EoR Challenges for the SKA

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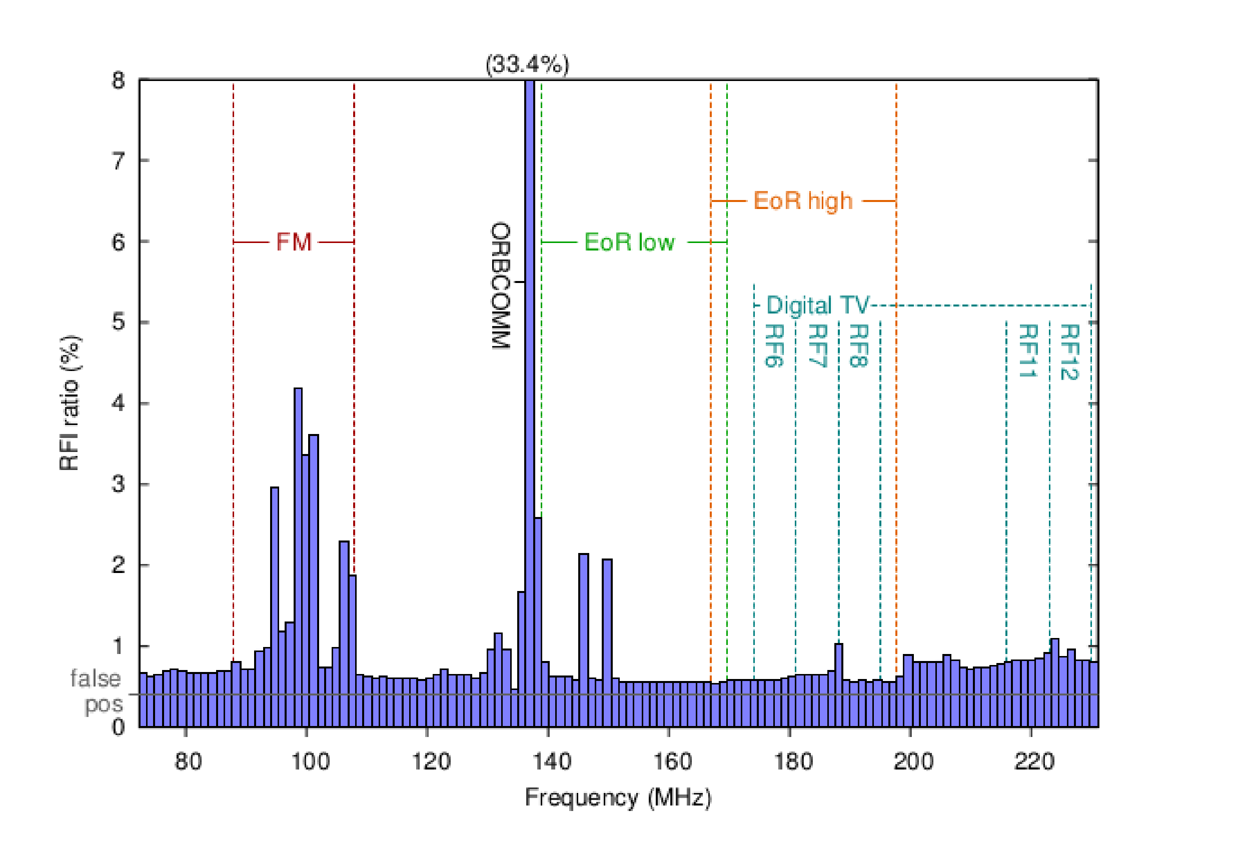
Introduction

- Detection of 21cm emission for the Epoch of Reionization is one of the primary science goals of SKA1-LOW
- Unprecedented sensitivity of the SKA will afford a whole new range of EoR science beyond 1st generation detection experiments
- However, like all precursor experiments, the SKA will need to overcome numerous systematics to measure the EoR signal
  - Collecting area is no guarantee of success
  - Precursors can declare victory when they reach thermal noise, SKA will need to keep going
- Here I highlight some of the less well-publicised EoR challenges, primarily as illustrated by the MWA

The Usual Suspects

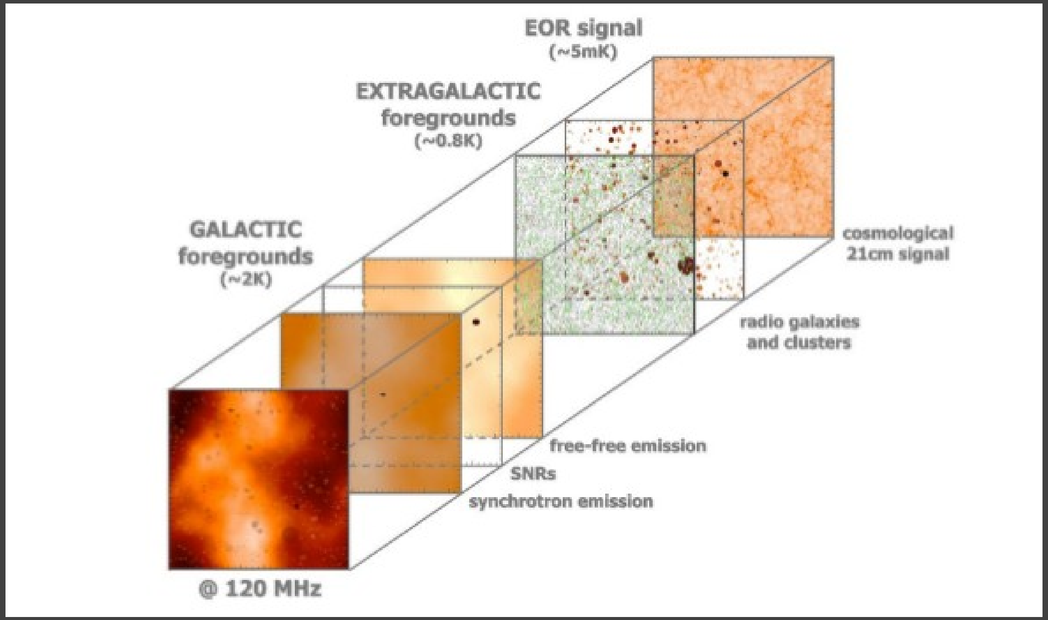
- Ionosphere
- RFI
- Astrophysical Foregrounds
- Instrumental Effects
- Once the Data Arrives

RFI for the MWA



(Offringa 2015)

Astrophysical Foregrounds:



(V. Jelic)

- Most of the universe is between us and the EoR
- Foregrounds are 4-5 orders of magnitude brighter than EoR (2-3 orders in fluctuations)
  - GDSE, Radio Galaxies, FF Emission, etc.

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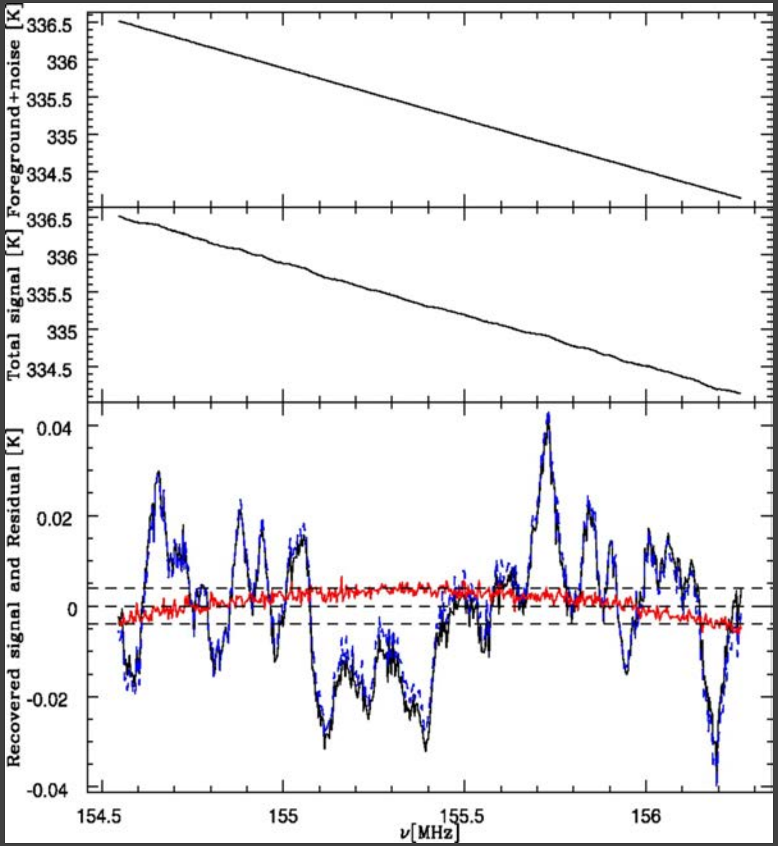

(Wang 2006)

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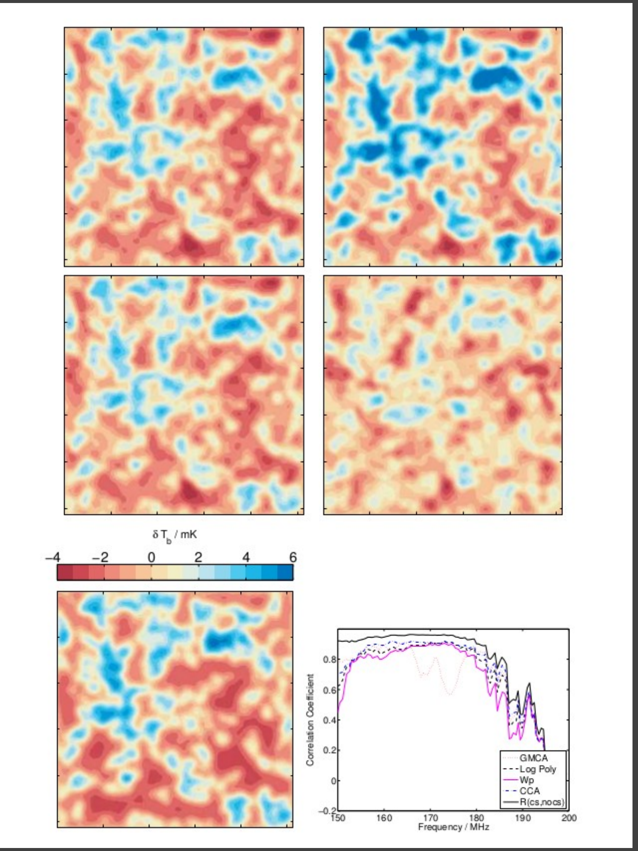

(Chapman 2015)

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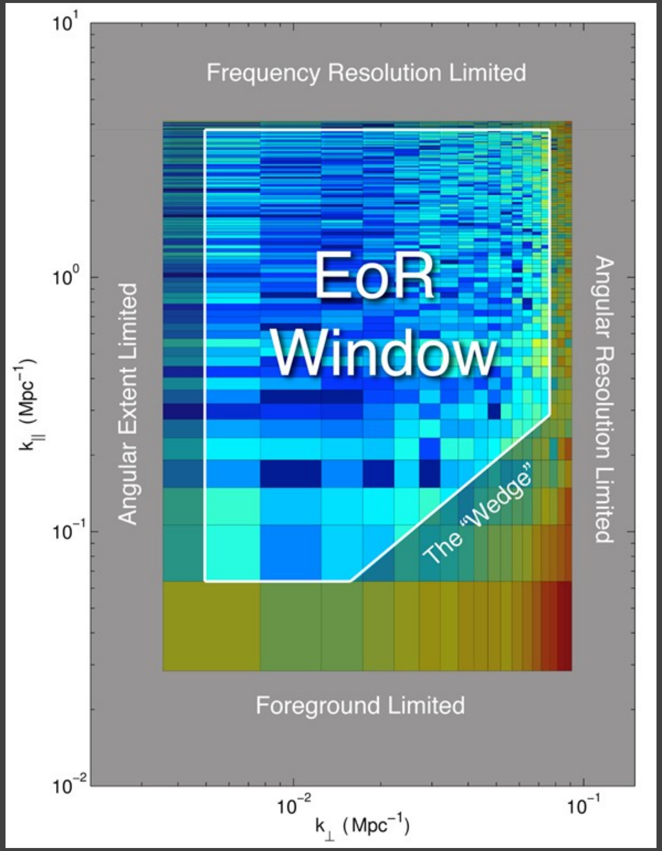

(Dillon 2013)

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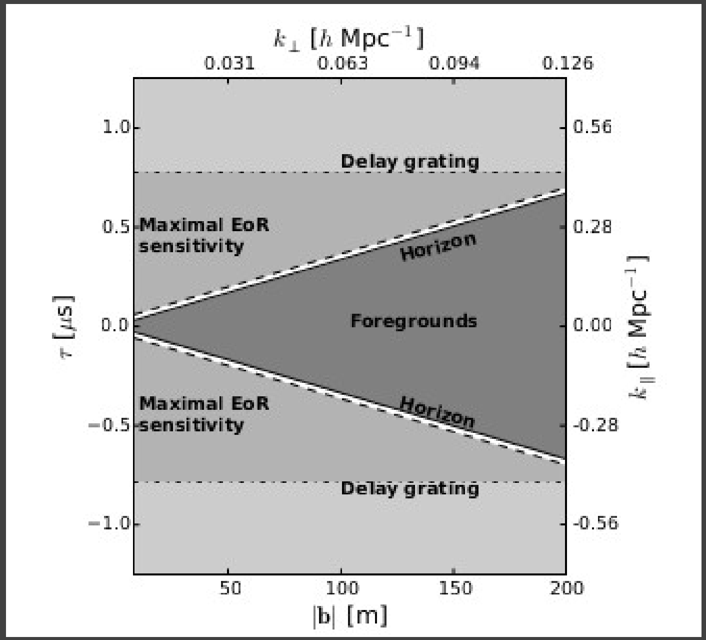
- Chromatic PSF introduces spectral contamination within the wedge

Widefield Effects



(Thyagarajan 2015)

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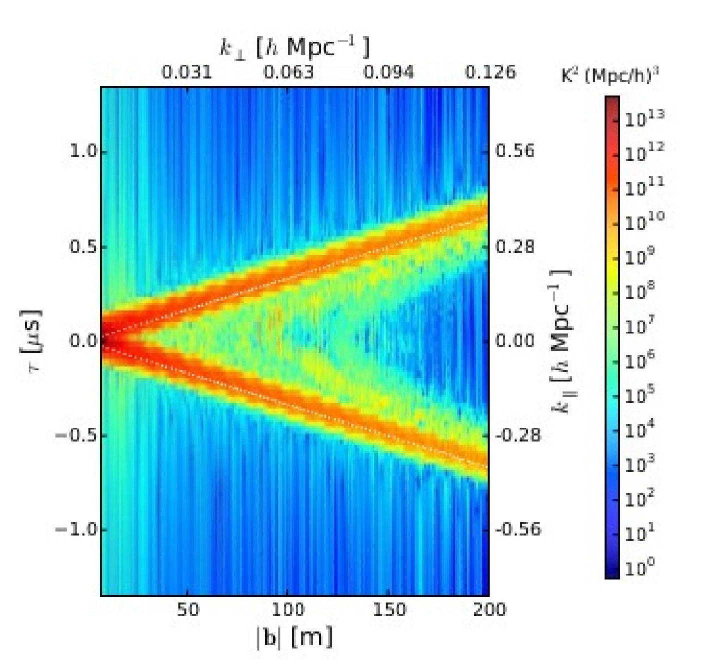

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- An interferometer sensitive to the entire sky sees power even from a uniform sky

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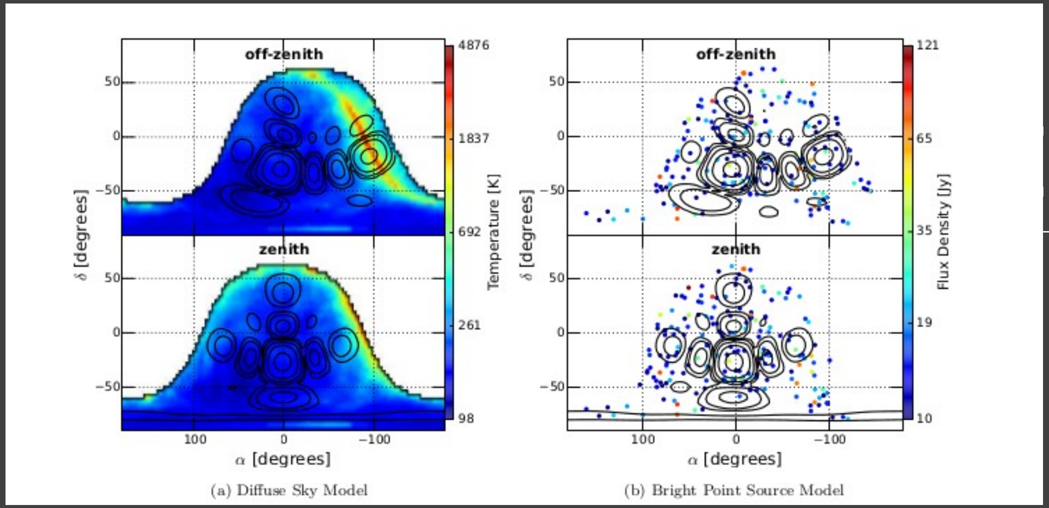

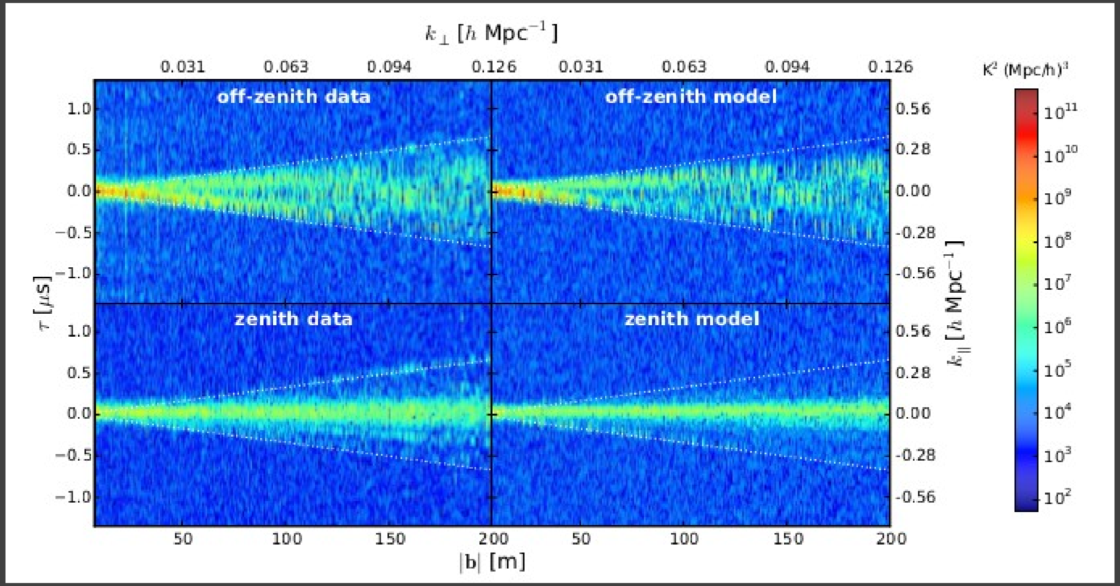

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- An interferometer sensitive to the entire sky sees power even from a uniform sky
- Realistic model which combines bright point sources and diffuse emission shows complex FG shapes in this space
  - Primary FOV only one factor

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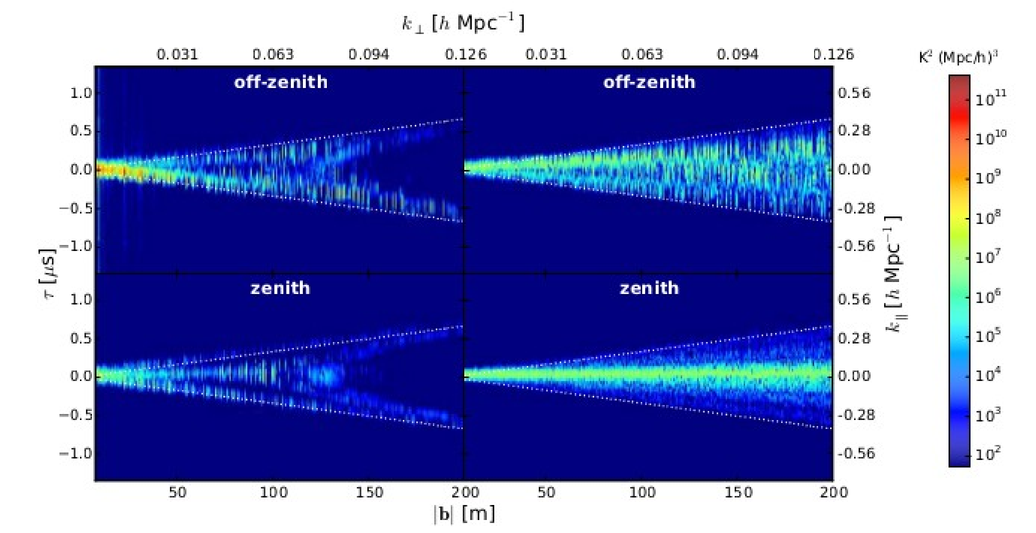

DIFFUSE COMPACT

(Thyagarajan 2015)

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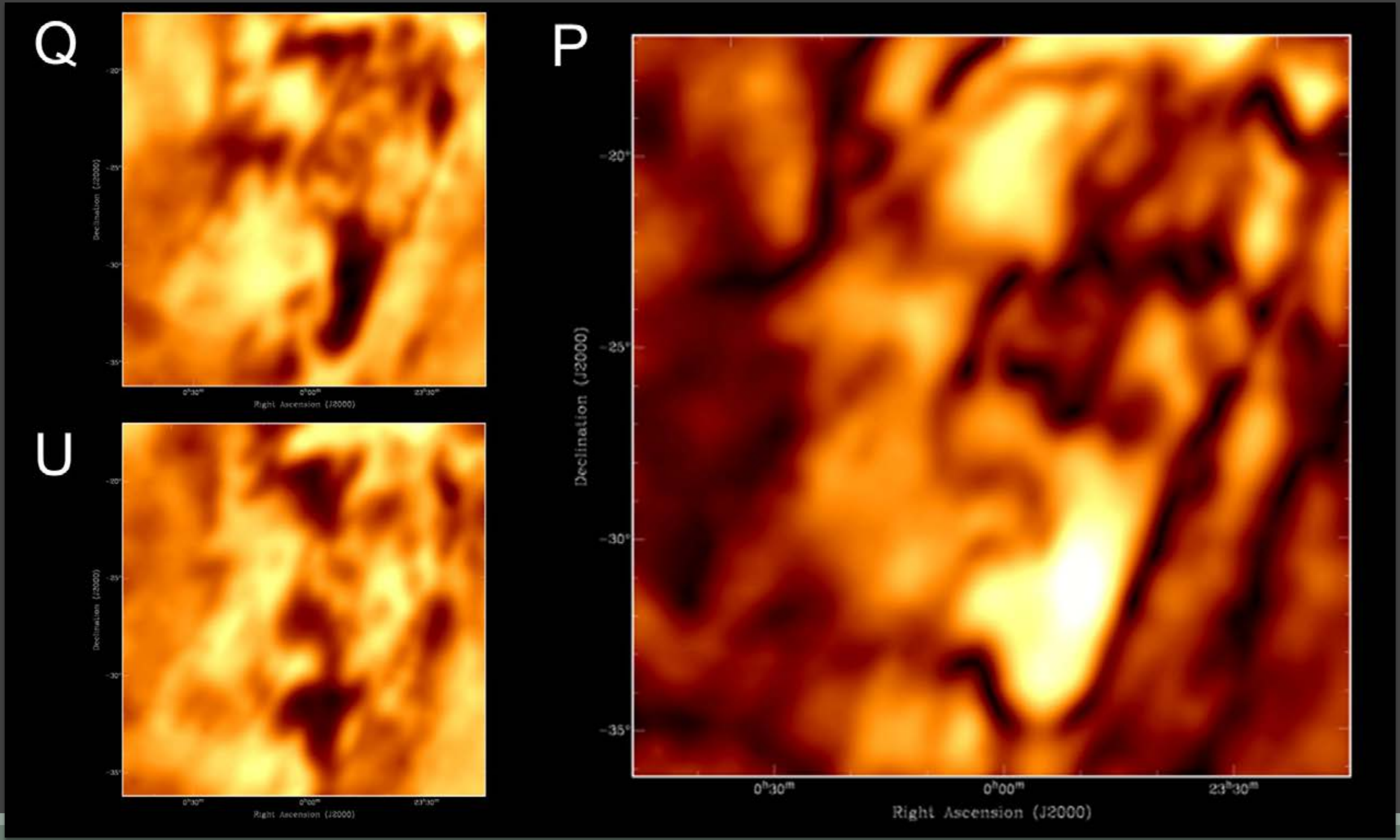
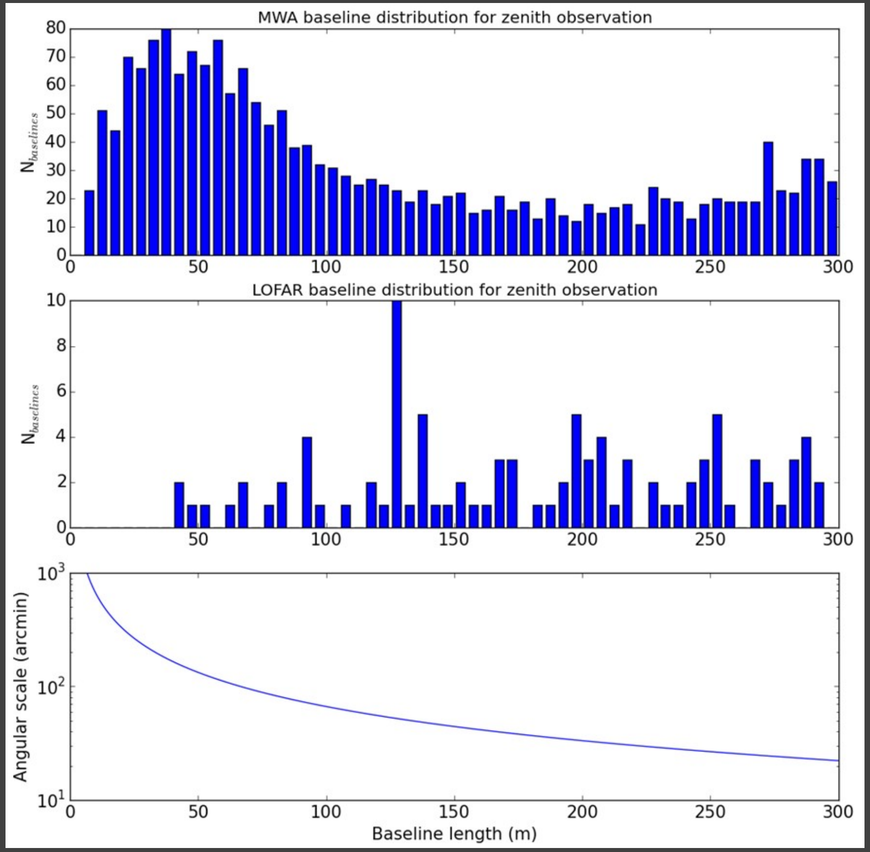
- Realistic model which combines bright point sources and diffuse emission shows complex FG shapes in this space
  - Primary FOV only one factor
- Long baselines are still effected by diffuse emission due to foreshortening (‘Pitchfork’)

Diffuse Polarization



- Diffuse Polarization in the SGP, as imaged by Emil Lenc
  - Not seen by LOFAR
- Leakage will transfer power from polarized FG to Stokes I
- Some theoretical work (eg Geil 2011) for dealing with this but never tried in anger
  - Knowledge of polarized FG required

LOFAR vs MWA Polarization



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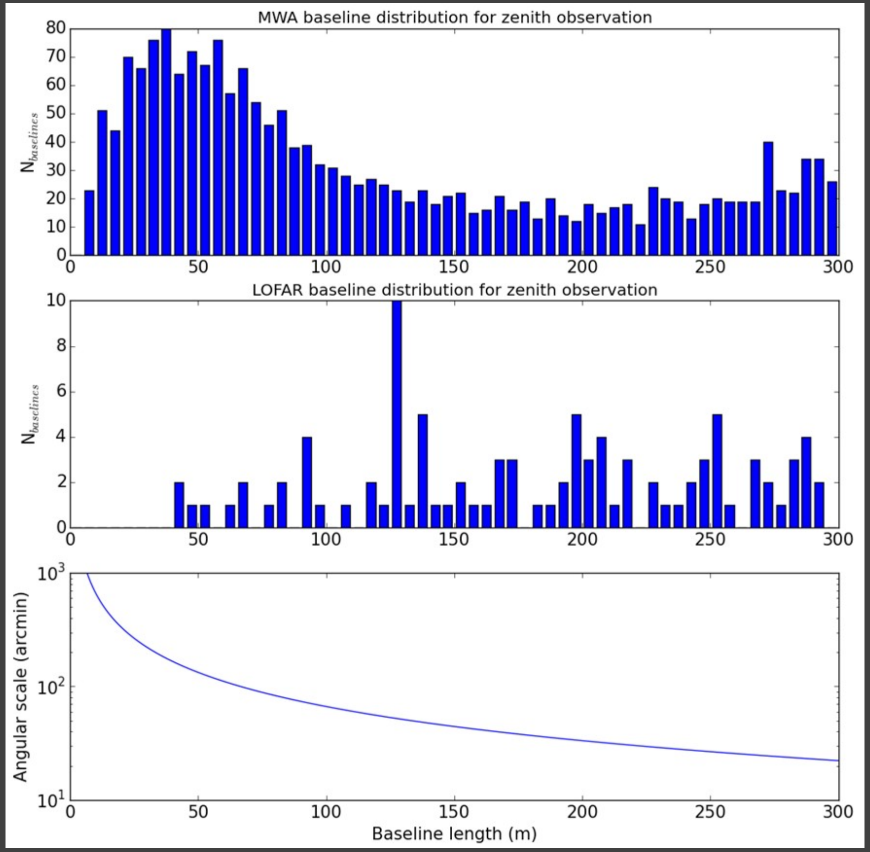

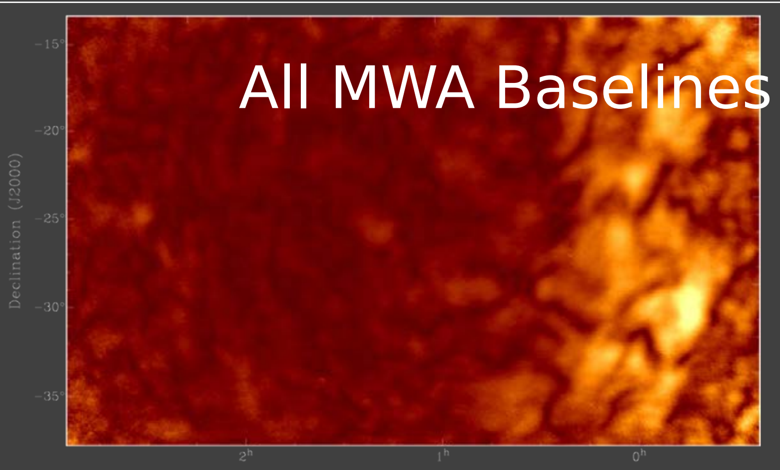

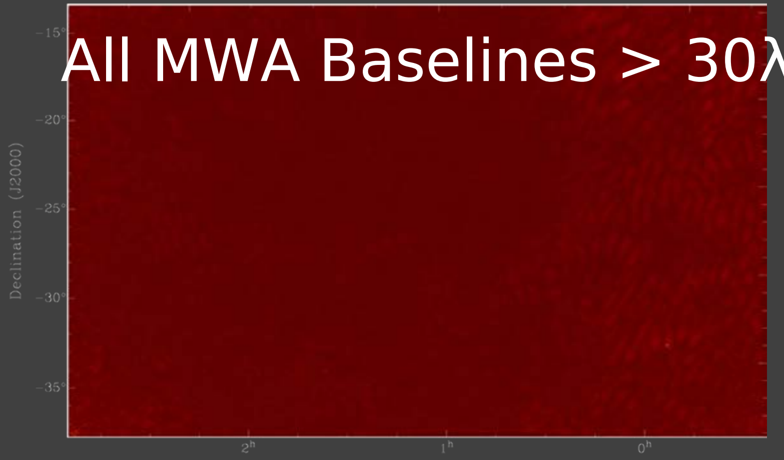

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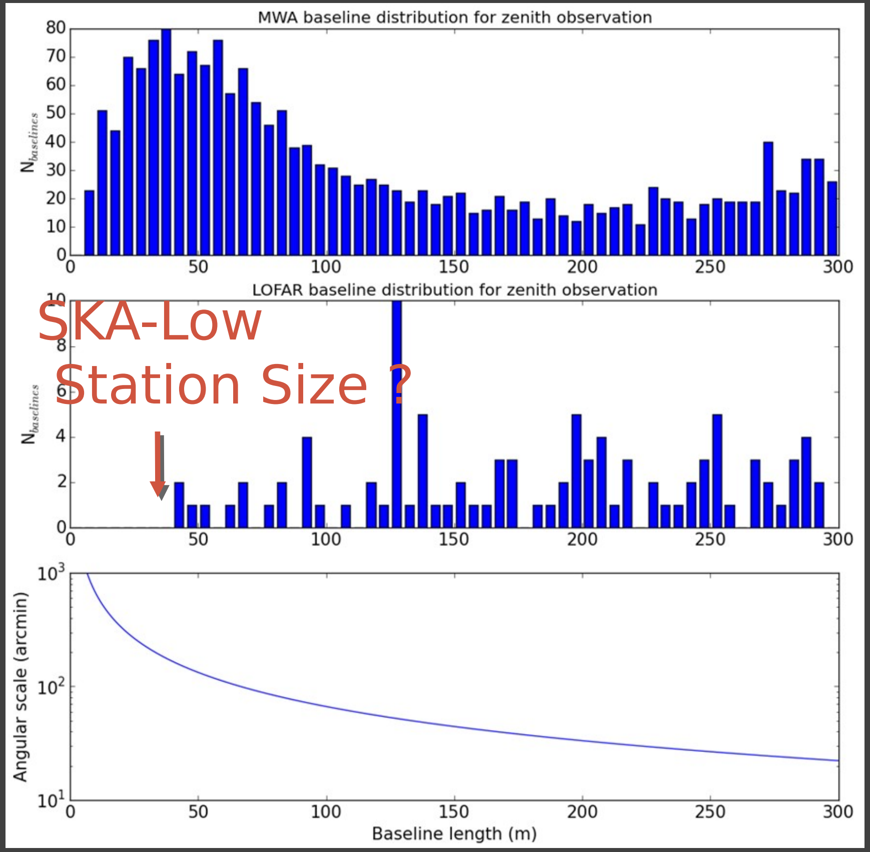
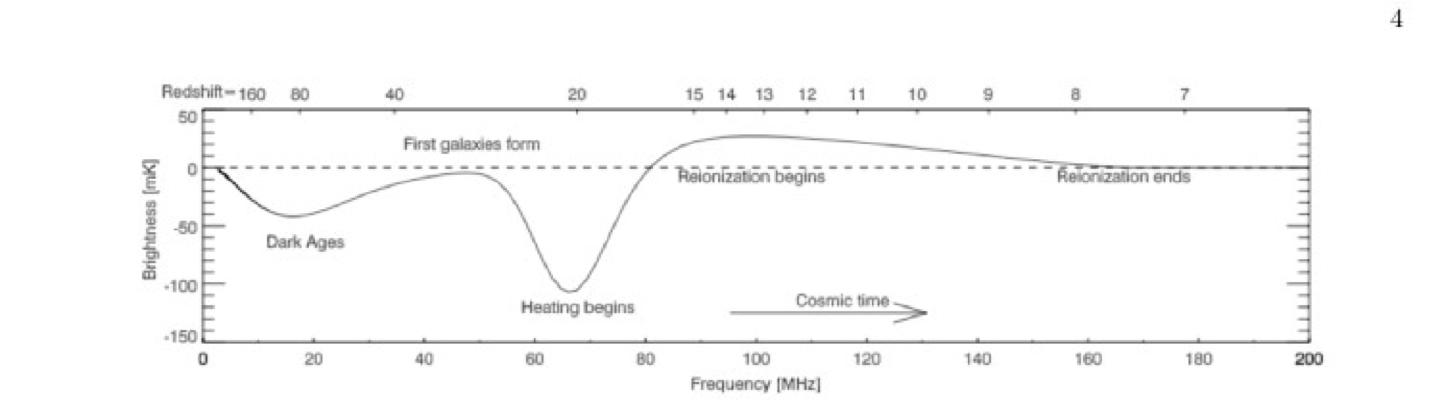


- Will the SKA be able to image polarized FG which are the source of EoR FG?
- Does foreshortening have the same effect on polarized FGs?

Cosmic Dawn



Pritchard 2012

Cosmic Dawn - Foregrounds

Non EoR Science

EoR

Cosmic Dawn

Measuring the Beam

- Knowledge of the primary beam limits the effectiveness of all processing steps
  - Calibration
  - Source Subtraction
  - FG cleaning
  - Extended Sources
- How to measure the beam?
  - EM Simulations
  - Map sources in the sky
  - Drones?
  - Use ‘handy’ calibrators

Measuring the Beam: Orbcomm

Neben 2015

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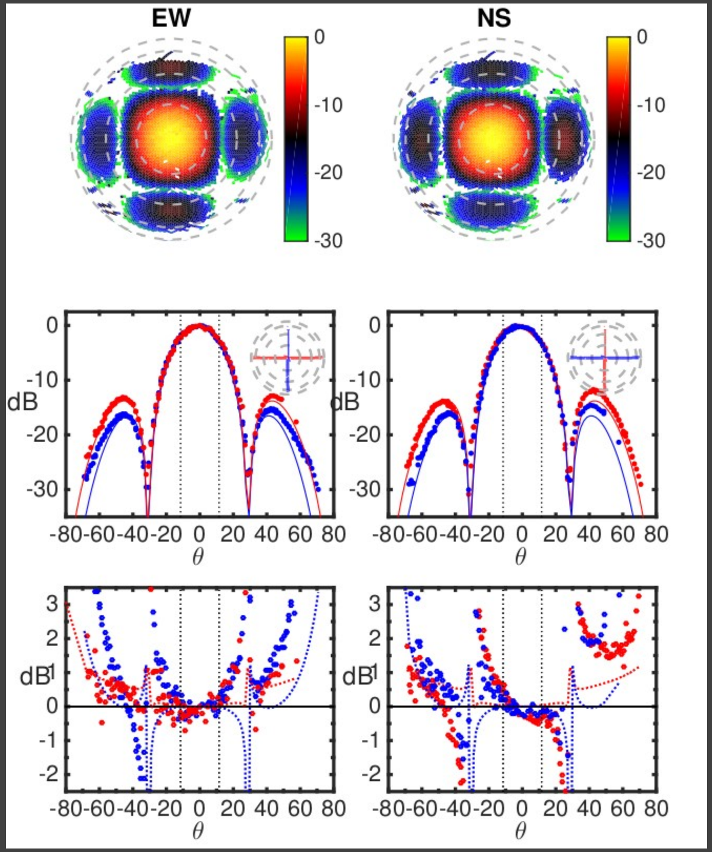

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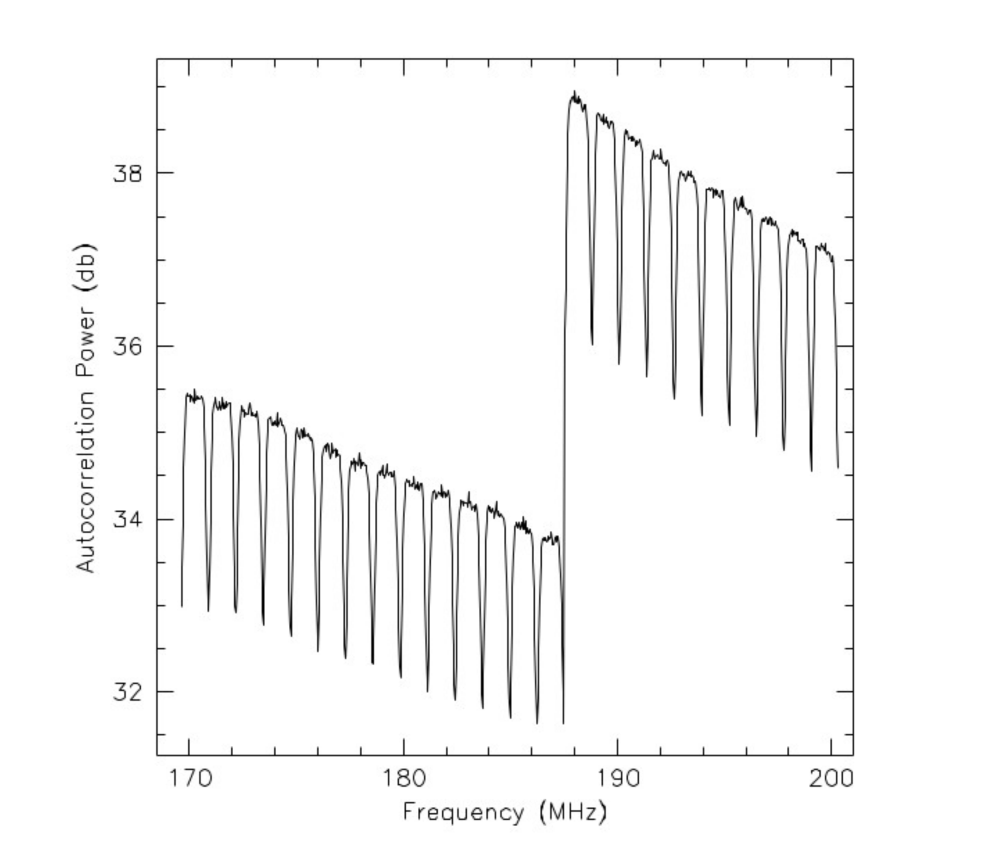
- Beam must also be mapped vs frequency

Instrumental Effects



Levine 2012

- Any elements of the signal chain which imprint spectral features will complicate EoR analysis
- MWA PFB architecture imprints 1.28MHz coarse channels on MWA bandpass

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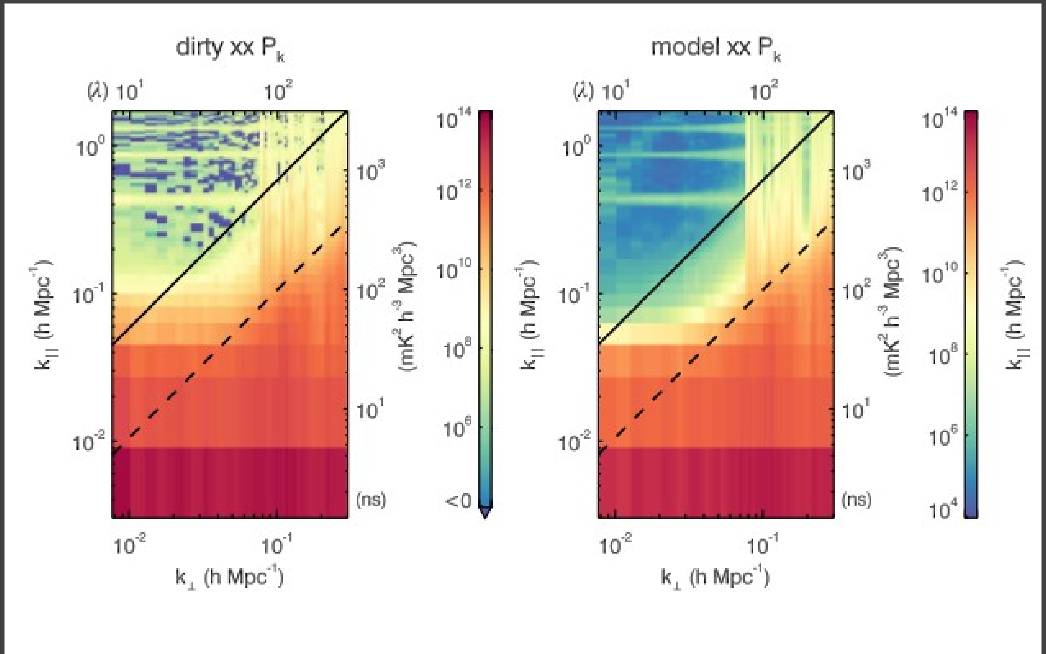

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Beardsley

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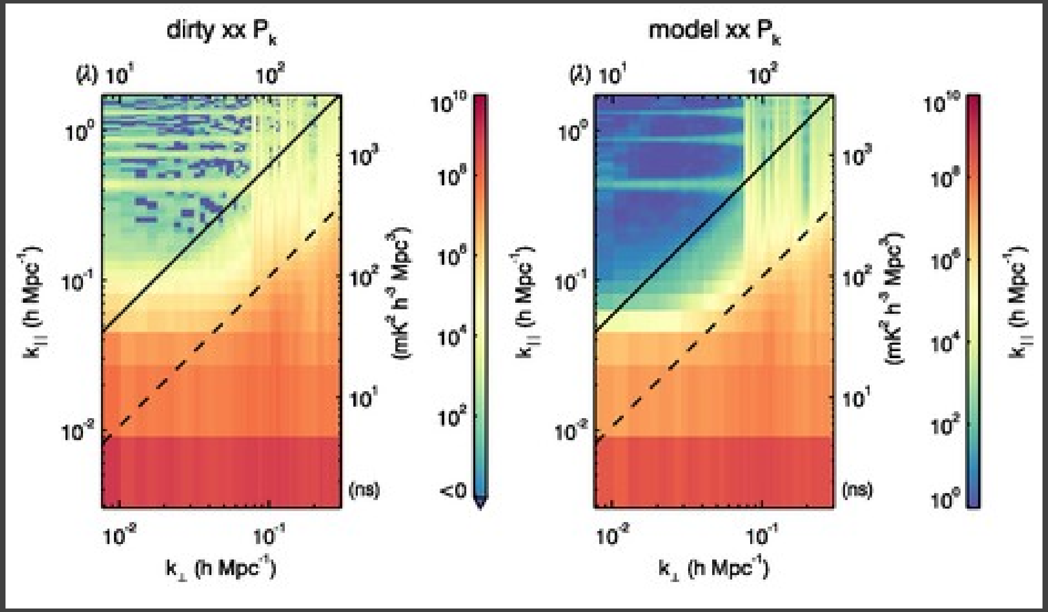

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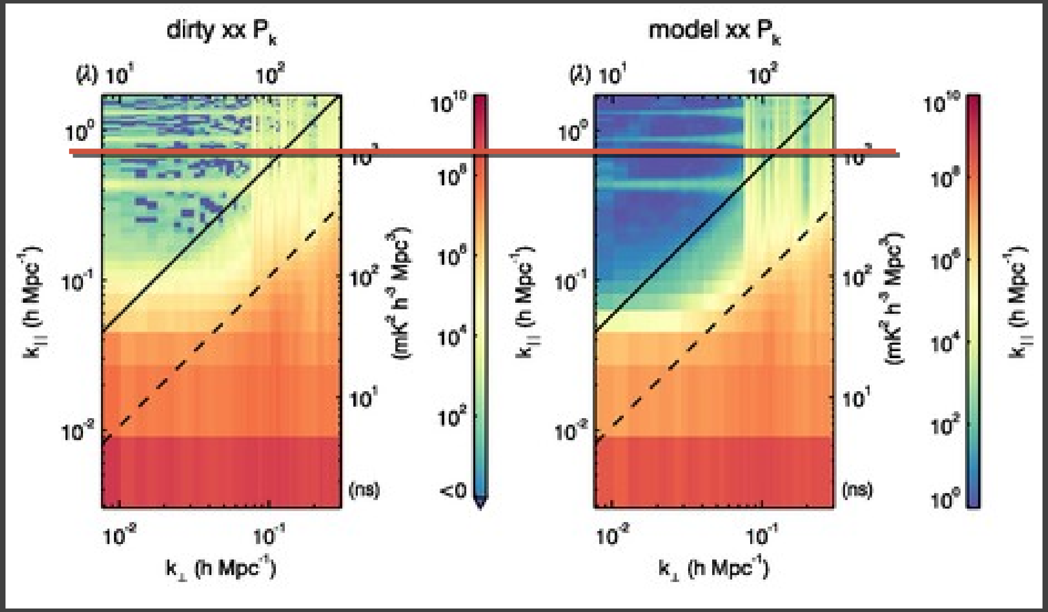

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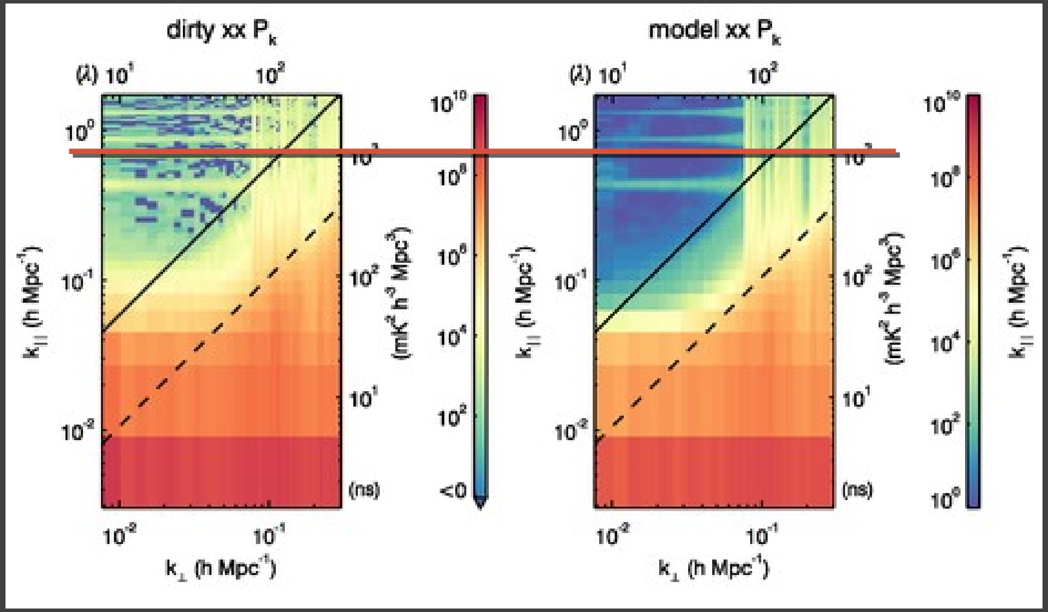

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Once the Data Arrives

- Well-understood that SKA is a huge HPC challenge
- For MWA, majority of EoR software did not exist when 128T installed
- How will EoR science be fed back into SKA computing?
  - Calibration models and choices
  - Access to visibilities
  - Choices on averaging
- We will almost certainly want to make changes once we have data in hand
  - Reconfiguring the instrument will be nearly impossible
  - What about software?
    - Flexibility
    - Resources

Conclusions

- SKA1-LOW will enable a huge new range of EoR science
  - With great sensitivity comes great responsibility
- MWA and other 1st Gen EoR experiments are continually learning about this space
  - Ability to incorporate these lessons will give SKA EoR science a massive head start
- Designing and building the SKA is only the first step
  - Unlocking full potential will only be possible once the data have arrived