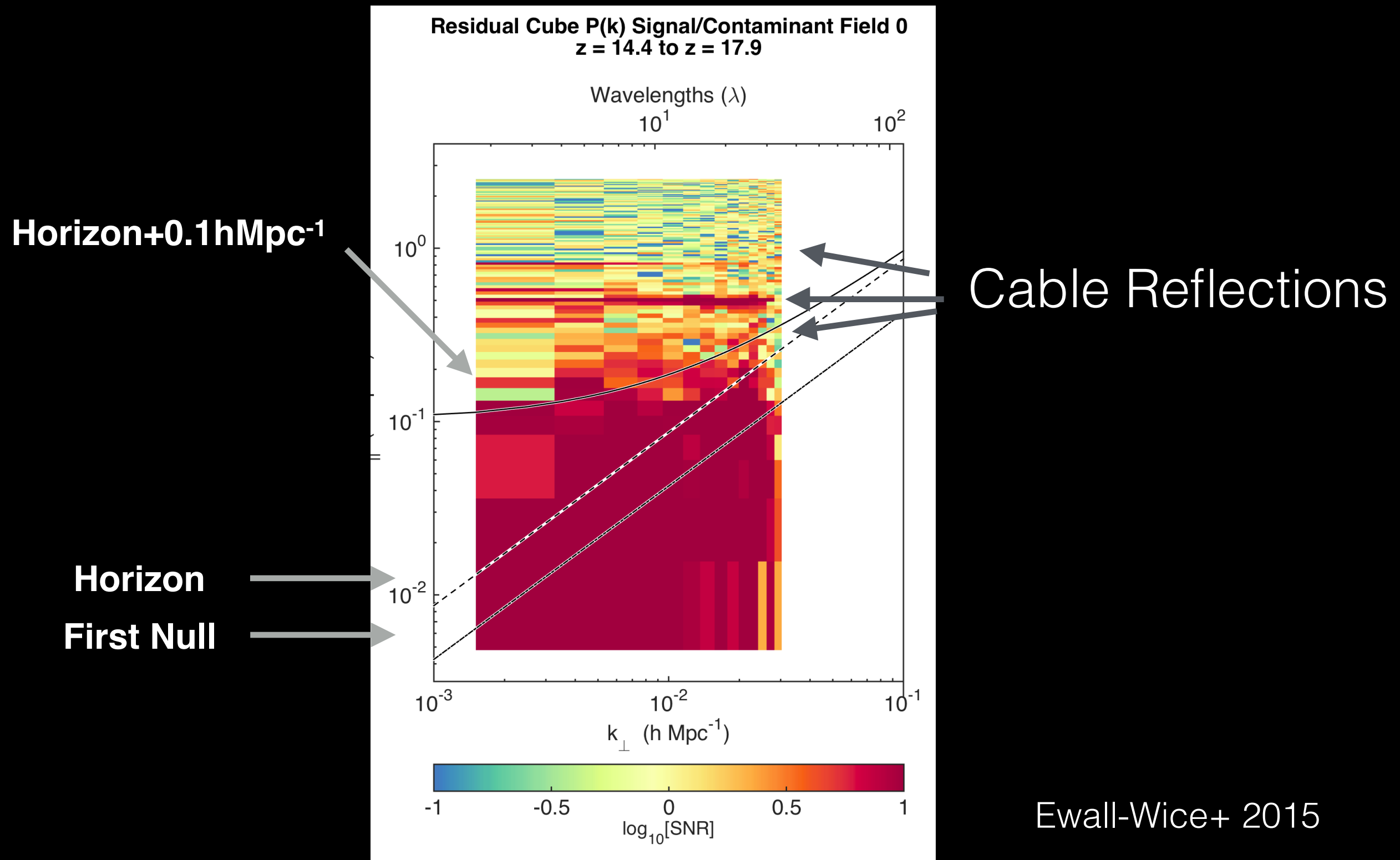
Higher Redshift Complications

- $z=12-15$ is inside the FM band: increased RFI challenge
- Larger Field of View $\rightarrow$ greater calibration challenge+foreground contamination (MWA: FWHM=40 degrees)
- The Foregrounds are intrinsically brighter
- Ionospheric severity increases

EoX Power Spectrum Observations on the MWA

- Determine to what extent low frequency systematics effect a measurement of the power spectrum
- Put a first upper limit on the 21 cm power spectrum between $z=12$ and $z=18$.

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



The Effect of uncalibrated Cable Reflections

Real Space

Power

Fourier Space

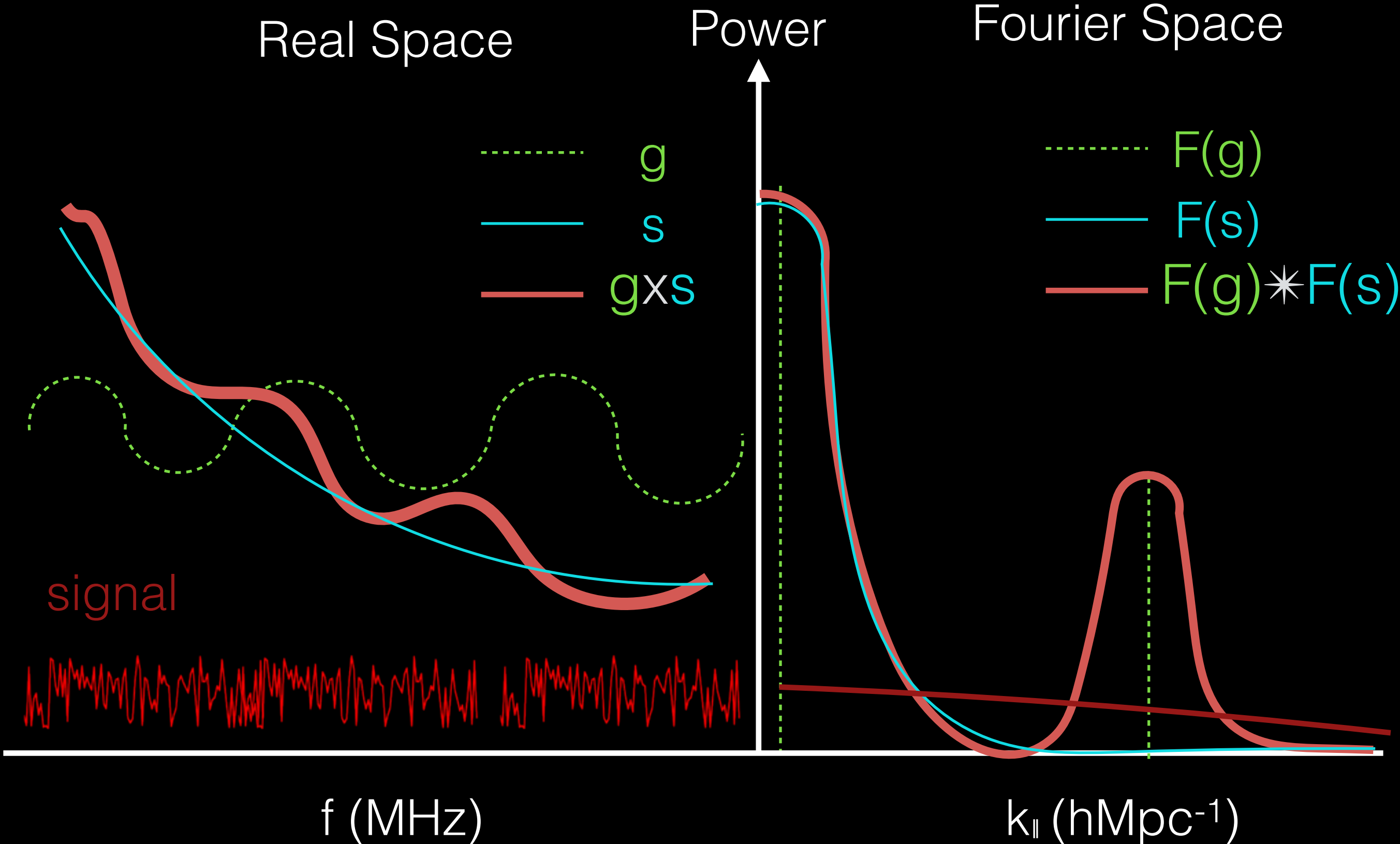
..... g
— s
— $g \times s$

..... $F(g)$
— $F(s)$
— $F(g) * F(s)$

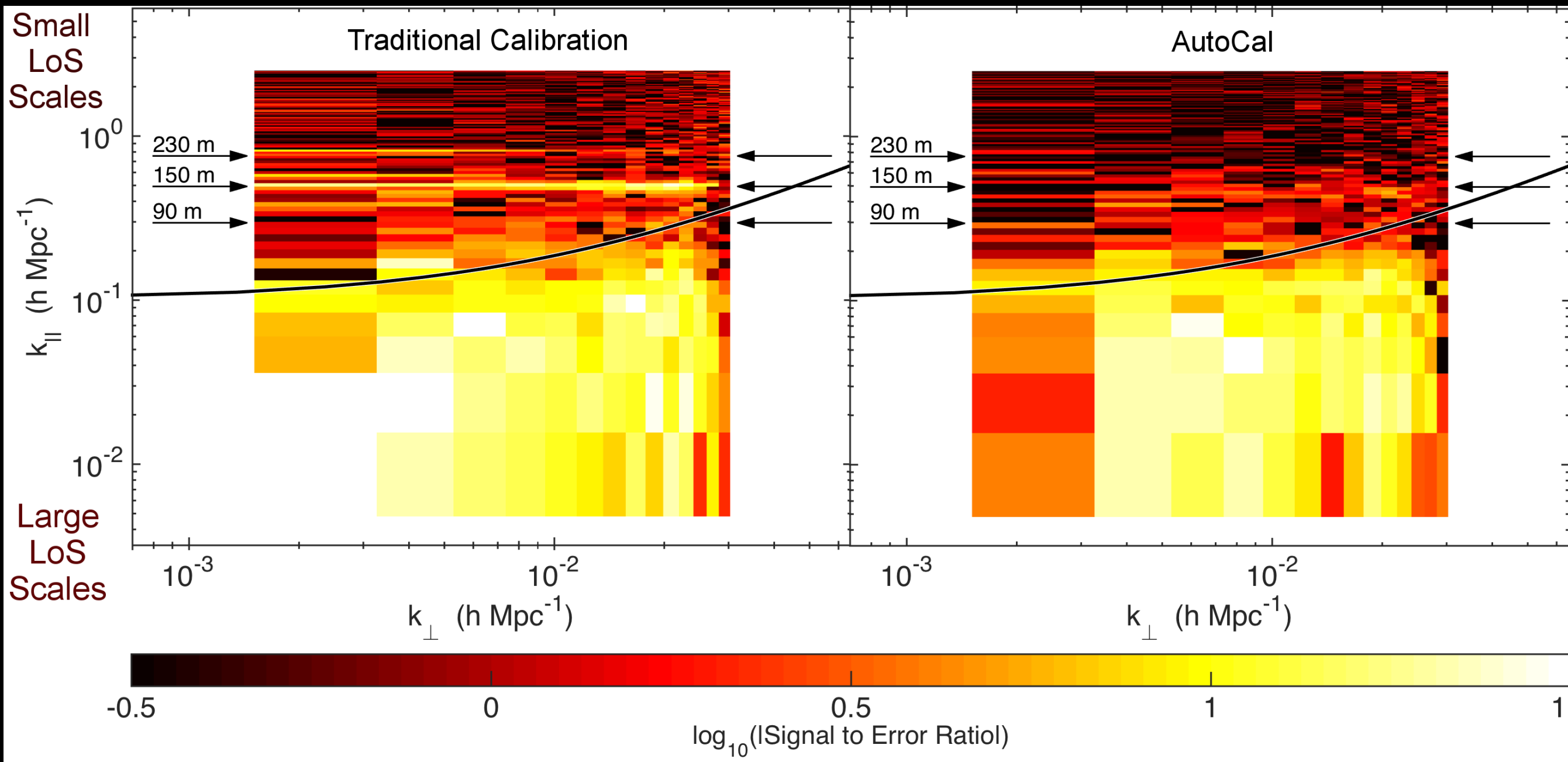
signal

f (MHz)

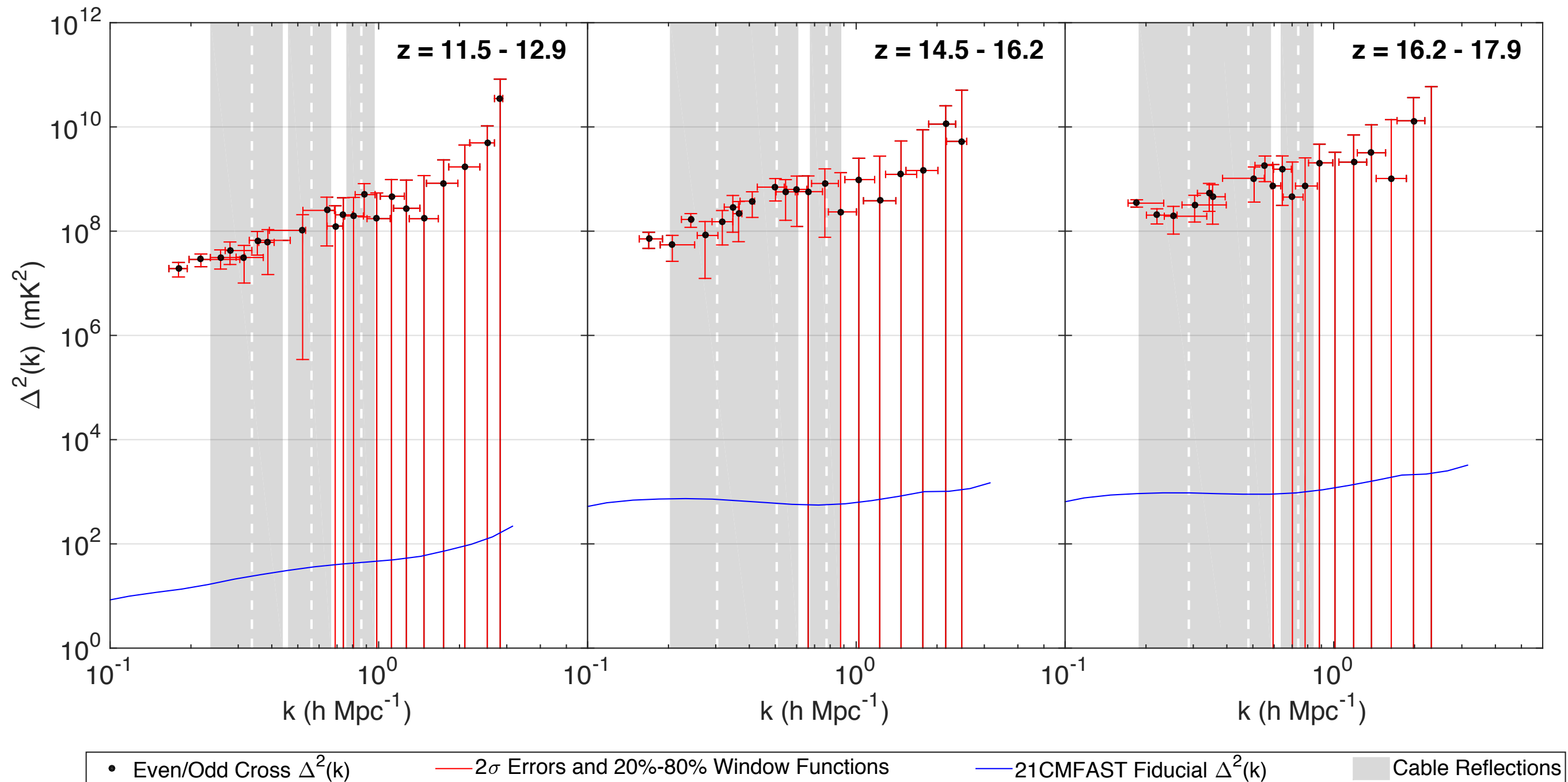
$k_{\parallel}$ (hMpc $^{-1}$)



Reduced Reflection Amplitudes Using Information in the Autocorrelations



1d power spectra limited by intrinsic spectral structure



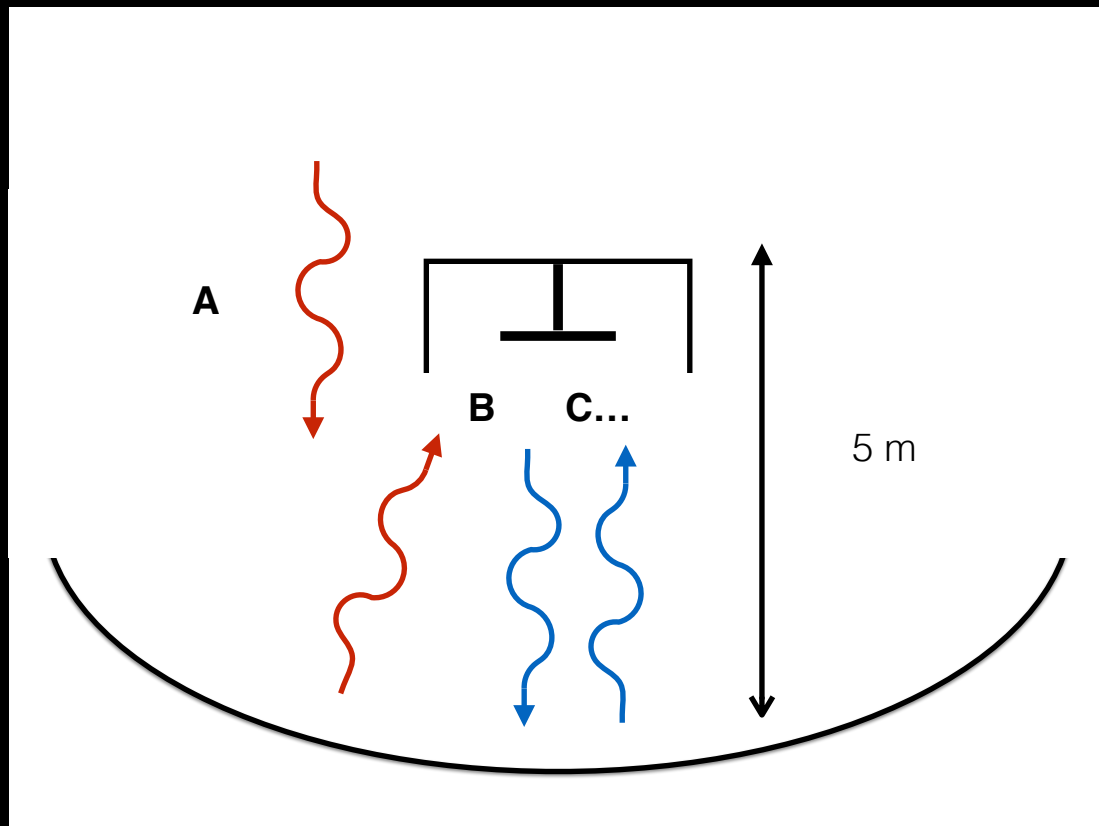
The Problem

- Intrinsic Fine Frequency Spectral Structure within our instrument.
- Cannot be calibrated out due to uncertainties in the sky model (Barry+, 2016)

Potential Solutions

- Redundant Calibration (Wieringa 1992, Liu+ 2010, Zheng+ 2014).
- Very high fidelity sky model .
- Intrinsically Smooth Signal Chain

Understanding Spectral Structure in the HERA signal path.

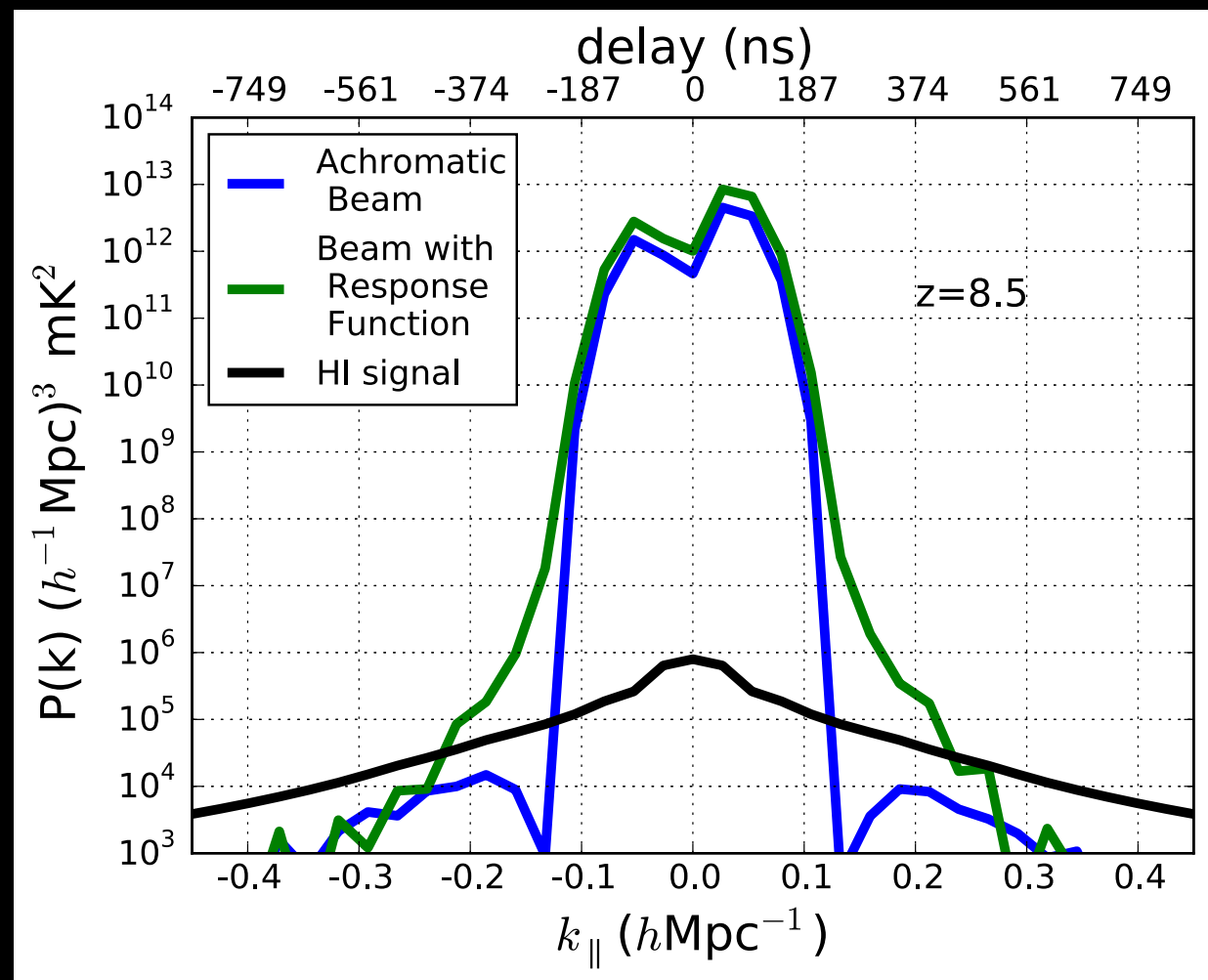


Neben+, 2016

Ewall-Wice+, 2016

Thyagarajan+, in Preparation.

Patra+, in Preparation,



Reflections in the Dish only Contaminate a small region.

Summary

- **Box Power Spectrum measurements with HERA**
 - Will deliver $<10\%$ constraints on spectral properties of X-ray sources and their host galaxies
 - Break lower redshift Degeneracies between heating and Reionization.
- **Investigation of systematics with the MWA**
 - Limited by intrinsic instrumental structure
 - Calibration of intrinsic spectral structure is very difficult due to uncertainties in our sky model.
- **We are not eliminating reflections in the signal chain for HERA that will enable a detection of the EoX power spectrum.**