

Ionospheric Calibration for the MWA

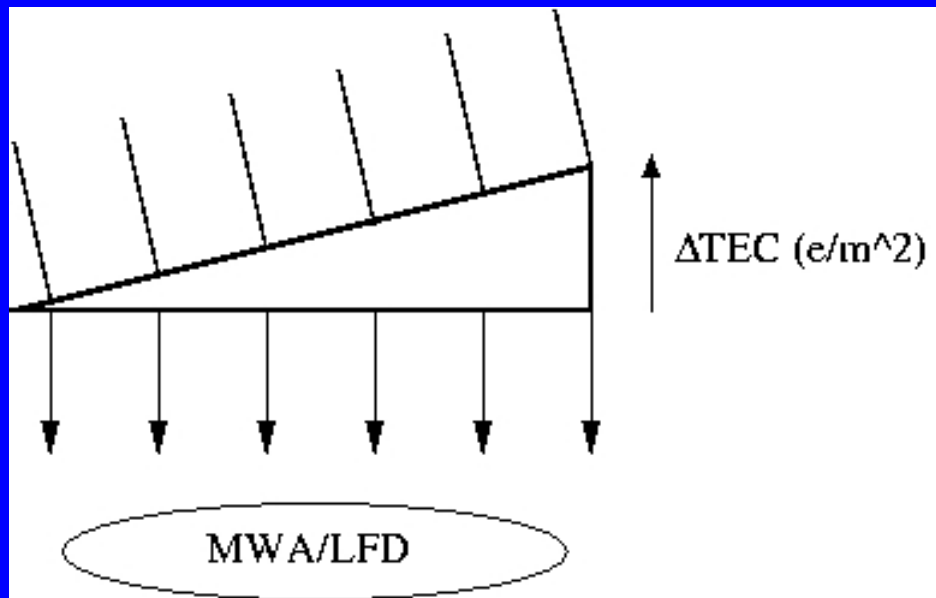
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Ionospheric Calibration for the LFD

- Over the LFD, the ionosphere has a position dependent refraction effect.
- Ionospheric calibration involves fitting the image plane distortions by using the observed offsets of known calibrators: creation of deformation map.
- Sources in a Global Sky Model can then be subtracted from the UV data and position dependent ionospheric shifts can be removed from images.
- Simulation results of this algorithm show promise.

Magnitude of Ionospheric Refraction



$$\Delta Path = -\frac{40.3}{\nu^2} \int n_e dh$$

$$bend\ angle = \frac{2.7 \times 10^{14}}{\nu^2} \left(\frac{dTEC}{dx} \right)$$

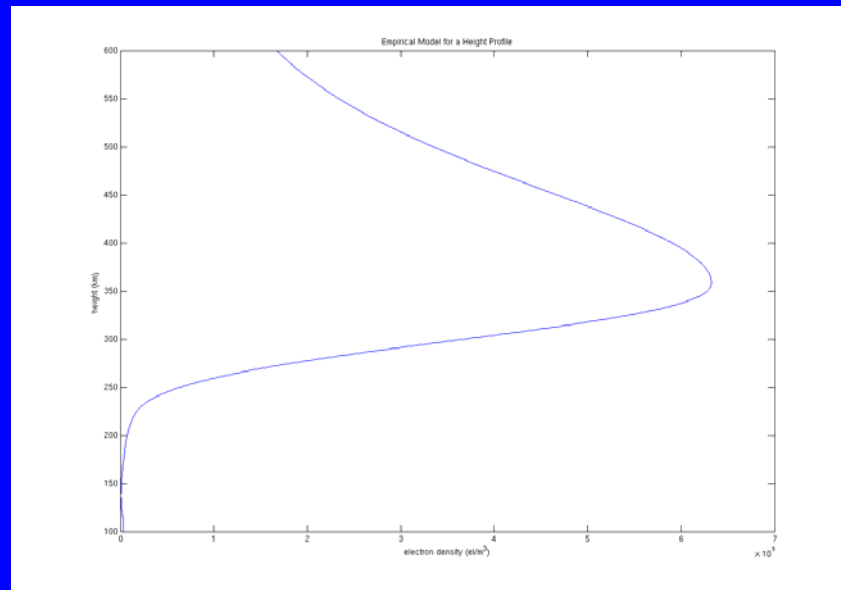
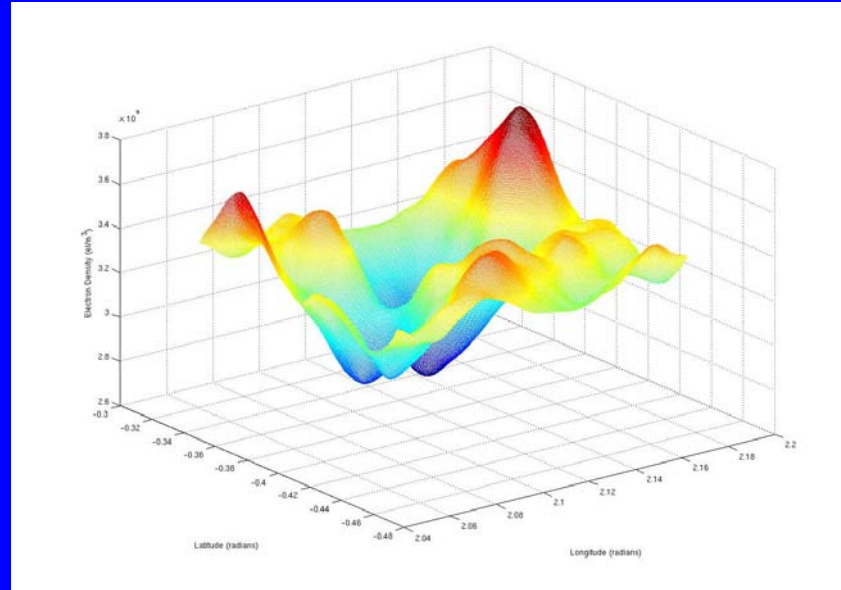
Freq (MHz)	Refraction (degrees)	Refraction (λ/D)	ΔTEC for 1 λ/D
100	1.55 ΔTEC	13.5 ΔTEC	0.074
200	0.39 ΔTEC	6.75 ΔTEC	0.15
300	0.17 ΔTEC	4.5 ΔTEC	0.22

How Many Ionospheric Calibrators?

Frequency (MHz)	FOV (Steradians)	10σ Thermal Limit (Jy) (1MHz,8sec)	$N>10\sigma$ In Field of View	Source Separation (arcmin)	Source Separation at 200km (km)
100	0.437	1.06	1202	65	3.8
125	0.28	0.6	1408	48	2.8
150	0.195	0.32	1819	36	2.1
175	0.144	0.24	1606	33	1.9
200	0.11	0.2	1437	30	1.75
225	0.087	0.2	1023	32	1.8
250	0.076	0.2	823	33	1.9
275	0.058	0.28	452	39	2.2
300	0.049	0.34	289	45	2.6

Modeling the Ionosphere

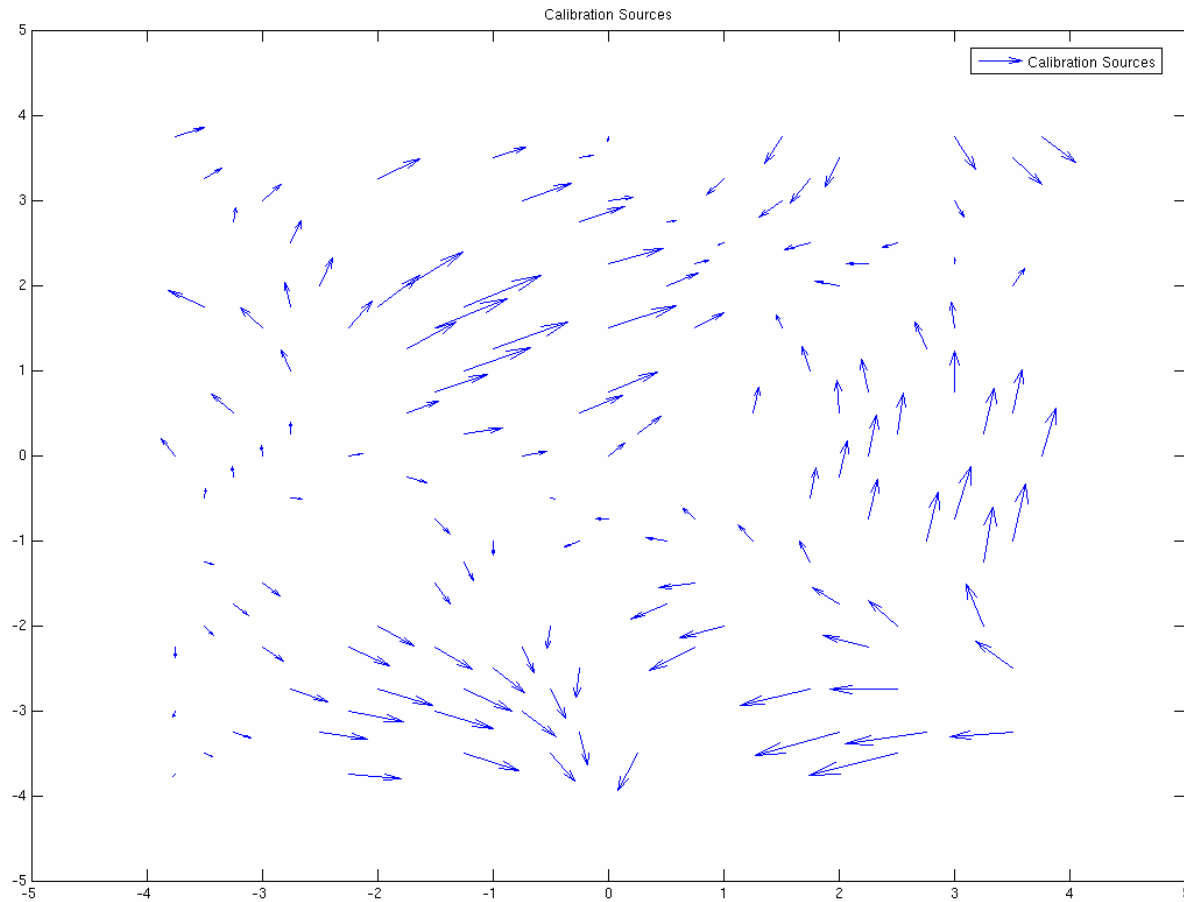
- Kolmogorov Turbulence (2km to 100km)
- Chapman density profile
- 3-D ionosphere placed above array.
- Line integrals through ionosphere above each element provide ionospheric phase across field of view



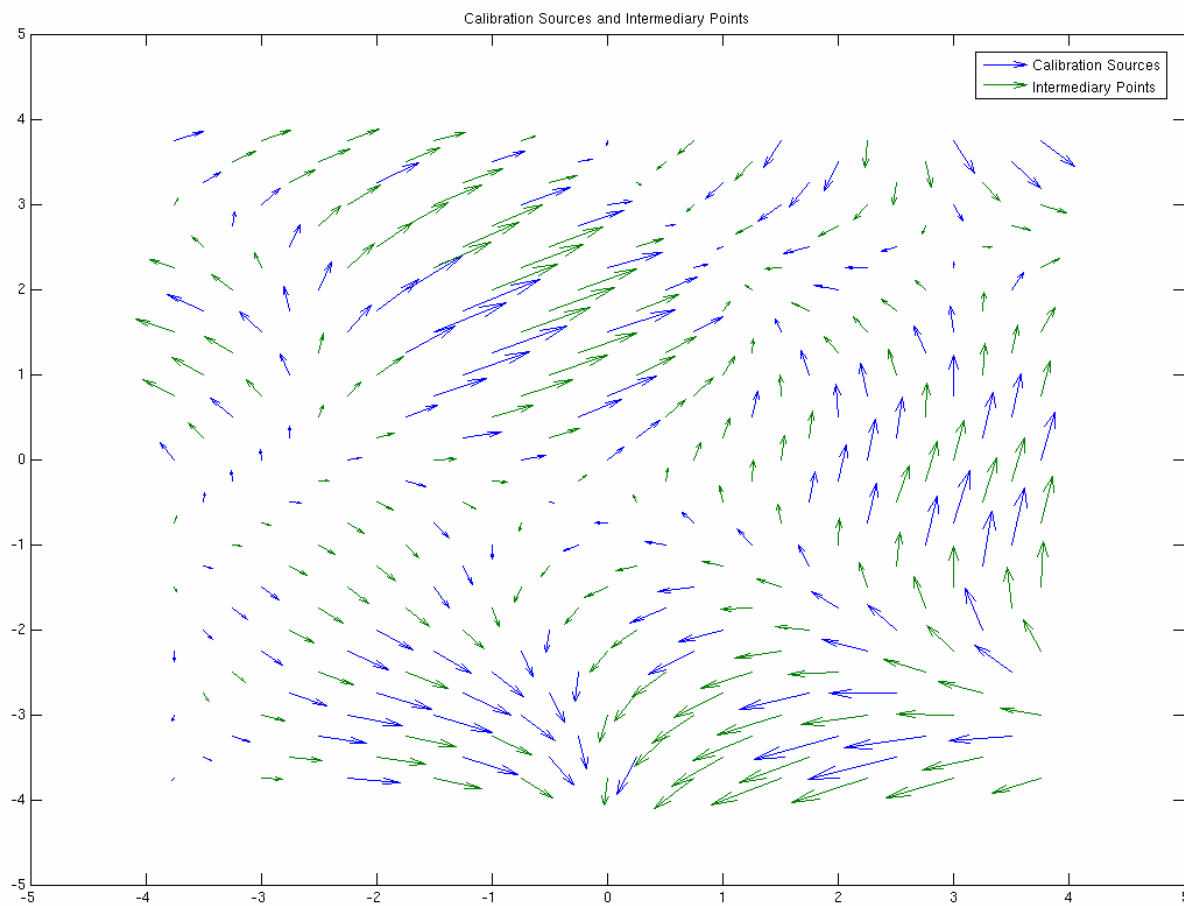
MAPS

- For each baseline, the position dependent differential phase is fourier transformed and convolved with (u,v) data.
- Convolved (u,v) data are numerically integrated to give ionospherically corrupted visibility.
- Imaging shows distorted sky.

Refractory Offsets of Calibrators



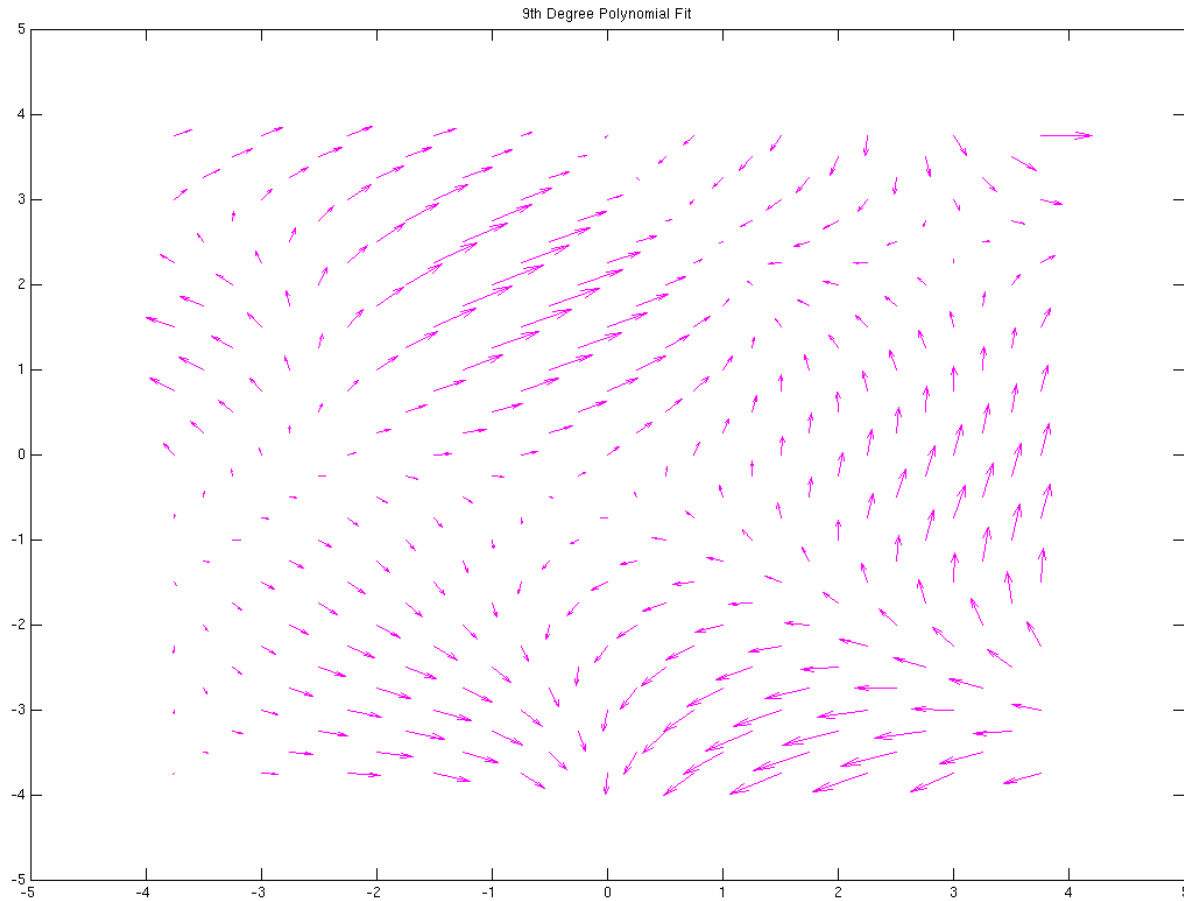
Offsets of all sources



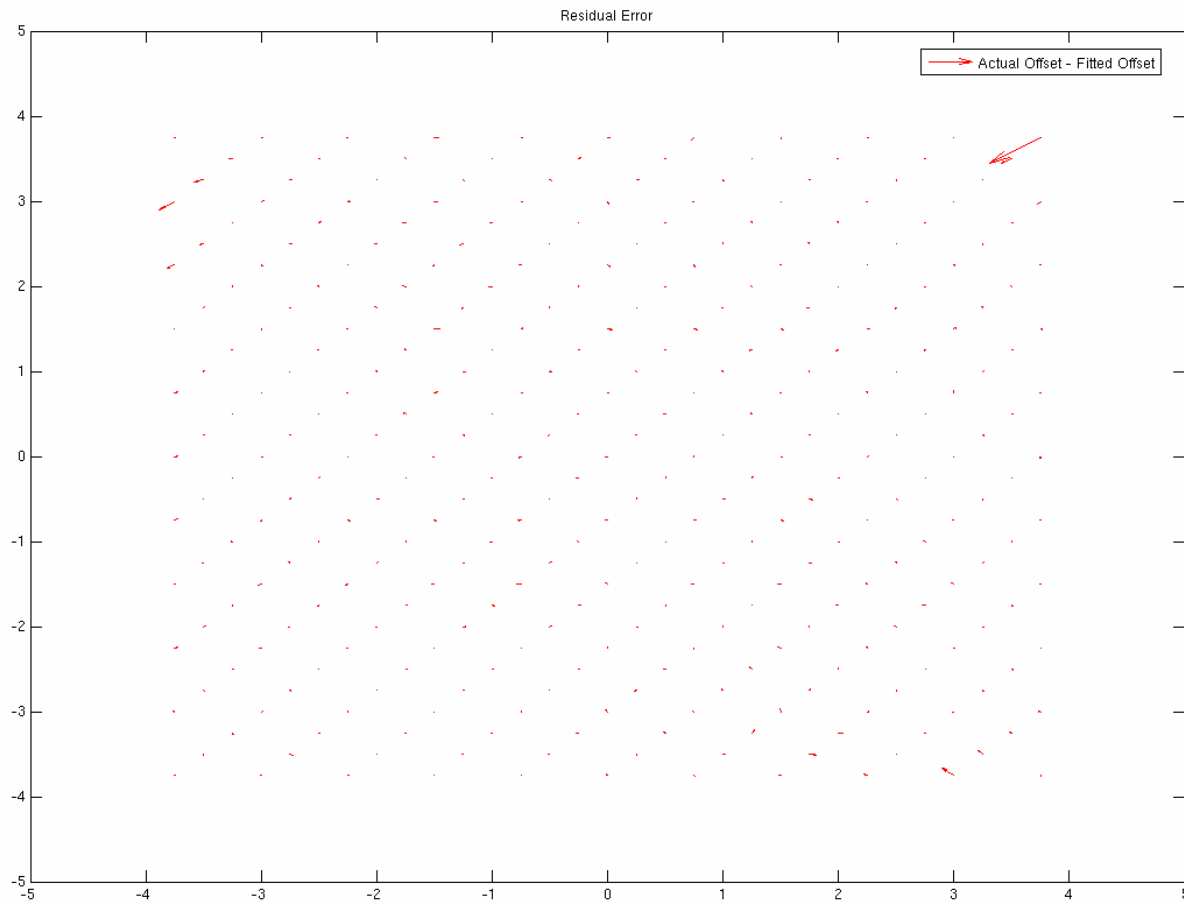
Finding best fit polynomial

- Cotton uses Zernike polynomials: 74MHz VLA has ~10 calibrators in 10deg sq field.
- MWA will have ~300 calibrators in same field.
- Exploration of algorithm to generate orthogonal polynomials over basis of calibrator positions.
- Makes estimation of most likely solution straightforward.

9th Degree Poly fit to calibrator offsets



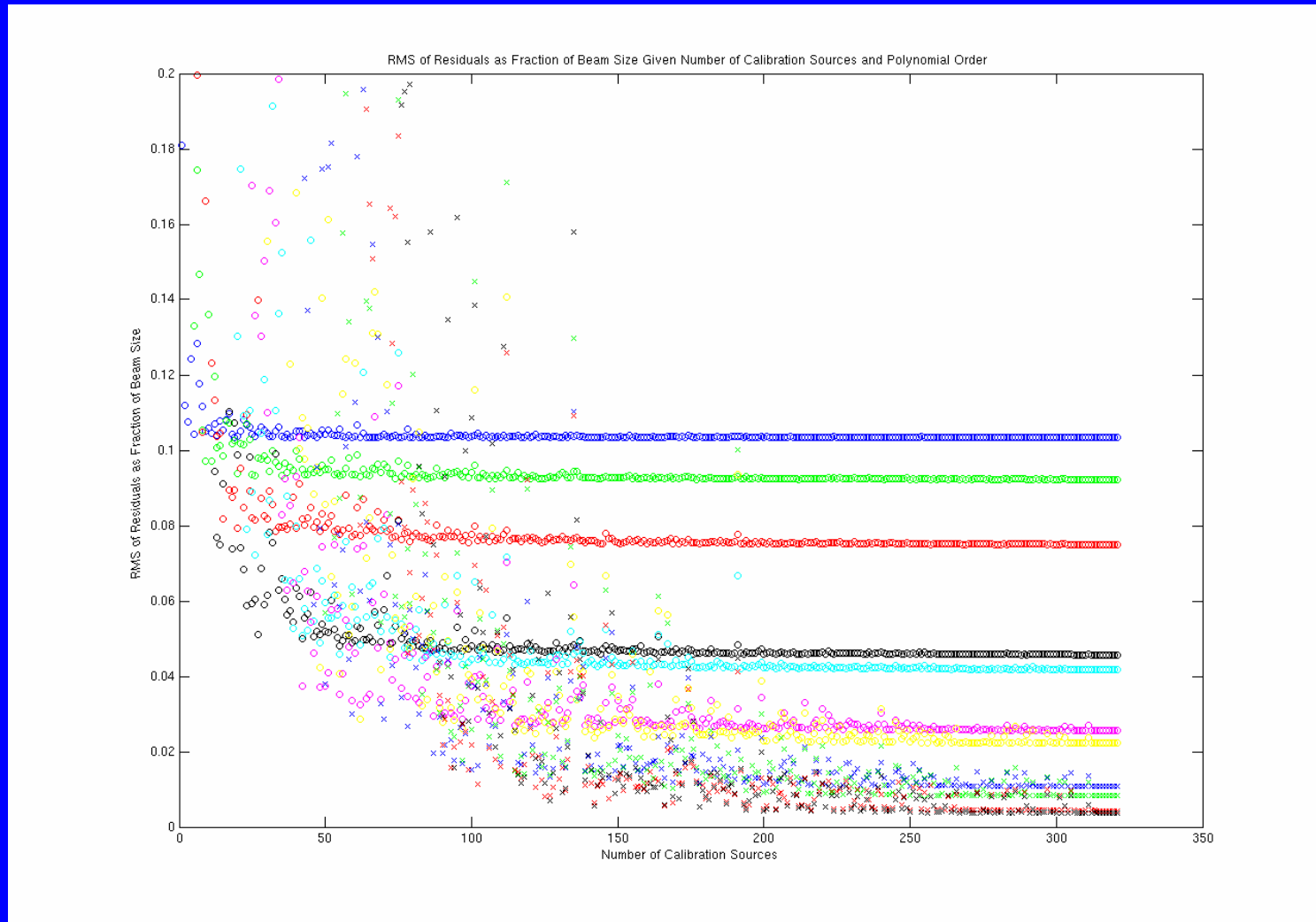
Residuals to 9th degree Offset model



Simulations

- 8x8 sq degree field
- 200MHz, MWA beam ~210 arcsec
- ~330 sources, some number of them calibrators (variable).
- Questions:
 - What degree of poly is best given a fixed number of calibrators?
 - How well can method perform?

RMS residuals vs degree poly fit



Output of Iono Calibration

- N degree polynomial 'Rubber Sheet' deformation giving RMS residuals down to ~2-3% of beam: a map of TEC gradients.
- Every 10 seconds.
- Data base with calibrator position offsets and poly fit as function of frequency.
- Algorithm development:
 - frequency to de-couple instrumental calibration.
 - more realistic tests/simulations.
- How to extract ionospheric science from this data base?

Ionospheric Science

- time evolution
 - wind speeds in ionosphere (50-2000m/s)
 - 3.2km to 16km in 8 seconds : ~frozen flow
- faraday rotation
 - calibration TEC gradient map useful guide for mapping rotation measure (depends on B field).
- irregularity size scales.
 - Turbulence and coherent structures.