

Imaging and Ionospheric Calibration

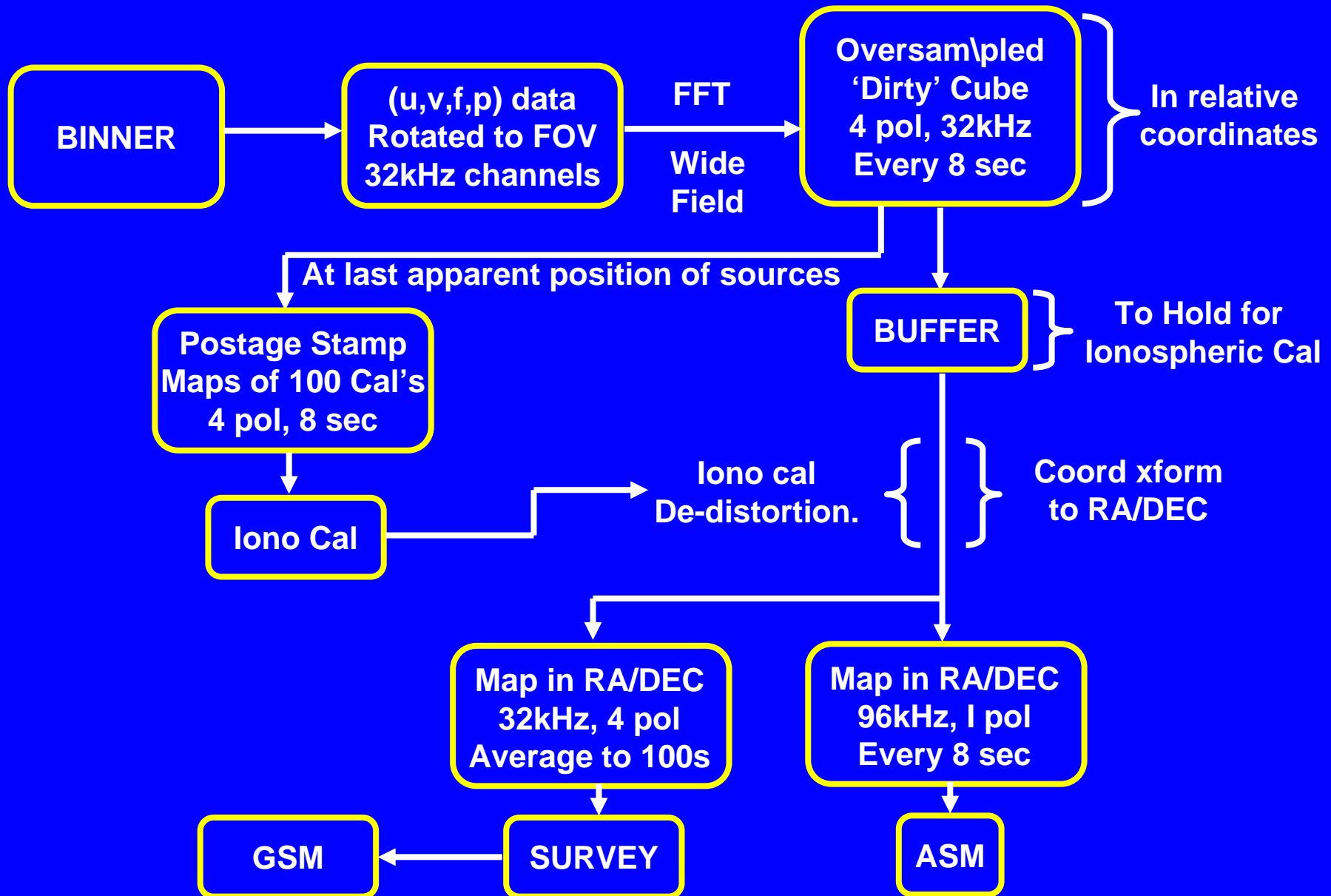
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Making Real-Time Images

- The Mapper and Iono-Cal workpackages produce calibrated images in RA/Dec: in real-time C.
- Inputs:
 - visibilities rotated to relevant sky position and binned to appropriate FOV.
 - true positions of ionospheric calibrator sources.
 - Small maps of out-of-beam ionospheric calibrators.
- Outputs:
 - Full Tile Maps: ASM, Survey/GSM
 - 2deg Solar Map: Solar Imaging
 - ~100 small maps: Ionospheric Calibration
 - 2-D Ionospheric calibration for correcting images and subtracting out-of-beam sources: parameterized func.

Imaging Data Flow



Widefield Imaging

- Breakdown of 2-D Fourier (uv, sky) xform:

$$\varphi = 2\pi w(\sqrt{1-l^2-m^2}-1) \geq 1$$

- If co-planar array then coord transform allows application of 2-D Fourier Transform again.
- If not, how many w-planes necessary:

$$\# \text{ w-planes} : 2\pi\Delta w$$

- ~ of order a few w-planes (10).
- Then 2-D FFT and a few DFT's to account for w-planes: 3-D deconvolution required for later image processing.

Widefield Imaging cont'd

- Can create widefield image by facets, each imaged and deconvolved separately and combined later.
- Use w-projection algorithm to project and grid $V(u,v,w)$ points to $V(u,v,w=0)$ and then use 2-D FT to obtain image: about an order of magnitude faster than faceting.
- Issue: where is widefield computation done
 - binner (w-projection, facets)
 - mapper (3-D solution, facets).

Subtracting the GSM

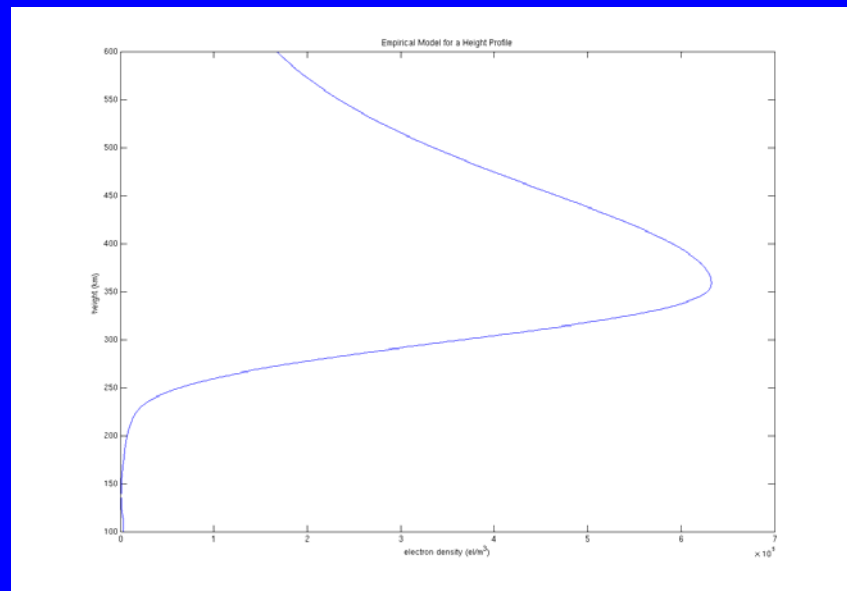
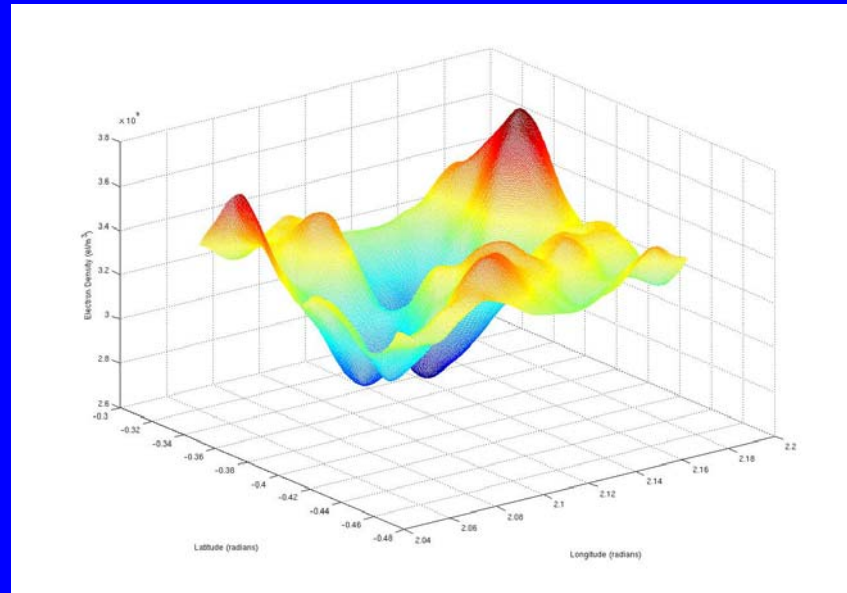
- Despite binning to tile (or solar) FOV, out-of-beam sources will contribute to image noise level via PSF sidelobes.
- Use instrumental and ionospheric cal to accurately subtract these sources:
 - From (u,v) data in binner
 - Or, from images in mapper.
- Image deconvolution via GSM subtraction within FOV.

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.
- Sources in the 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.

Modeling the Ionosphere

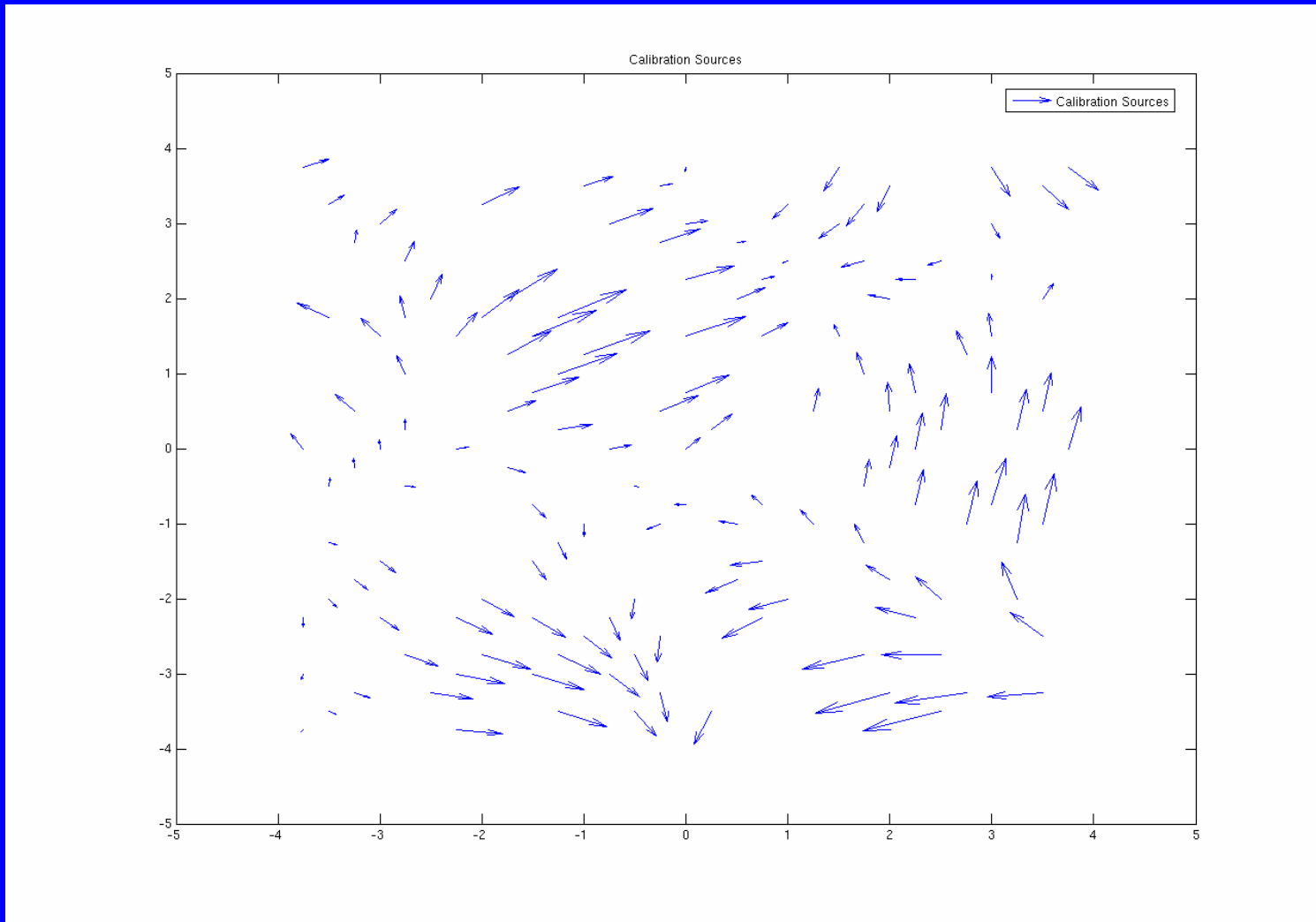
- Kolmogorov Turbulence (2km to 100km)
- Chapman density profile
- 3-D ionosphere placed above array.
- Line integrals through ionosphere above each element provide ionospheric phase across field of view



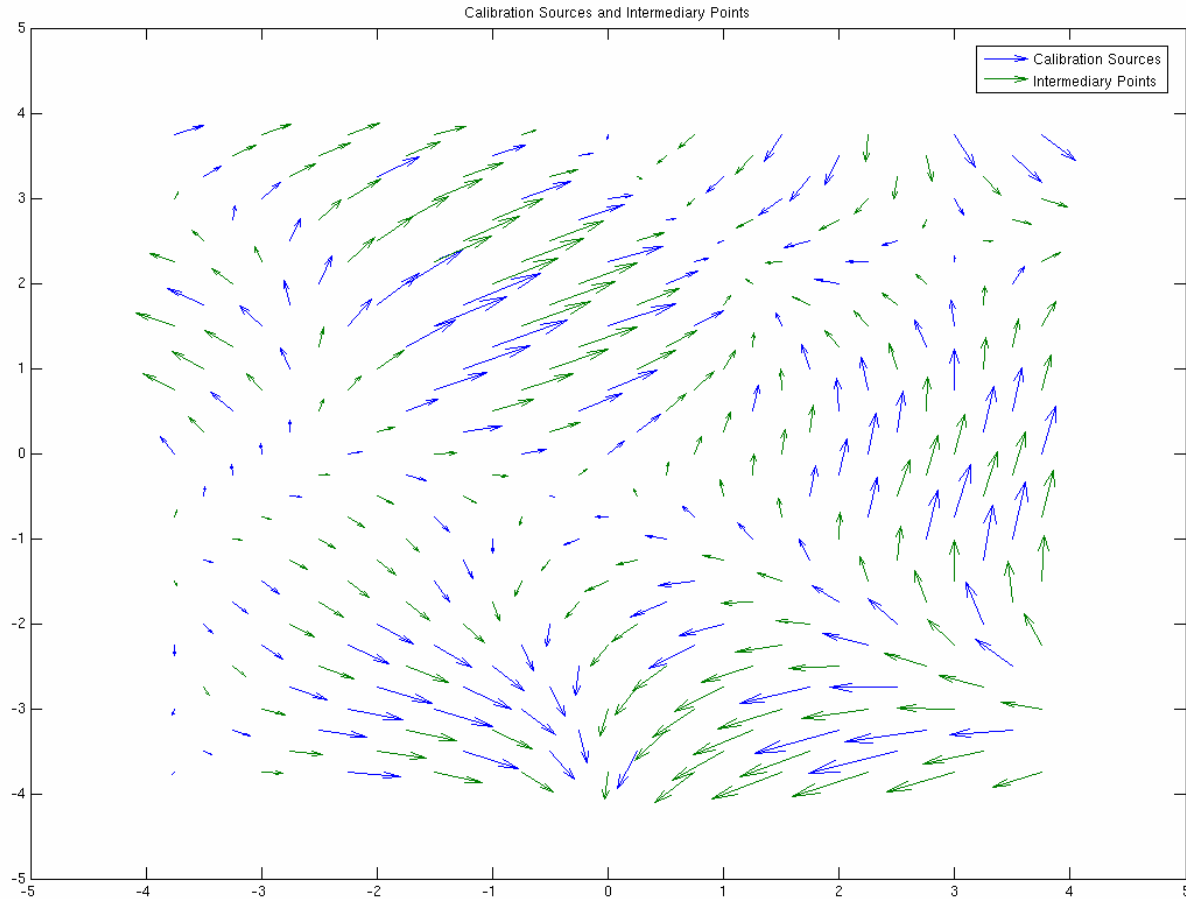
MAPS

- 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



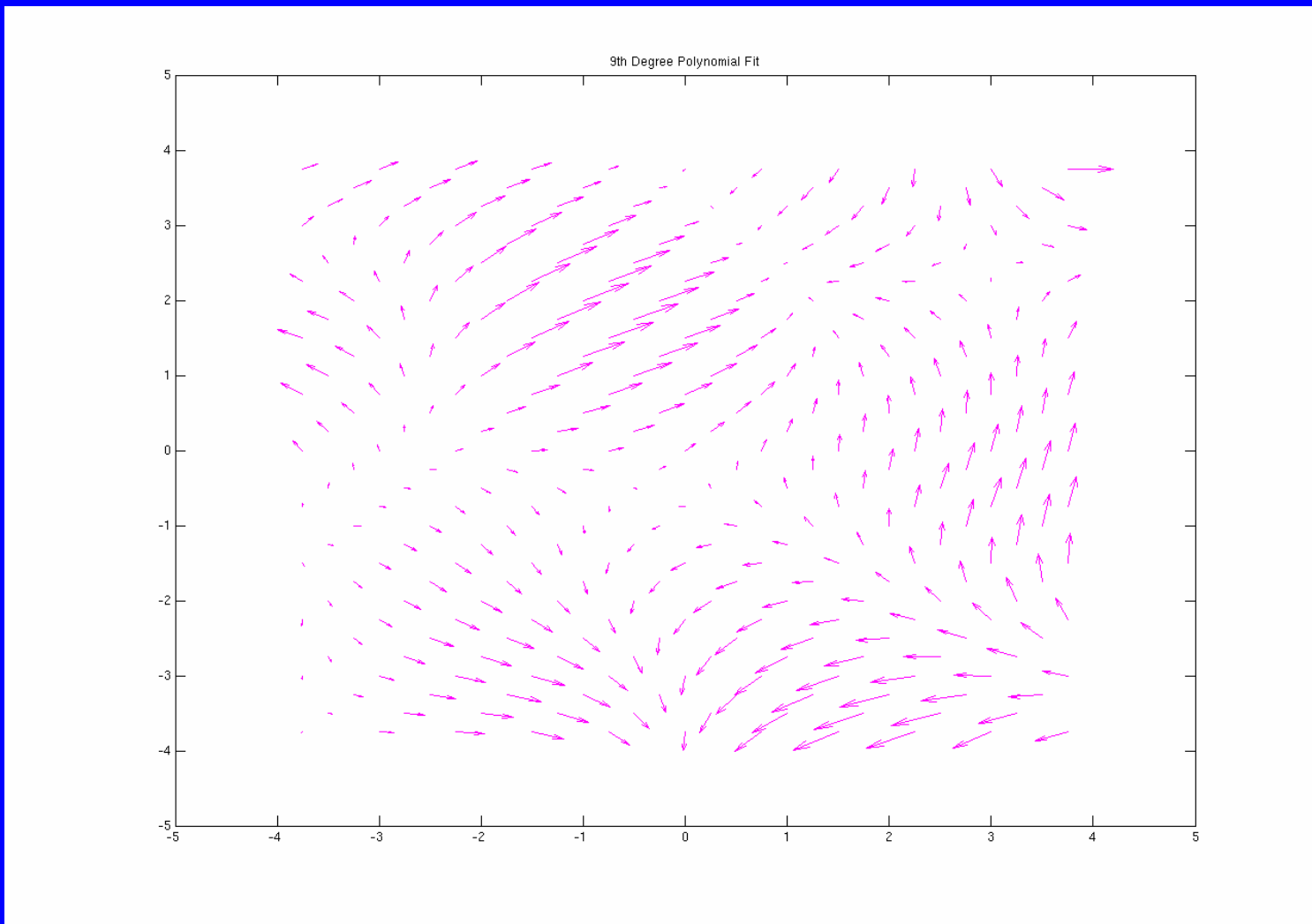
Offsets of all sources



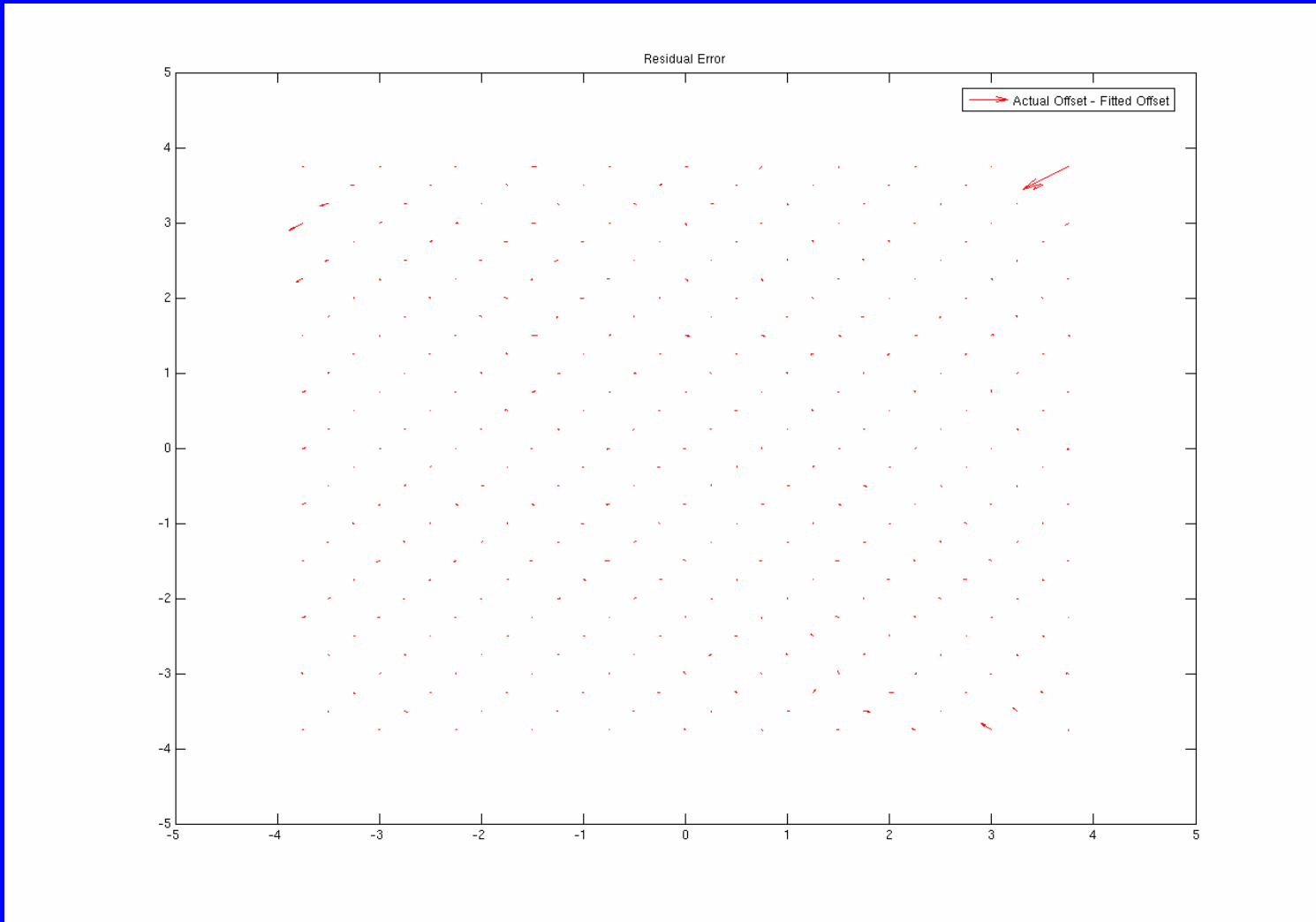
Finding best fit polynomial

- Cotton uses Zernike polynomials: 74MHz VLA has ~10 calibrators in 10deg sq field.
- MWA will have ~200 calibrators in same field.
- Sean Ting (REU) implemented algorithm to generate orthogonal polynomials over basis of calibrator positions.
- Makes estimation of most likely solution straightforward.

9th Degree Poly fit to calibrator offsets



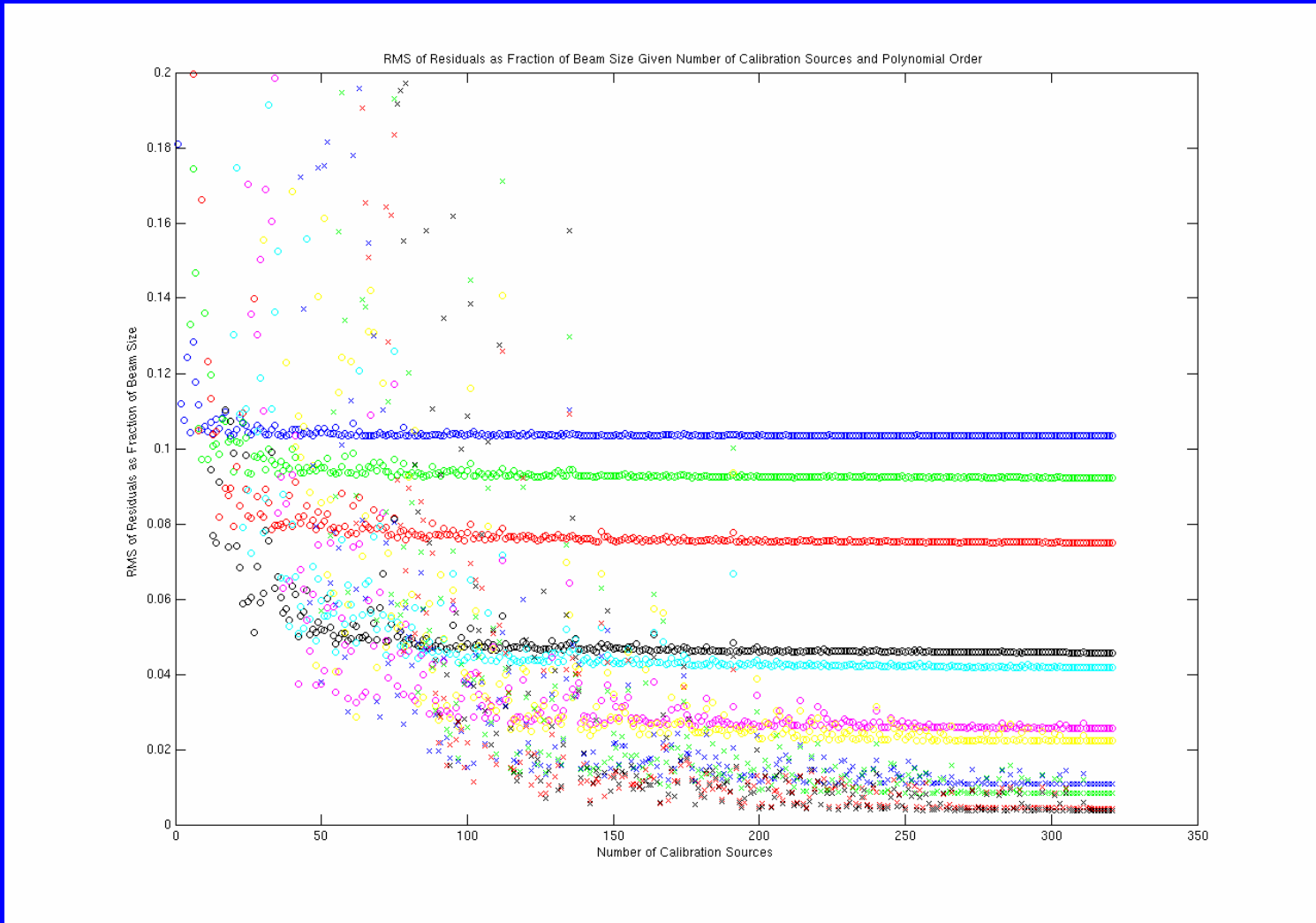
Residuals to 9th degree Offset model



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



Results

- RMS residuals with 9 degree poly gets down to $\sim 2-3\%$ of beam offset.
- Sidelobe noise (after GSM subtraction)
 $\sim (1/N_{\text{stat}}) * (\text{beam fraction offset}) * (\text{integrated flux density of sources})$
– $\sim 10 \text{ uJy}$
- Compares to thermal noise of MWA in ~ 1000 hours.
- Need to put real sky into simulations and verify sidelobe noise.

Outlook

- Outstanding Issues:
 - Widefield approach and implementation (location).
 - GSM subtraction and implementation (location).
 - Establish standard interface for image x-fer.
- No major risks, all algorithms exist, but must be tailored and tested for LFD implementation
 - will require effort.
- Advantage: Mapper and Iono-cal amenable to rigorous testing with simulated data and applicable to some existing data sets (VLA).
- Skills: Interferometric imaging, fitting software, algorithm implementation, testing.
- Reliant only on binner.