Ionospheric modeling using the Peeling Scheme

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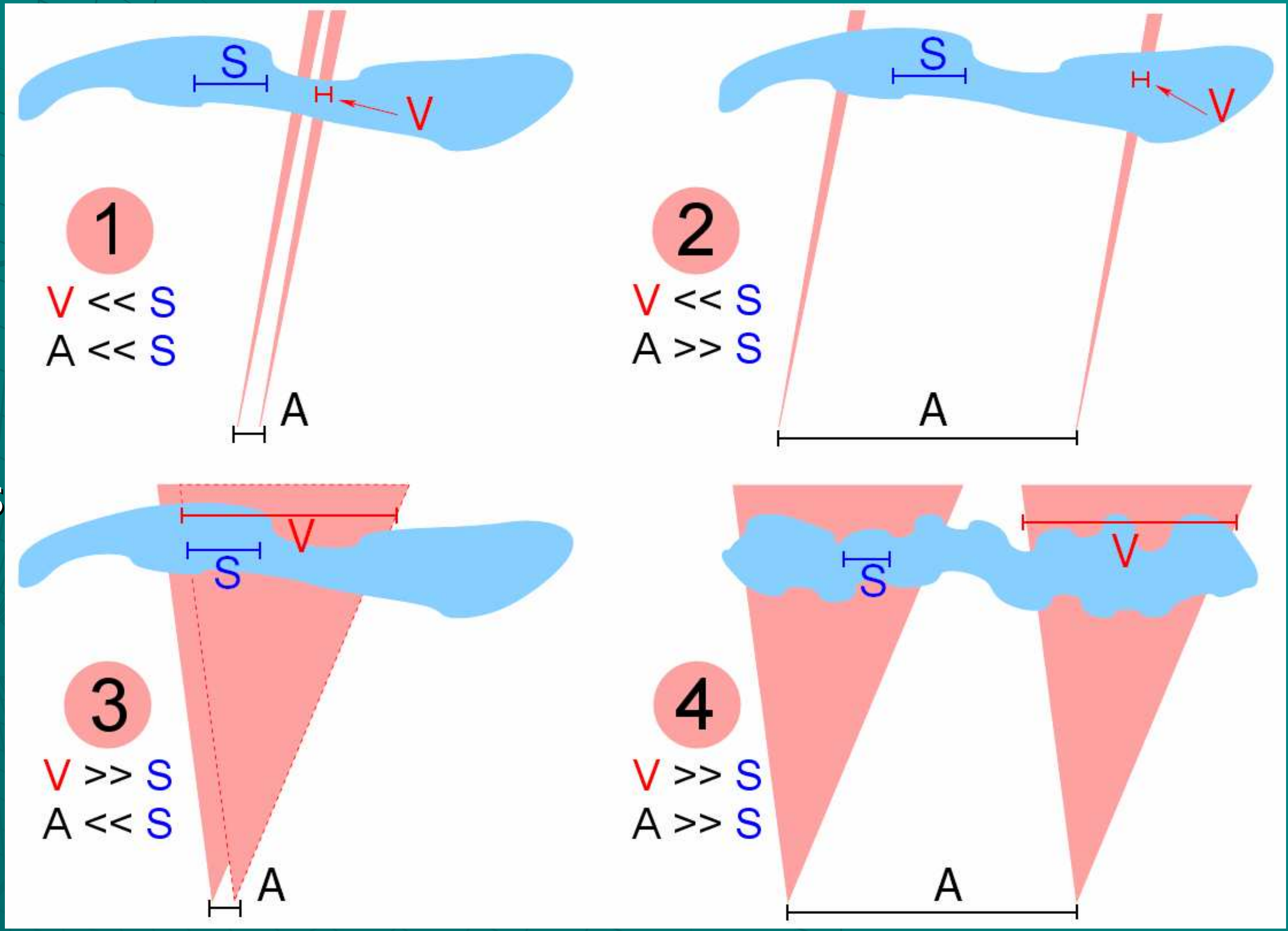
Problem Definition

V = FOV

A = array size

S = scale size
ionospheric
disturbances



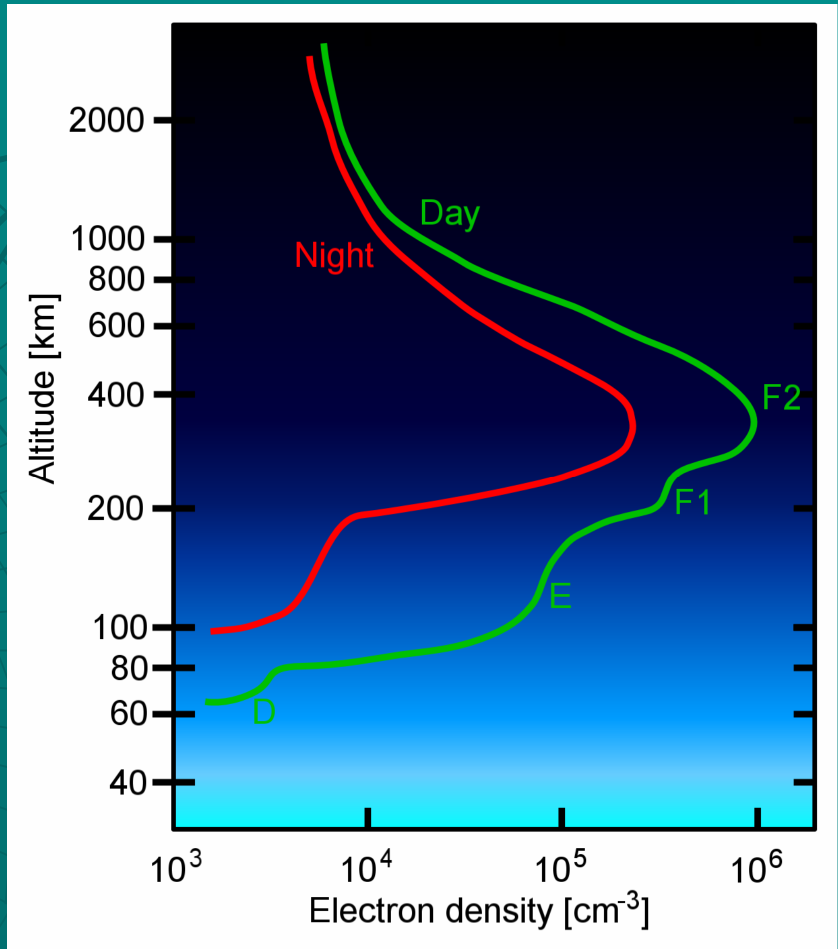
Lonsdale (2005)

'Simple' solution case 3 & 4

- Divide field-of-view V into small isoplanatic patches ΔV << S
- Model the (time-varying) Ionosphere over the array
- Use ionospheric model to obtain a single phase correction per antenna per patch ΔV per time-interval Δt

Simple model assumptions

- Thin layer ionosphere (no vertical structure) at fixed height
- 2D phase screen with limited number of parameters per Δt
- Phase per antenna is constant over ΔV and Δt
- Stokes I only



VLSS: case 3 model fitting

- Small array (A << S): gradient approximation
- Apparent shifts of bright sources across the FOV
- Snapshot-imaging every Δt to measure position offsets of sources and convert into gradients
- Low order model fit to gradients
- Model gradients applied to every patch ΔV

LOFAR: case 4 model fitting

- Larger array (A ≥ S): higher order phase effects over the array
- Apparent shifts and distortions of sources across the FOV
- Phase corrections through calibration towards different bright sources (peeling)
- Higher order model fit to calibration solutions
- Model phases applied to every patch ΔV

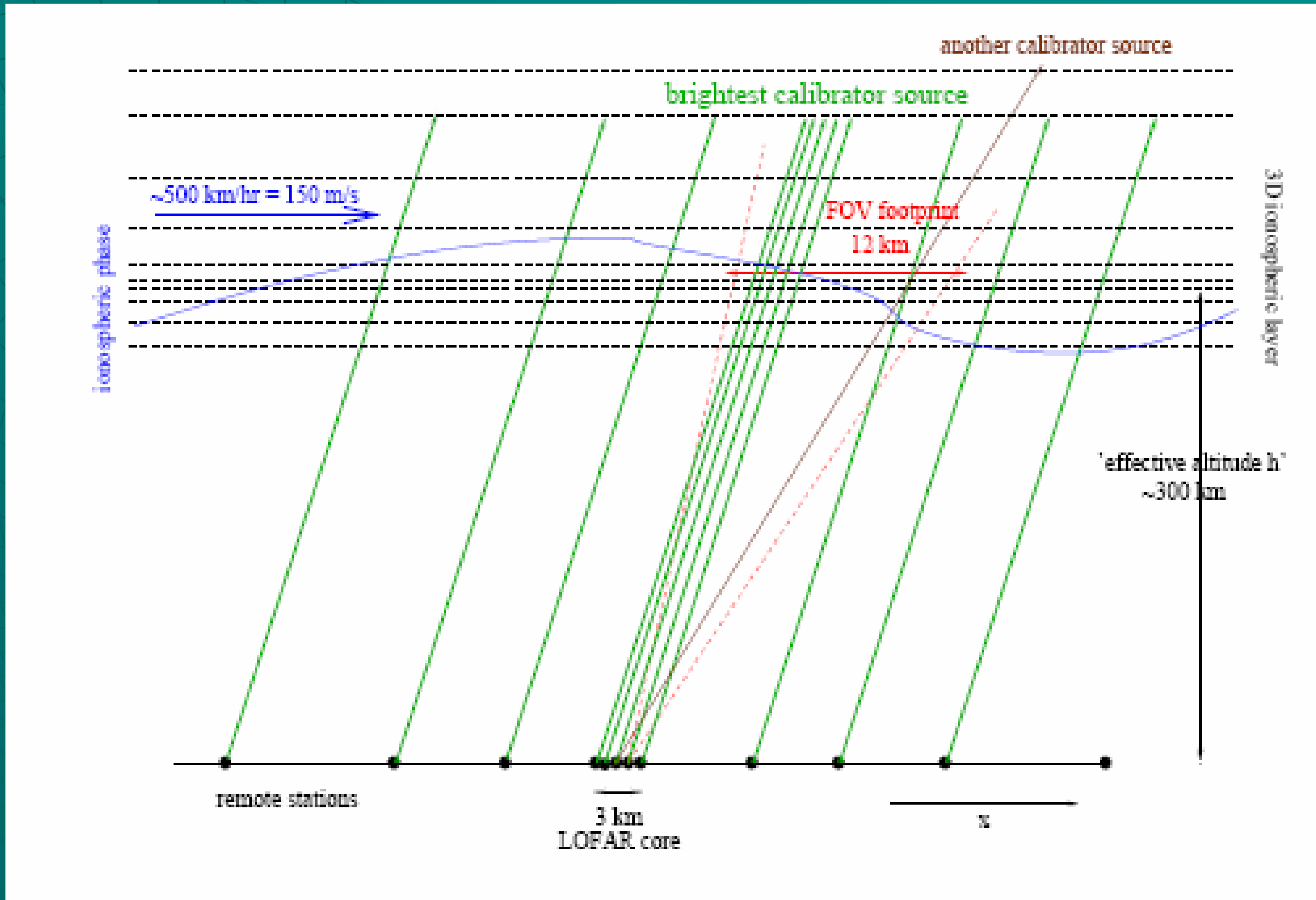
Simplified implementation for larger existing arrays (VLA-A, GMRT)

- Using Python and classical AIPS through ParselTongue interface (RadioNet)
- UV data is self-calibrated and imaged before peeling, to obtain and subtract an initial source model
- One by one, bright sources are temporarily added back and self-called, thus producing a set of phase corrections
- Per time interval Δt, ionospheric puncture points from antennas towards peeled sources are calculated
- Phase corrections are mapped to puncture points and a model fit is performed (Zernike pol's using LM-method)
- Model is used to predict phase corrections at every patch ΔV covering the FOV
- The whole FOV is imaged by iteratively imaging and cleaning individual patches while using the appropriate phase corrections

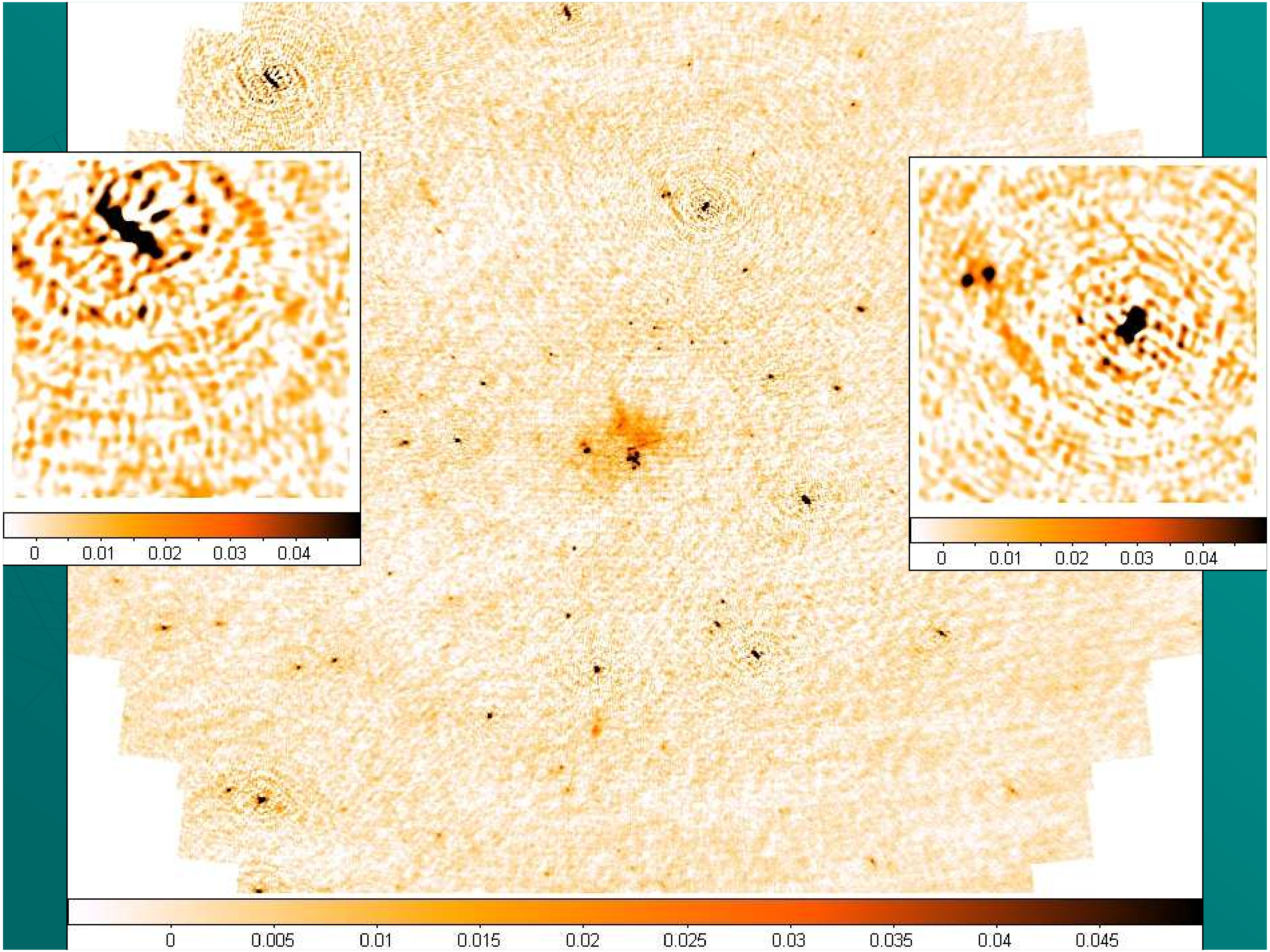
Collaborators

- NRAO: Bill Cotton, Jim Condon
- NRL: Aaron Cohen
- NCRA/GMRT: Pramesh Rao, Dharam Vir Lal, Ishwara Chandra
- Leiden: Huub Röttgering, Amitesh Omar, Ilse van Bemmel, Niruj Mohan, Berry Holl, Reinout van Weeren

Ionospheric layer puncture points

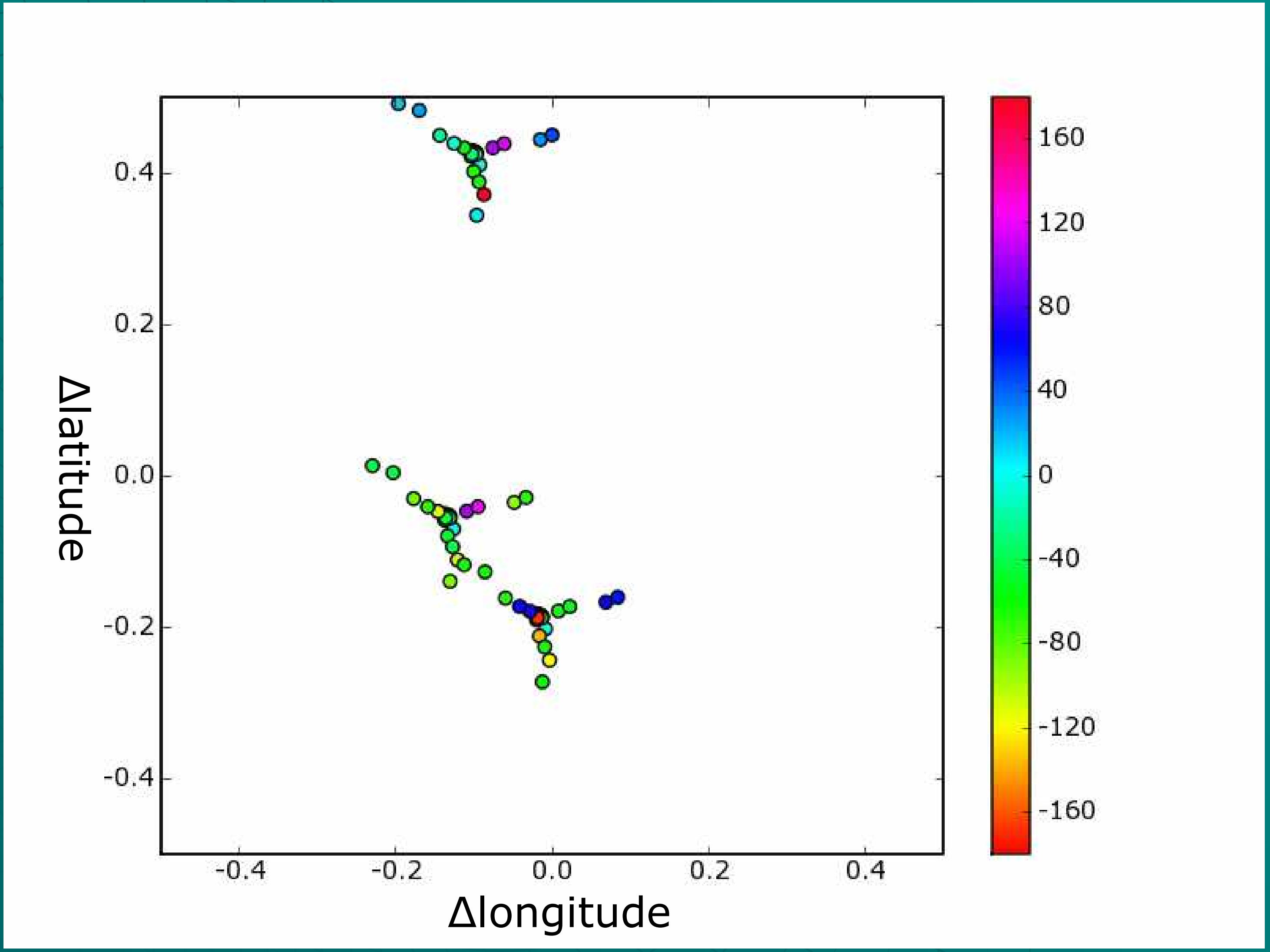


From Noordam (2006), LOFAR Calibration Framework



0 0.01 0.02 0.03 0.04
0 0.01 0.02 0.03 0.04
0 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04 0.045

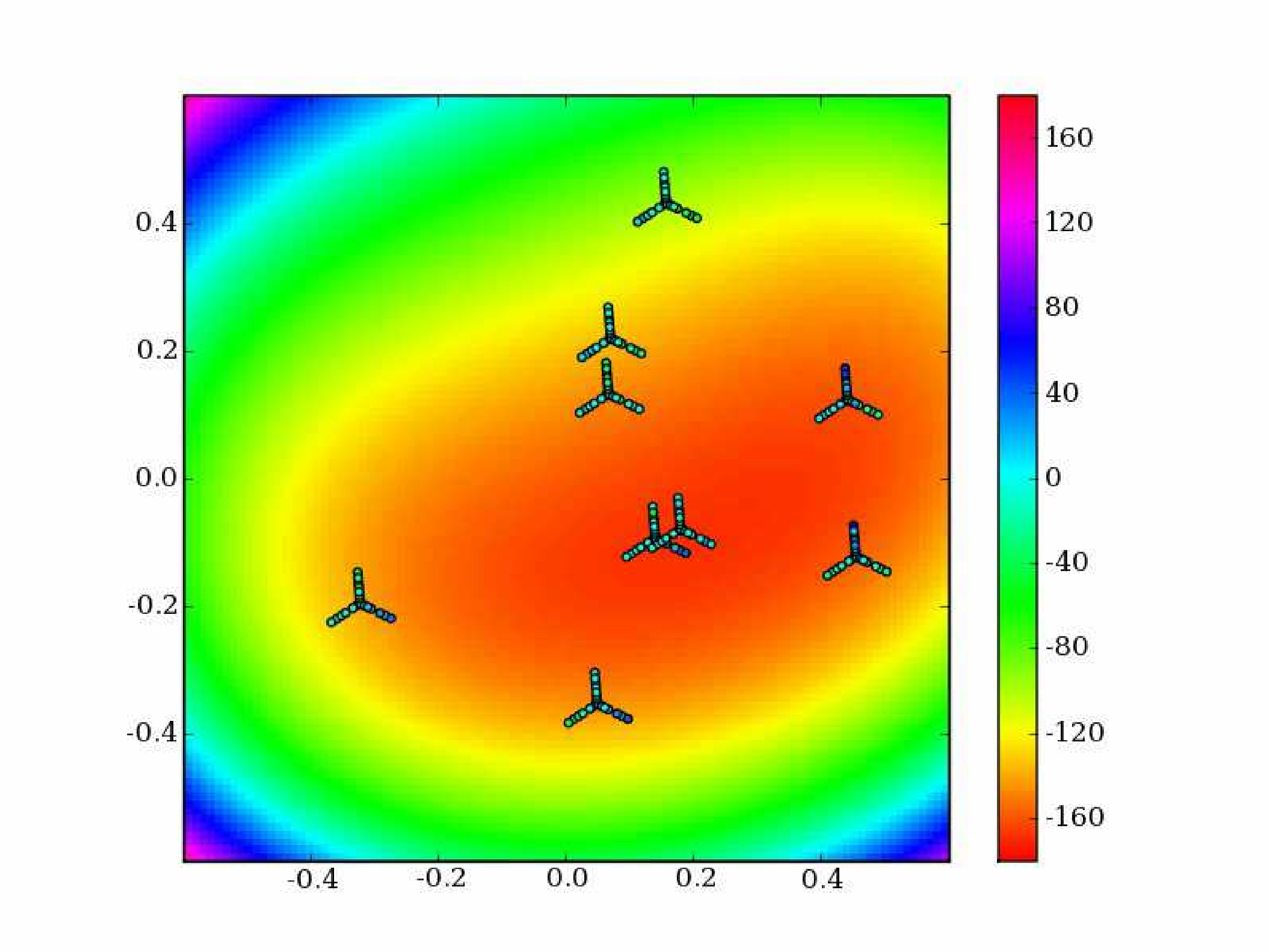
Mapping phases to puncture points



Test case: simulated data

- Model UV data set, based on real VLSS observations
- 20 point sources only
- No noise added, no instrumental errors
- UV data distorted by re-application of ionospheric model obtained from VLSS calibration scheme
- Relatively quiet ionospheric weather

Test case model fitting



Some test case results

- Used 9 out of 20 sources to fit ionospheric model using 8 Zernike polynomials
- Movie gives the impression of time-continuity
- Residual phase rms (model – observations):
  < 2 degrees for 9 sources used for fit
  < 6 degrees for 11 sources not used for fit
- Unfortunately no corrected images yet

Test case analysis

- Comparison between VLSS model's input phases and our model's output phases
- (Debugging of the imager routine)
- Image analysis: Strehl ratios, flux retrieval, dynamic range
- Comparison between output images of VLSS calibration scheme and our scheme

Further steps

- Increase complexity of model data:
  - More severe Ionosphere
  - Noise in visibility data
  - More complex sky model
- Apply calibration scheme to real data:
  - VLSS data with severe ionospheric weather
  - Other 74 MHz VLA data in A-configuration
  - GMRT data at 150 MHz
- Explore model parameter space