Precision Power Spectra with Real Instruments:
Mode-Mixing and Polarization

Bryna Hazelton
University of Washington
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Outline

- Multi-Baseline Mode-Mixing
- Polarization Effects
- Real Data!
Multi-Baseline Mode-Mixing

- Affects any analysis that coherently sums partially-coherent baselines for increased sensitivity
  - imaging, non-redundant arrays
- Baselines move in the $uv$ plane with frequency
  - The set of baselines that contribute to a $uv$ point changes with frequency
- This leads to frequency ripple from smooth foregrounds (mode-mixing)

Baseline Integration Area (Beam)

150 MHz

\( u, v (\lambda) \)

\( \theta_x, \theta_y \) (degrees)

Mode-mixed frequency ripple from a single flat-spectrum point source.


~5,000 flat-spectrum point sources between 0.1 - 1 Jy 
(dN/dS from 6C survey @ 151 MHz)
Polarization

- Going from instrumental polarization to Stokes I requires a primary beam correction
  - Divide each instrumental pol. by primary beam in image space and sum
  - Dividing in image space = convolving in uv plane
  - Throws power from baseline integration areas to areas not measured by that baseline
Effect of Primary Beam Correction

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**Initial**

- $k_x$ (h Mpc$^{-1}$)
- $v$ (Å)
- Phase (degrees)

**Gridded**

- $k_x$ (h Mpc$^{-1}$)
- $v$ (Å)
- Phase (degrees)

**Beam corrected (before 0 weight areas removed)**

- $k_x$ (h Mpc$^{-1}$)
- $v$ (Å)
- Phase (degrees)

**Beam corrected**

- $k_x$ (h Mpc$^{-1}$)
- $v$ (Å)
- Phase (degrees)
Effect of Primary Beam Correction
Effect of Primary Beam Correction

Gridded

Beam corrected
Polarization

- Primary beam correction causes mode-mixing
  - Power spectra need to be constructed in instrumental polarization and apparent brightness units
  - Comparisons with theory will have to take place in the same frame.
- Nothing new to the CMB community!
Real MWA Data

- ~ 30 minutes of data
- EOR 1 field (4h, -30°), Zenith pointed
- Sept 26, 2011 (X16)
- 165-195 MHz
- 29 tiles
- Calibrated in CASA, deconvolved with FHD
Real MWA Data

Cross-power between two interleaved cubes.

Raw

Deconvolved

Expected Noise
Multi-Baseline Mode-Mixing

Visibility measurement:

\[ m([v, f]) = B([v, f], [u, f])F([u, f], [\theta, f])I([\theta, f]) + n([v, f]) \]

Reconstructed Power at \( u_i \) (weighted average of contributing visibilities):

\[ \tilde{I}([u_i, f]) = \frac{\tilde{B}^T([u_i, f], [v, f])m([v, f])}{\tilde{B}^T([u_i, f], [v, f])n([v, f])} \]

Re-writing the numerator:

\[ \tilde{B}^T([u_i, f], [v, f])B([v, f], [u, f])F([u, f], [\theta, f])I([\theta, f]) \]

Hazelton, Morales & Sullivan (2013)
Real MWA Data

Difference power between two interleaved cubes.