Sky-Based Calibration and the EoR Power Spectrum: Contamination, Mitigation, and Implications

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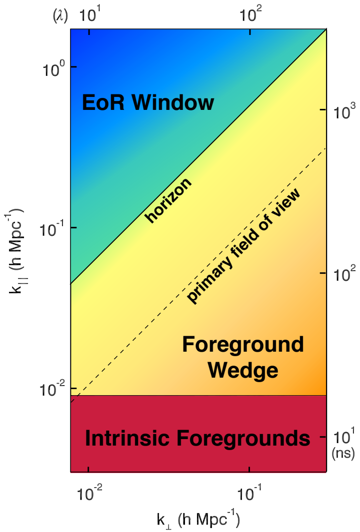
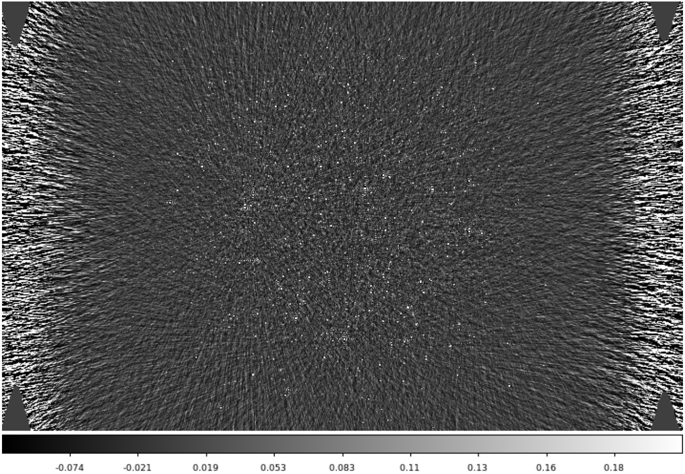
June 19th, 2017
Low Frequency Observing

The 2D Power Spectrum

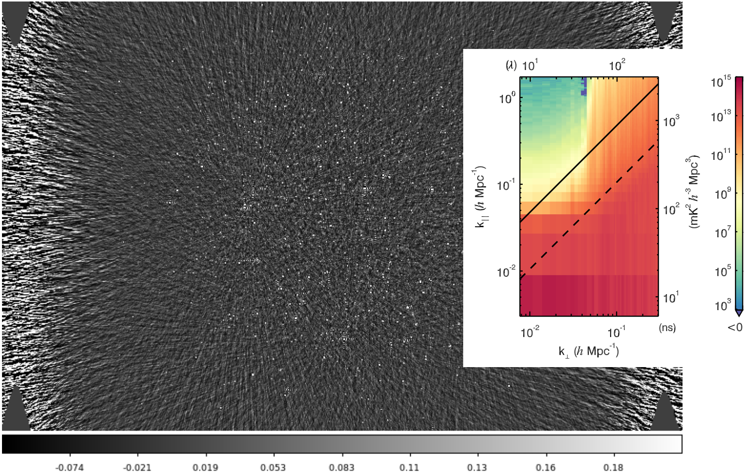


By Bryna Hazelton

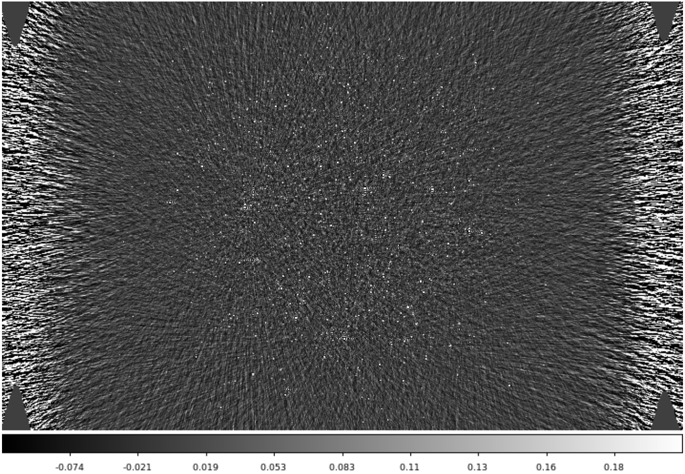
Dirty, calibrated (6950 sources)



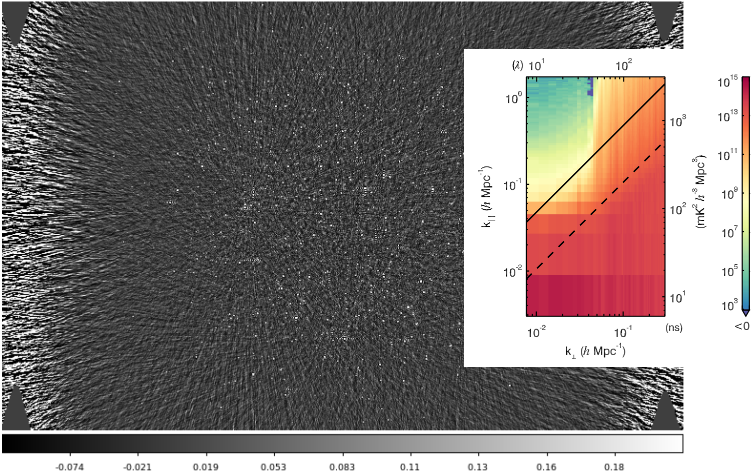
Dirty, calibrated (6950 sources)



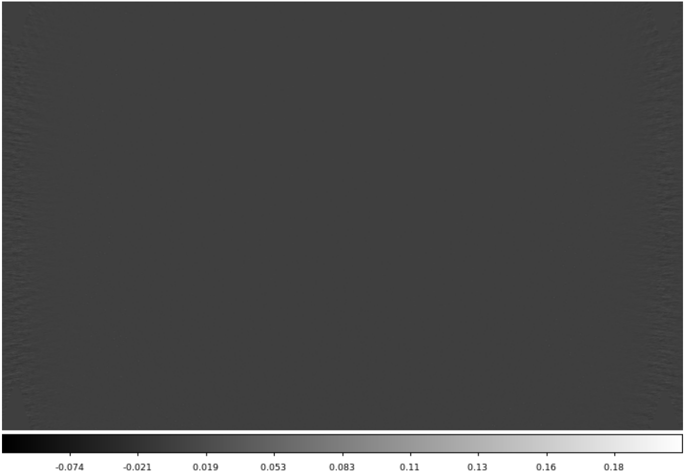
Model, 72% flux (4000 sources)



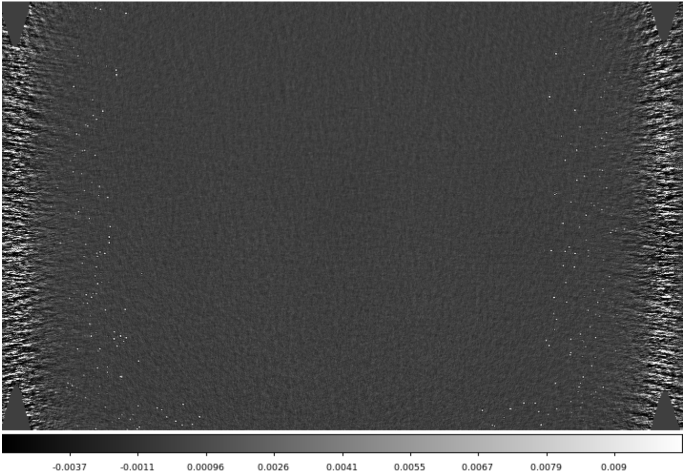
Model, 72% flux (4000 sources)



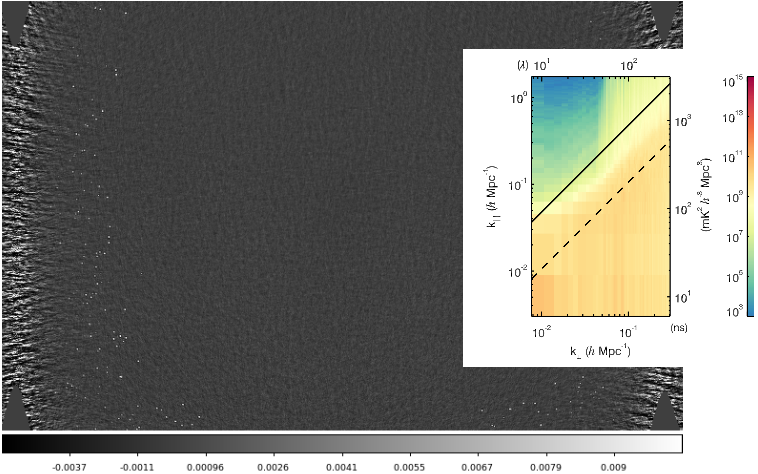
Residual, 28% flux (2950 sources)



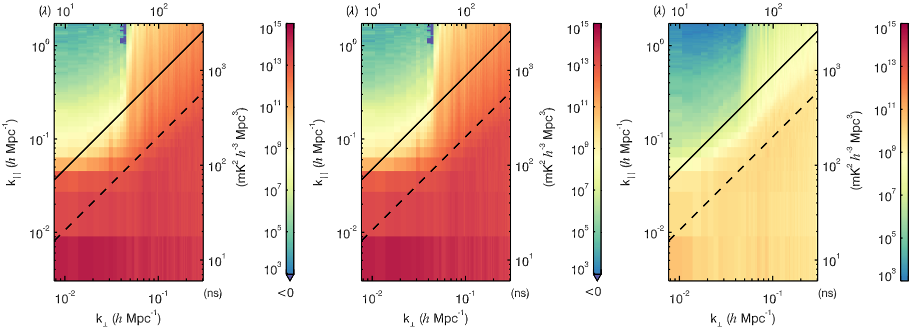
Residual, 28% flux (2950 sources)



Residual, 28% flux (2950 sources)

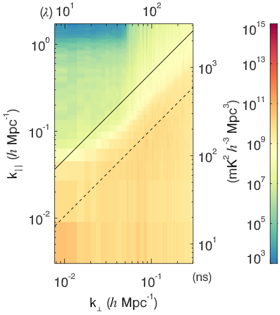


Residual PS

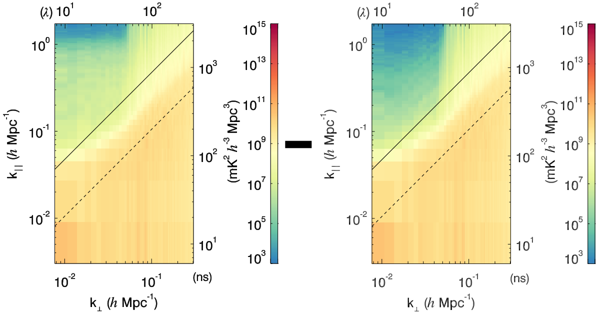


"perfect calibration" = no calibration errors

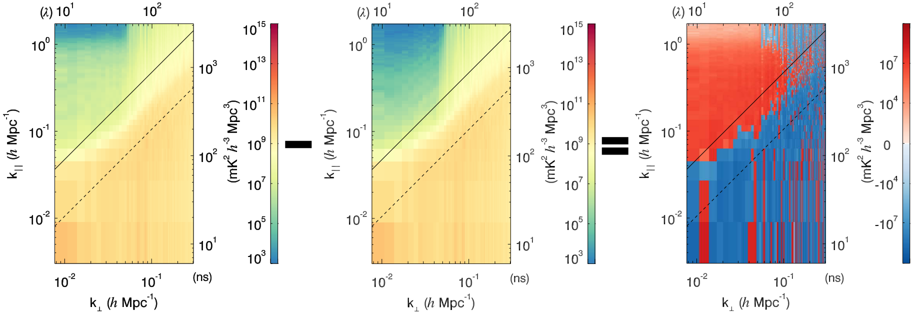
Difference – per freq, per pol, per antenna calibration



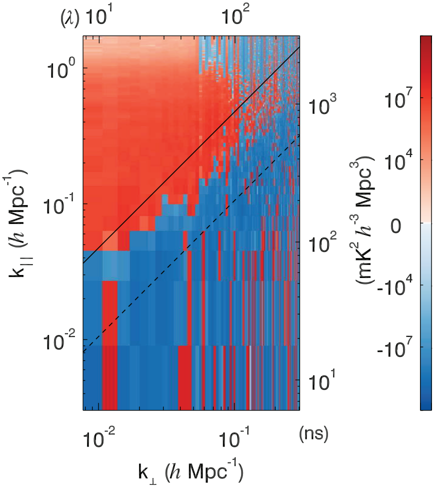
Difference – per freq, per pol, per antenna calibration

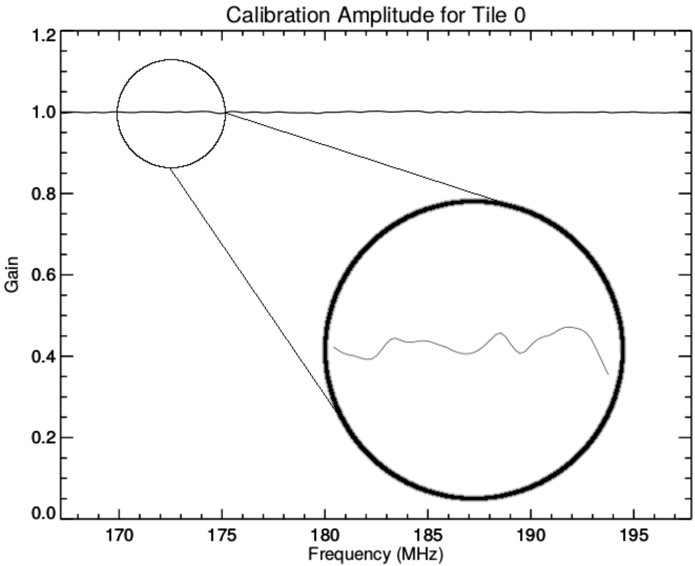


Difference – per freq, per pol, per antenna calibration



- Entire window is saturated by an order of magnitude (or 2) above the EoR
- Power removed from foreground wedge
- Measurement of the EoR impossible!




Calibration Amplitude for Tile 0
Gain
1.2
1.0
0.8
0.6
0.4
0.2
0.0
170
175
180
185
190
195
Frequency (MHz)

Modulation

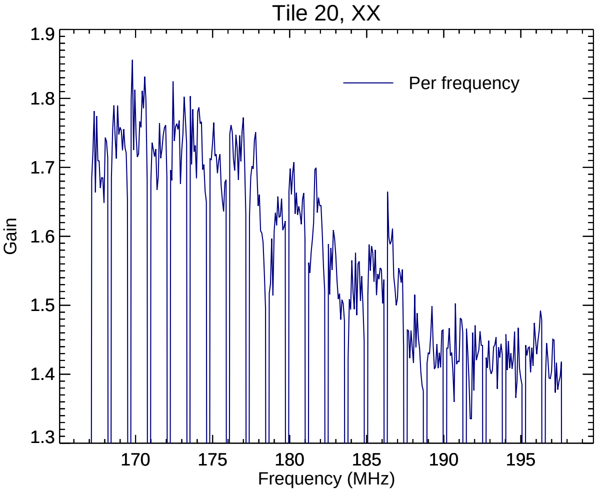
$$h(\nu) = f(\nu)\left(1 + \Delta g \cos \eta_0 \nu\right) \tag{1}$$

The modulation theorem results in the Fourier transform

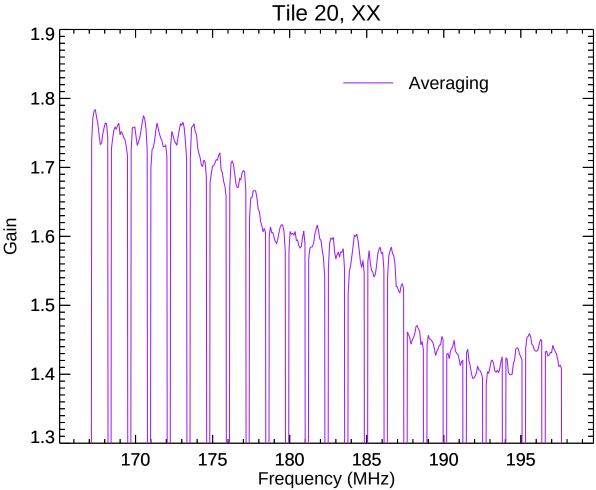
$$H(\eta) = \frac{\Delta g}{2} F(\eta - \eta_0) + \frac{\Delta g}{2} F(\eta + \eta_0) + F(\eta) \tag{2}$$

An order of magnitude estimate of the positive power spectrum of this modified signal is

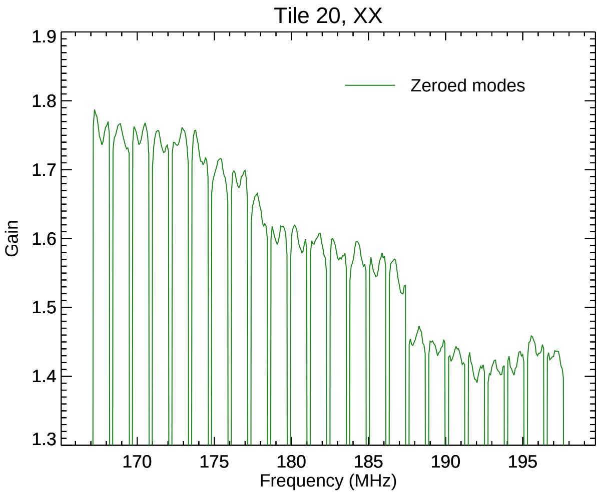
$$\mathcal{O}(|H(\eta)|^2) \approx \mathcal{O}(|F(\eta)|^2) + \mathcal{O}\left(\left|\frac{\Delta g}{2} F(\eta \pm \eta_0)\right|^2\right) \tag{3}$$



Per frequency, per antenna linear least squares



LST and cable averaged



Selected modes from LST/cable averaged

Recommendations

- No frequency structure faster than 8 MHz (125 ns) in instrument
- Frequency structure needs to be lower than 1 part in 10^5
- Validation of calibration techniques
  - **in the space of the measurement**
  - **using incomplete models**

For more information...

- Barry N., Hazelton B., Sullivan, I. Morales M. F., Pober J. C., 2016, MNRAS, doi:10.1093/mnras/stw1380
- Trott C. M. and Wayth R. B., 2016, PASA, 33, e019 doi:10.1017/pasa.2016.18.
- Patil A. H., Yatawatta S., Zaroubi S., Koopmans L. V. E., de Bruyn A. G., Jelić V., Ciardi B., Iliev I. T., Mevius M., Pandey V. N., Gehlot B. K., 2016, MNRAS, doi:10.1093/mnras/stw2277
- Ewall-Wice A., Dillon J. S., Liu A., Hewitt J., 2017, MNRAS, doi.org/10.1093/mnras/stx1221