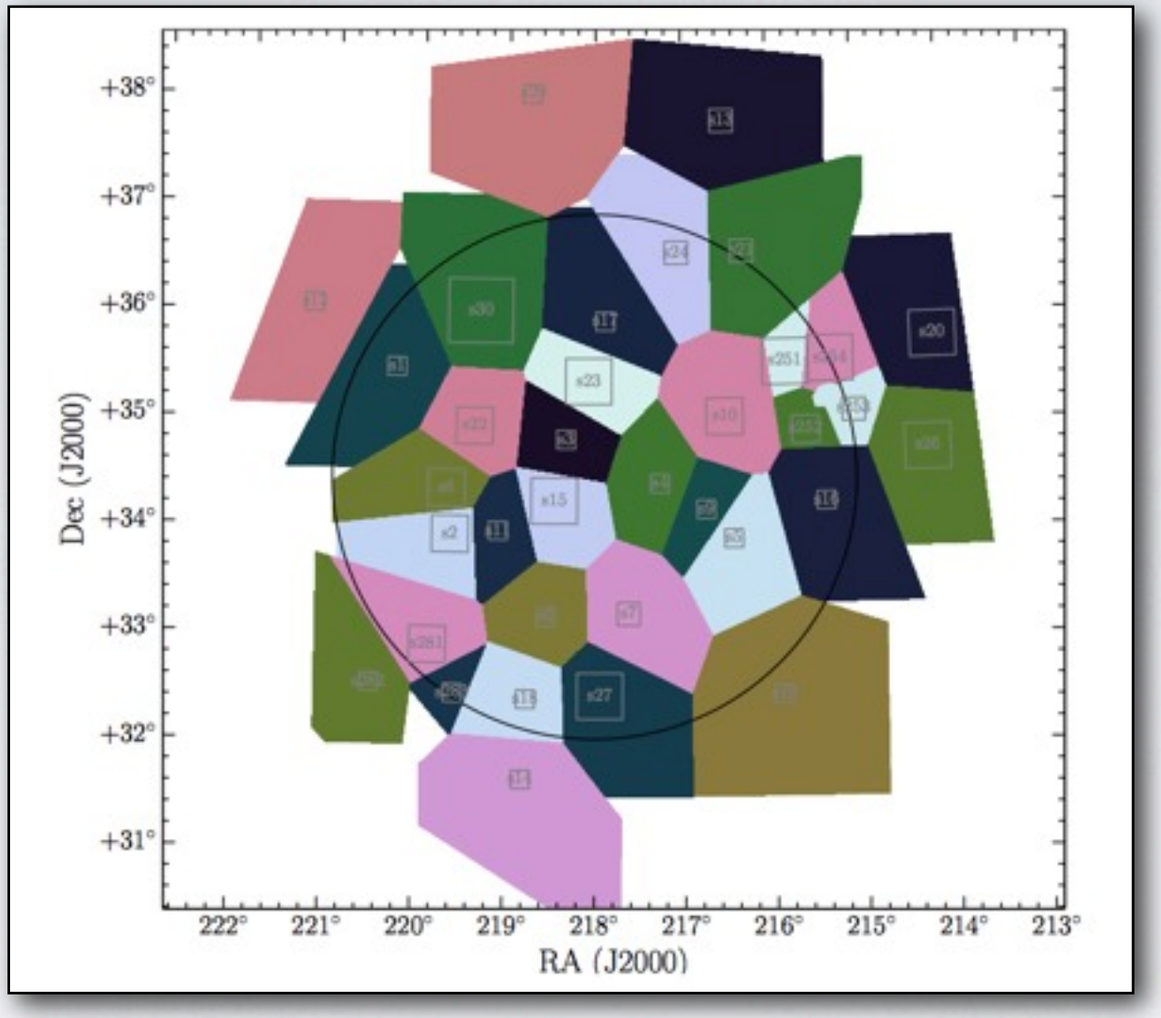
LOFAR FACET CALIBRATION



Reinout van Weeren

Harvard-Smithsonian Center for Astrophysics

Wendy Williams, Martin Hardcastle, Pepe Sabater, Tim Shimwell,
Facet Calibration Workshop Participants

OVERVIEW

- Introduction
- Initial calibration
- Direction dependent calibration

This talk

Achieving "Tier-1 type" depth and resolution

- resolution : ~ 5 arcsec
- depth: ~ 100 μJy beam^{-1} (~ thermal noise)

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Directional Dependent Calibration

Directional Dependent Calibration: Why ?

- Beam model not accurately known
- Ionosphere

Summary :

selfcalibration → facet calibration

Abell 2256
120-180 MHz
5 arcsec

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selfcalibration → facet calibration

Abell 2256
120-180 MHz
5 arcsec

I Before facet calibration

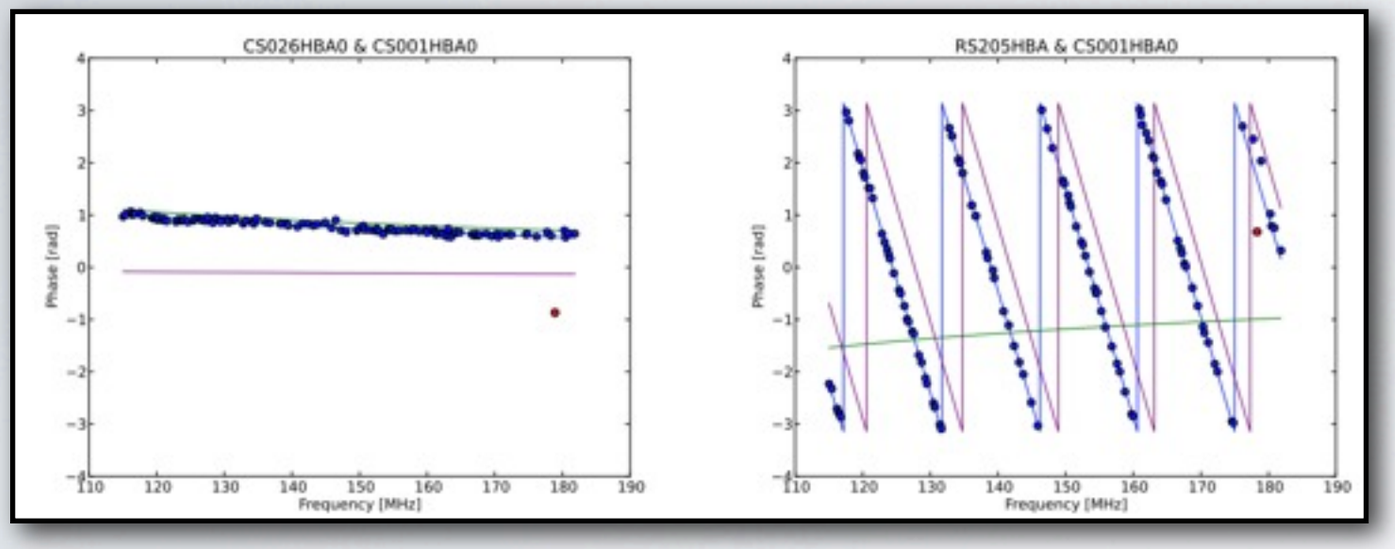
- Remove the clocks offsets
- Transfer the amplitude scale

} *~10 min calibrator scan*

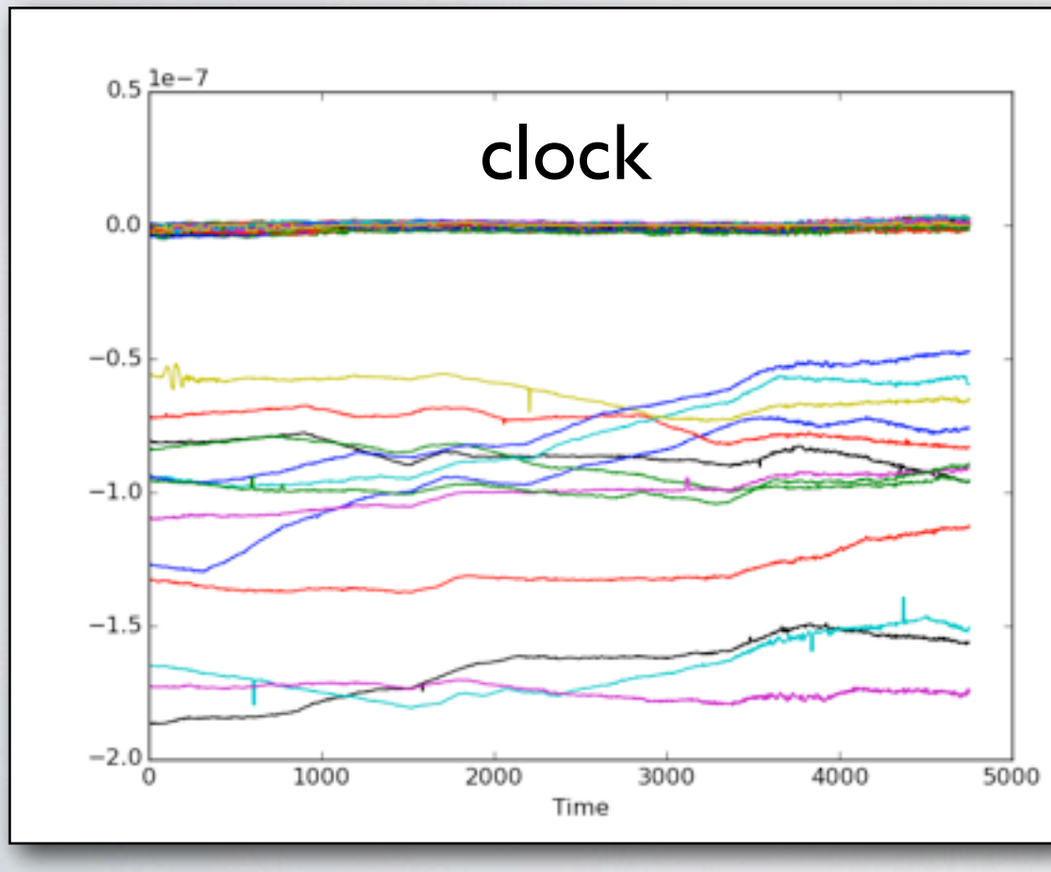
- Remove XX and YY phase offset

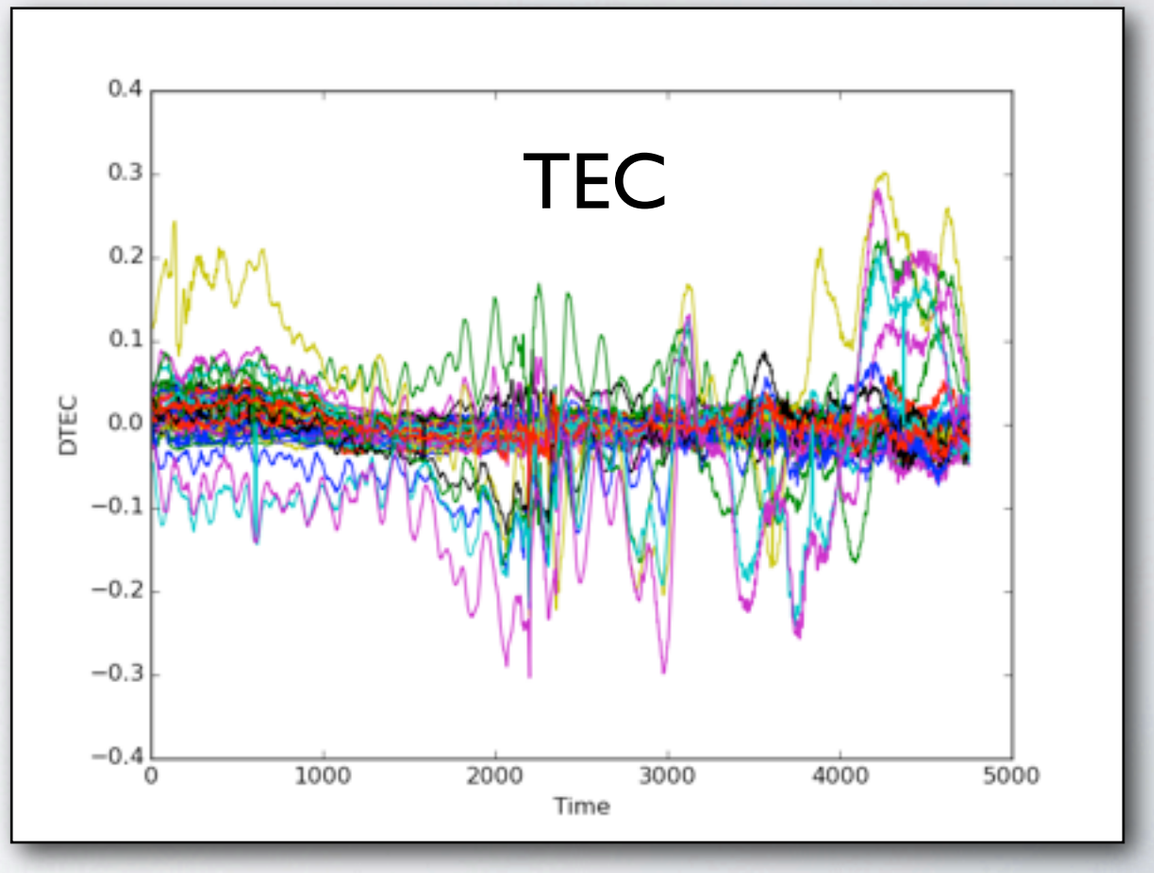
- Simple target field (self) calibration

Clock offsets

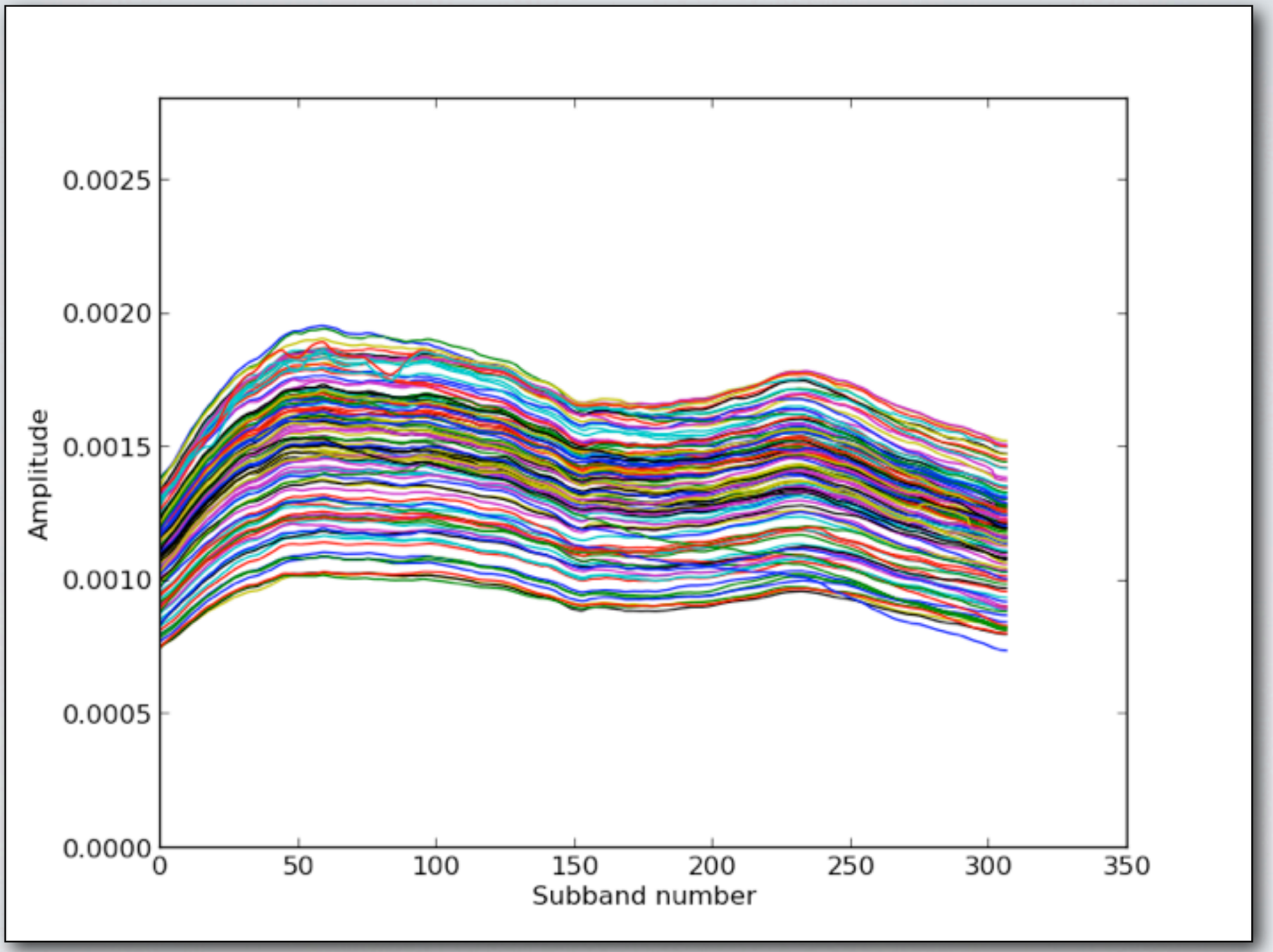


phase = (TEC/v)+ (clock×v)



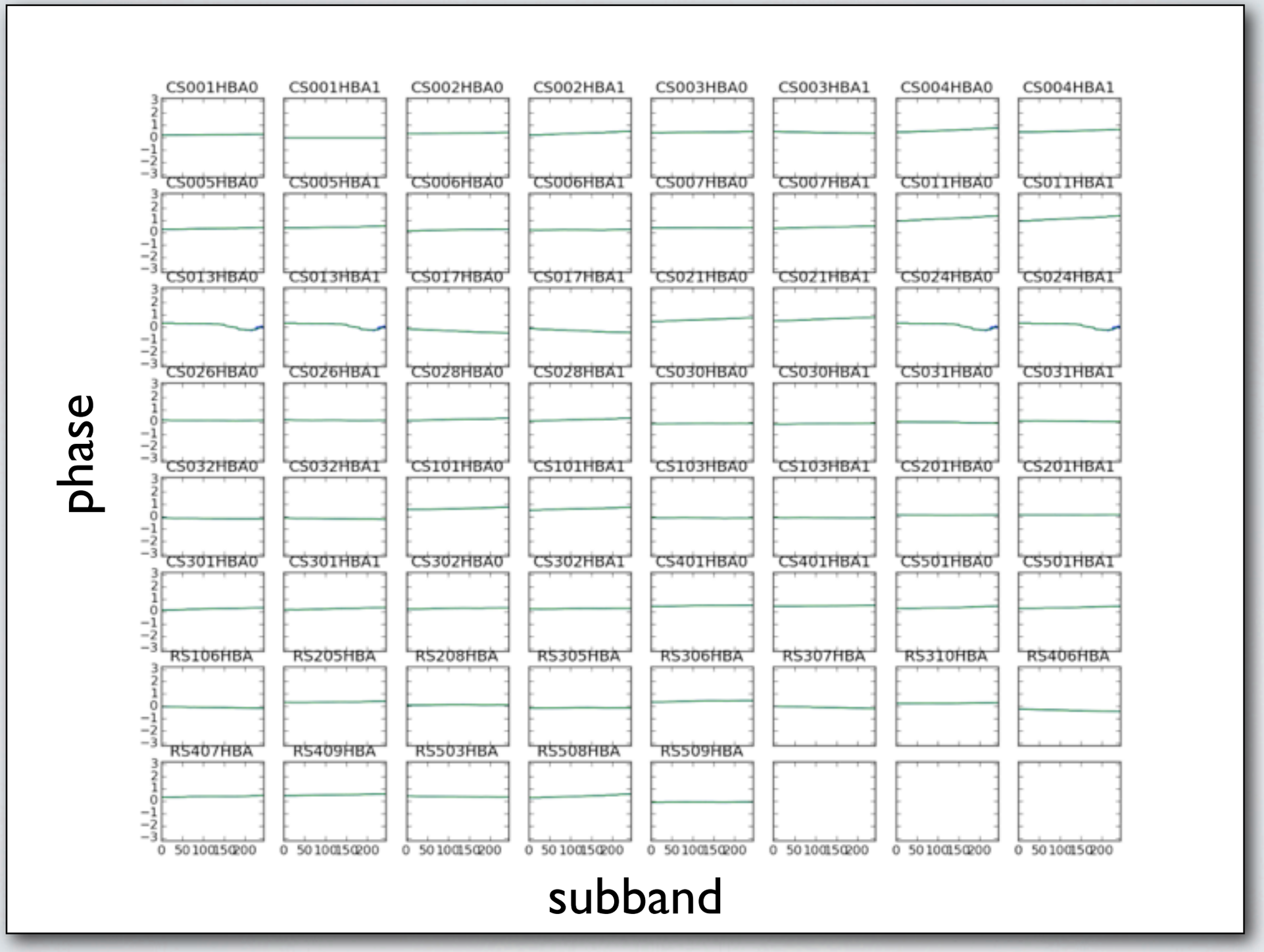


Amplitude transfer



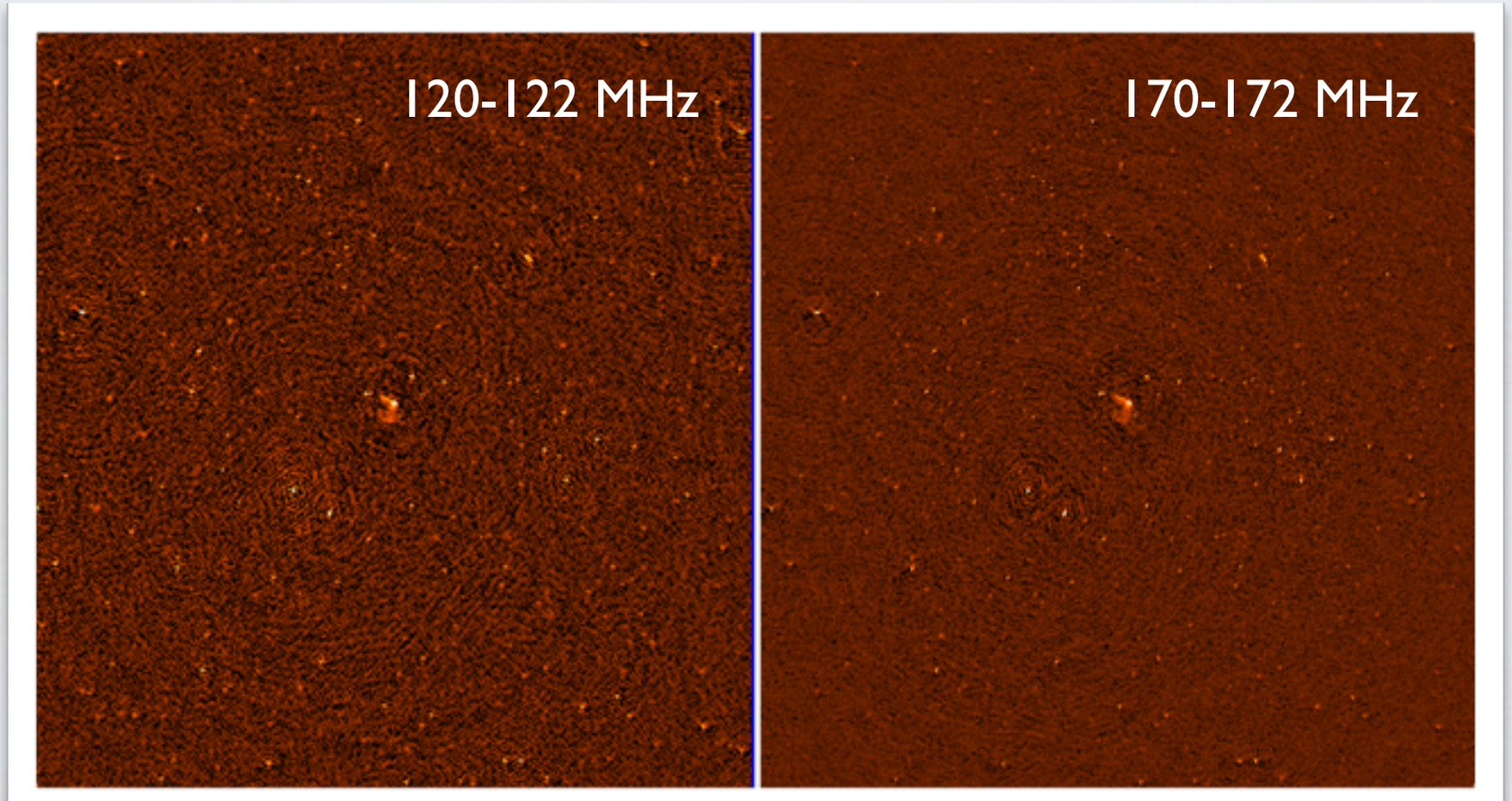
∝ frequency

XX-YY phase offsets



Target field calibration

- Standard gain calibration
  - Use GSM model (optional selfcal)
  - External model (GMRT)
- Done with 10 SB (=2 MHz) blocks



20 arcsec x 20 arcsec noise ~ mJy/beam

2 Direction Dependent Effects (DDEs)

- Degrees of freedom vs number of parameters solved for
- Relevant timescales:
  - ionosphere: 5-20 sec (Stokes I phases, $1/\nu$ dependence)
  - beam: 5-20 min (XX and YY amplitudes and phases)

Assumptions

- Station beams vary slowly over time and frequency
- Phase $\propto$ (TEC/frequency) + (clock$\times$frequency)
- Both ionosphere and beam errors vary slow across the FoV

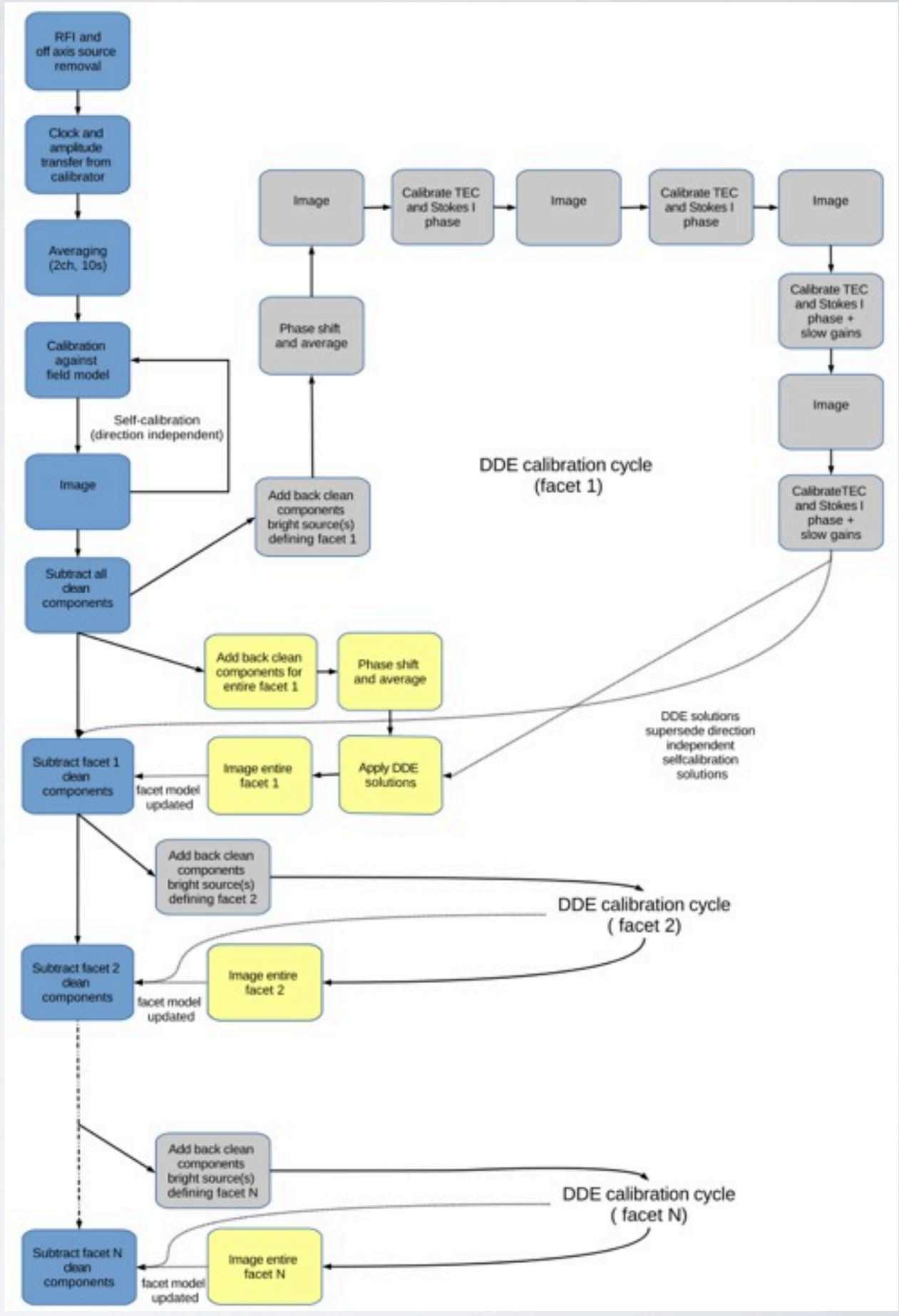
FACET CALIBRATION

- Subtract all sources from data
- Define facet centers

- Add back central source(s) defining facet
- Phase shift + average
- *DDE self-calibration Cycle*

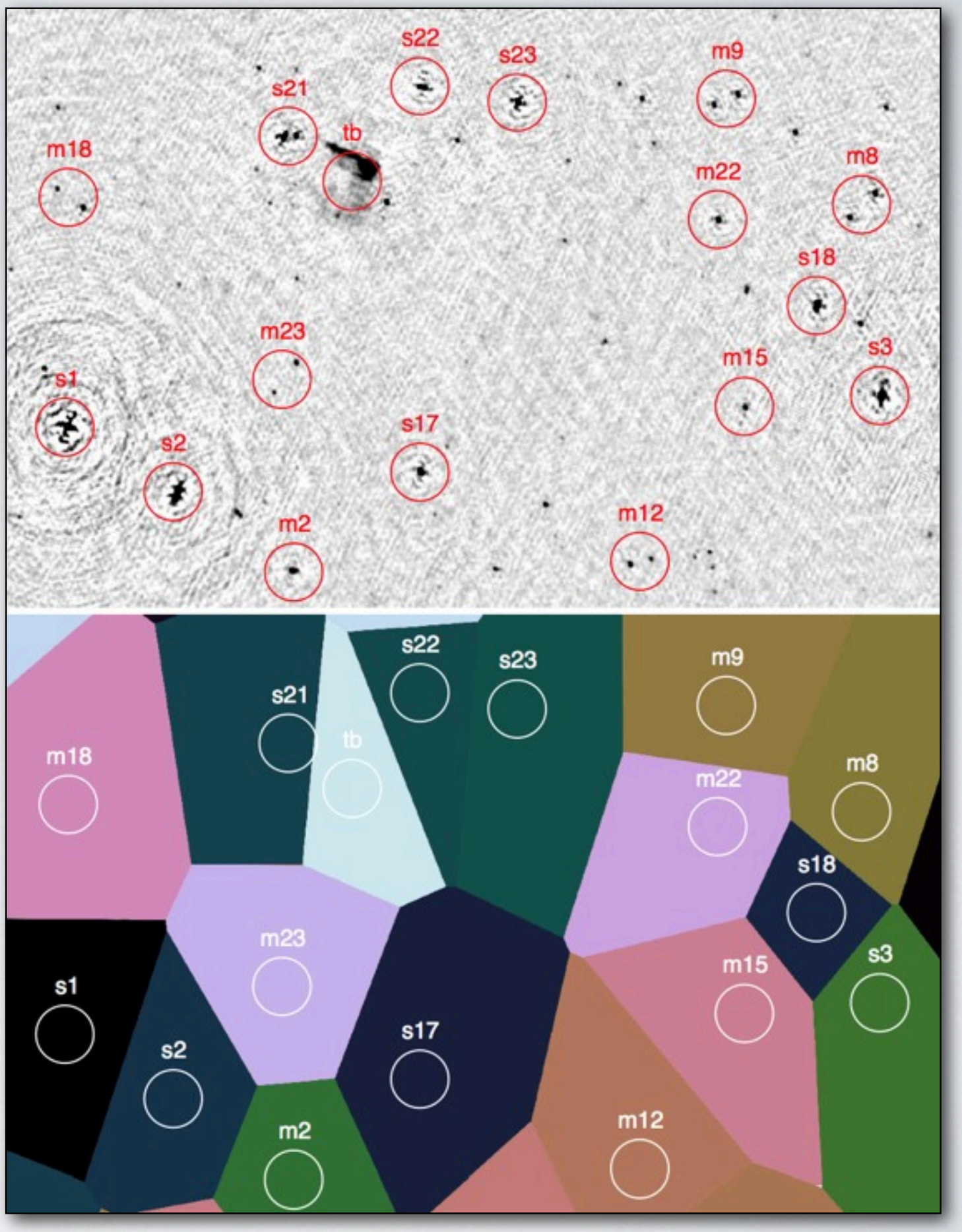
- Add back all sources in facet
- Correct with solutions
- Image
- Subtract updated facet model with solutions

loop over facet



FACET LAYOUT

- 0.5 + Jy of flux



DDE SELF-CALIBRATION CYCLE (PER FACET)

takes care of spectral index across the band

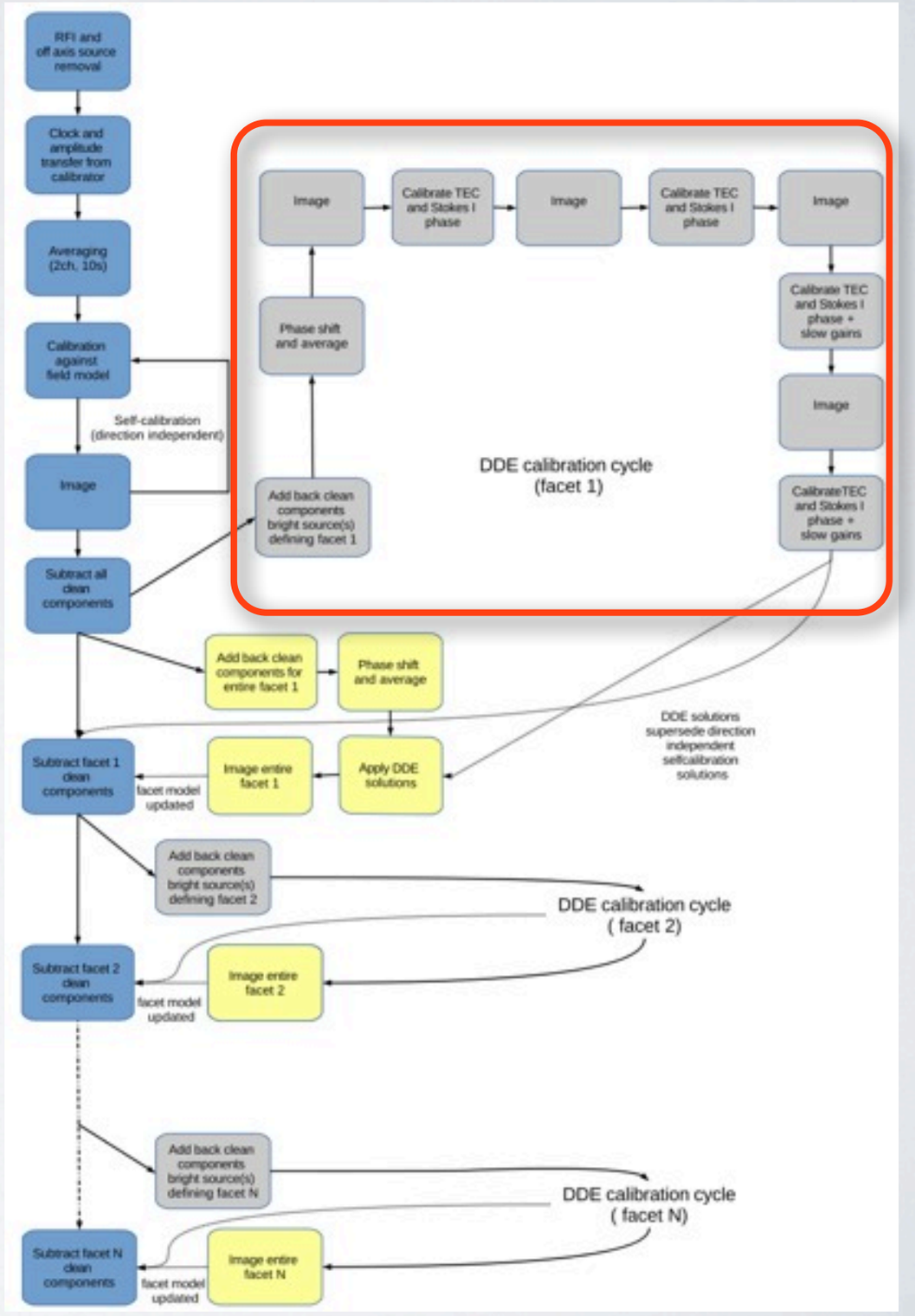
- Nterms > 1 option
- Automatic clean masking
- slow and fast timescale calibration
- Multi-scale clean option

- DDE selfcalibration works on phase shifted frequency averaged data

Small FoV → no bandwidth smearing

limit set by ionosphere

- 2 MHz frequency averaging
- No time averaging



DDE CALIBRATION CYCLE (PER FACET)

- Solving for various effects on different timescales
  - 1. TEC → 10-20 seconds (ionosphere)
  - 2. Gains → 5-20 min (beam)
- Need to iterate between 1 and 2

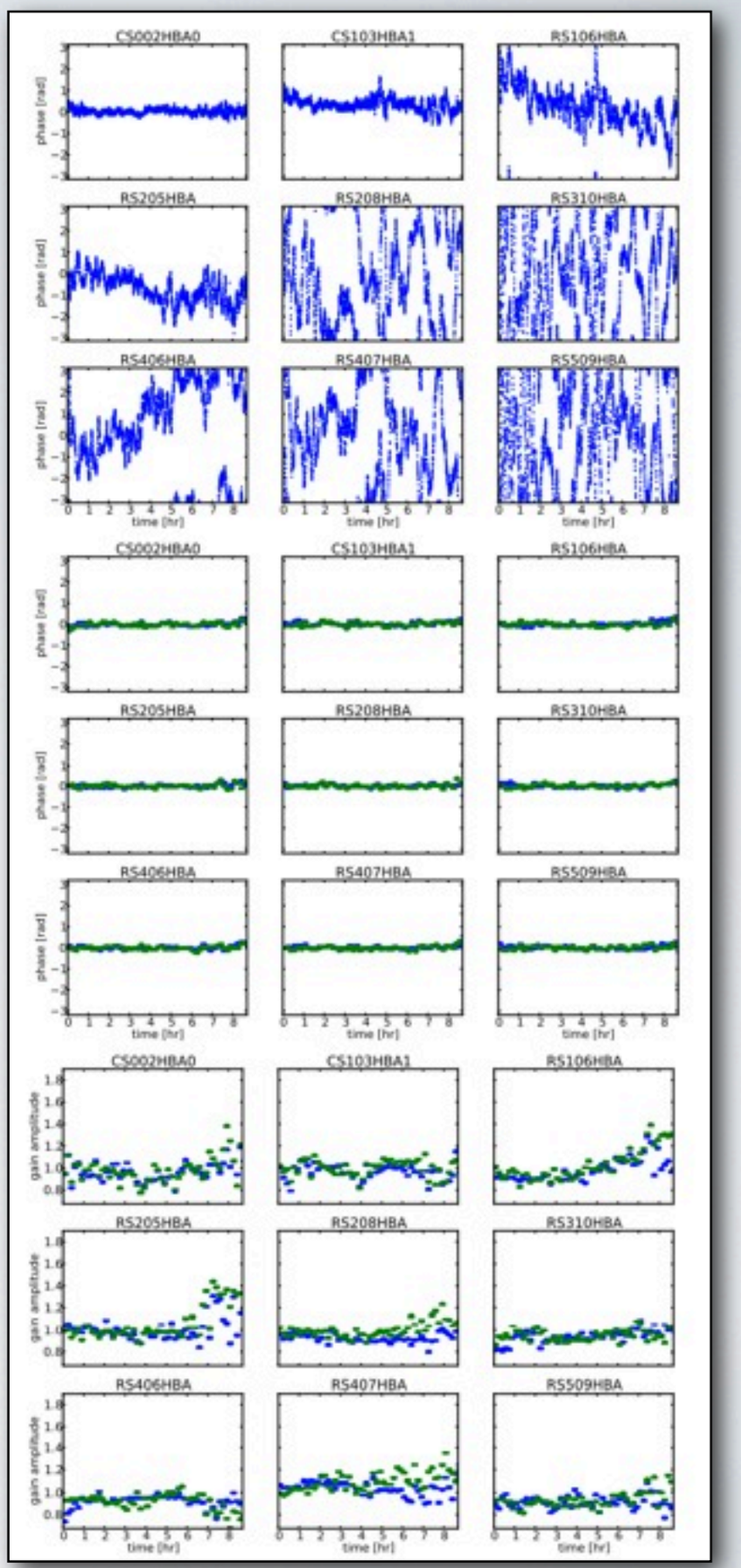
- This makes the calibration scheme "look" complex
- Slow convergence due to poor instantaneous uv-coverage (scheme needs to be repeated)

solution for one direction

TEC+SCphase

Gain (phase)

Gain (amp)



10 SB block selfcal solution (no DDEs)

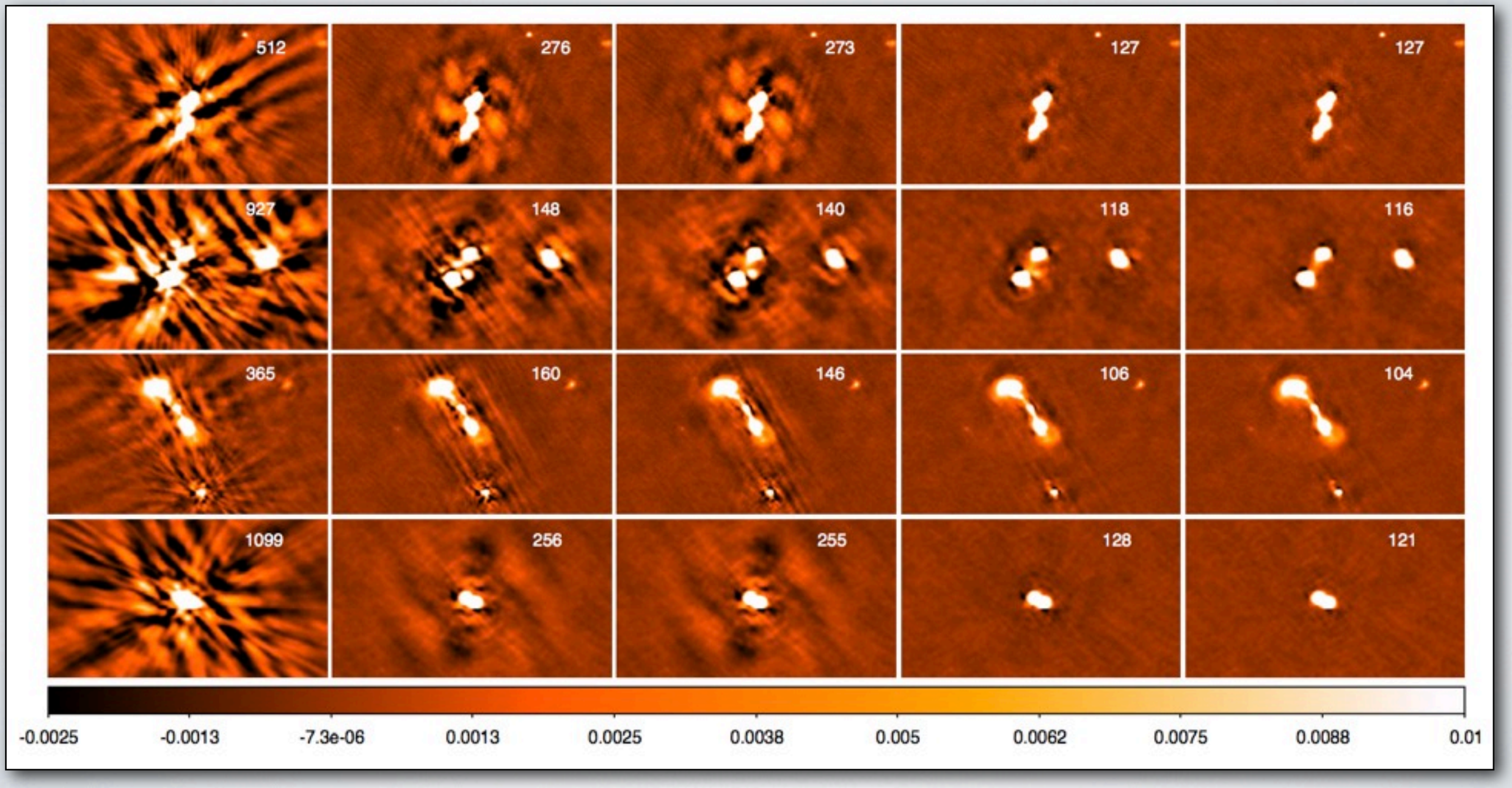
CommonScalarPhase TEC

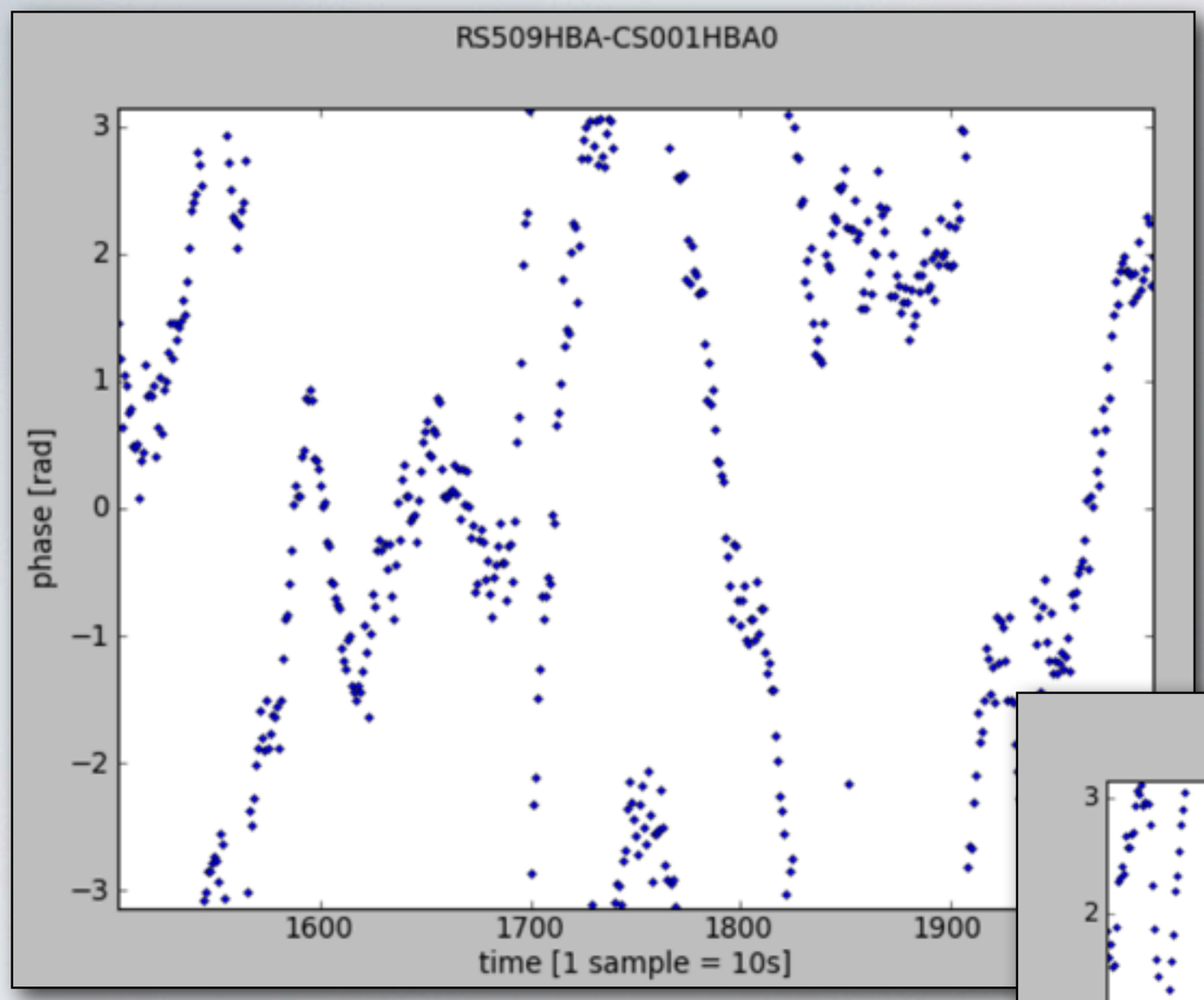
CommonScalarPhase TEC

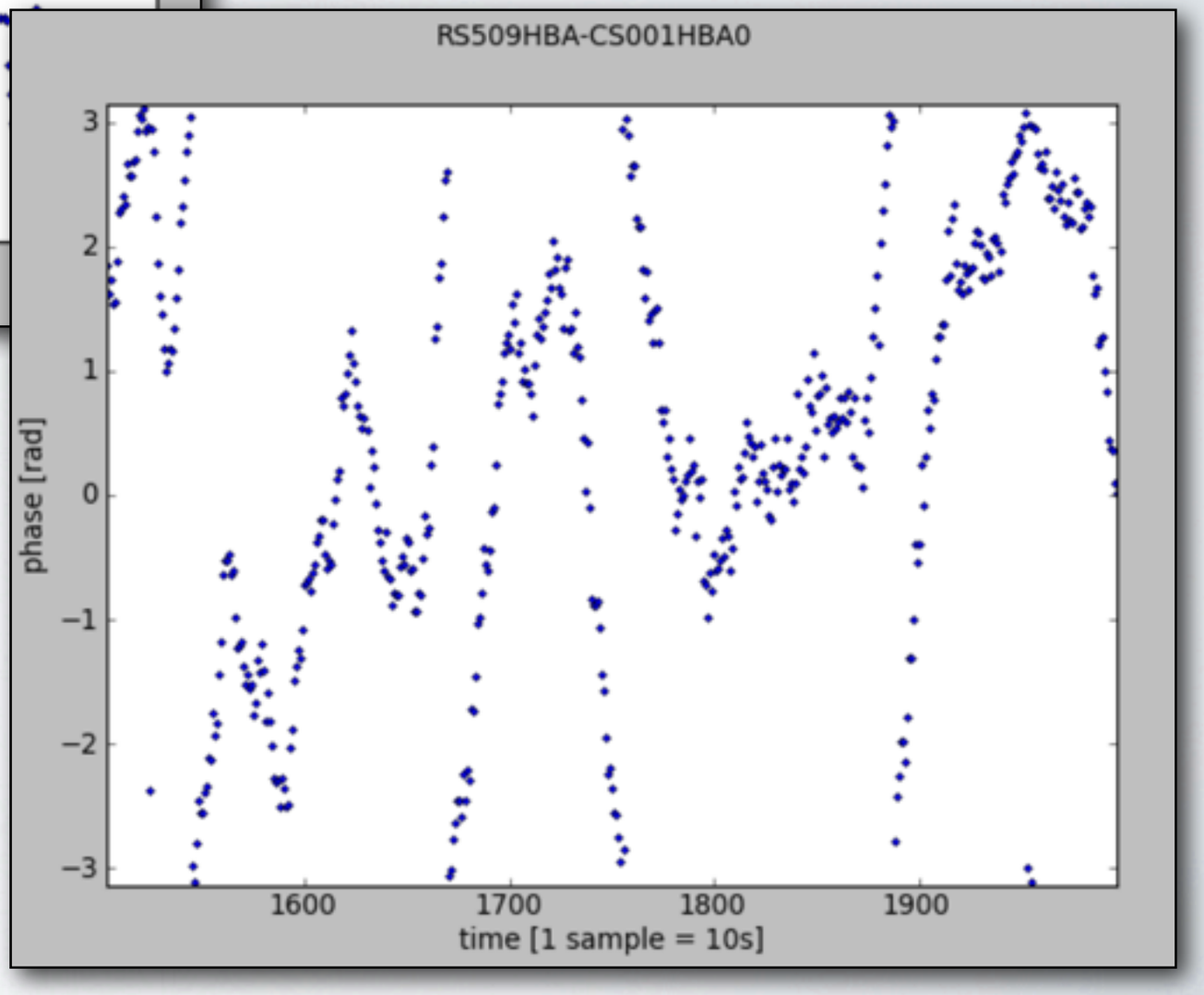
CommonScalarPhase TEC Gain:x:x Gain:y:y

CommonScalarPhase TEC Gain:x:x Gain:y:y

SELFCAL | IONOSPHERE | IONOSPHERE | IONOSPHERE+BEAM | IONOSPHERE+BEAM







Two DDE sources separated by 20 arcmin

FACET IMAGING

- Assume DDE solutions at the facet center apply to the full facet

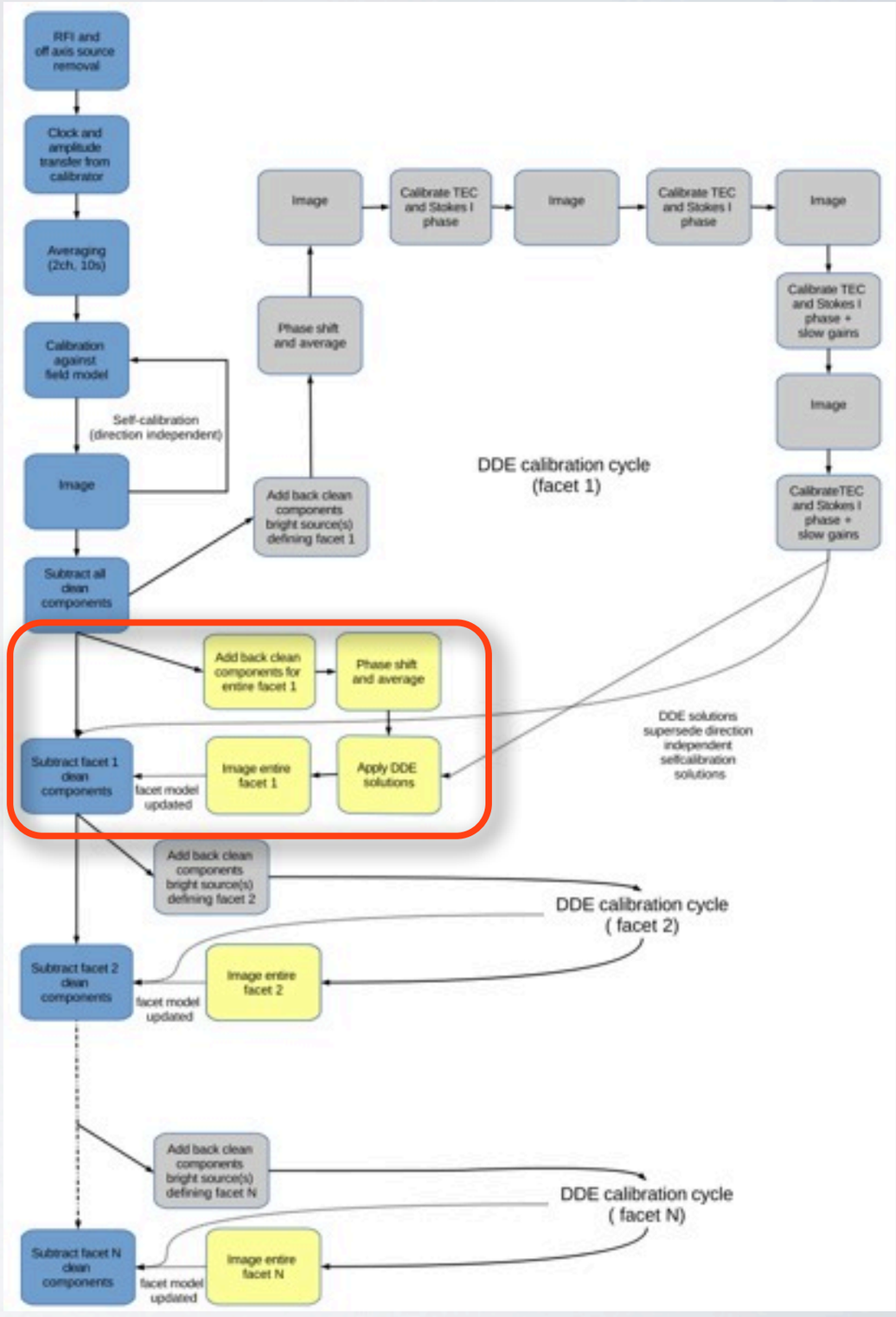
  rest of facet contains fainter sources

- Facet still small w.r.t. full FoV

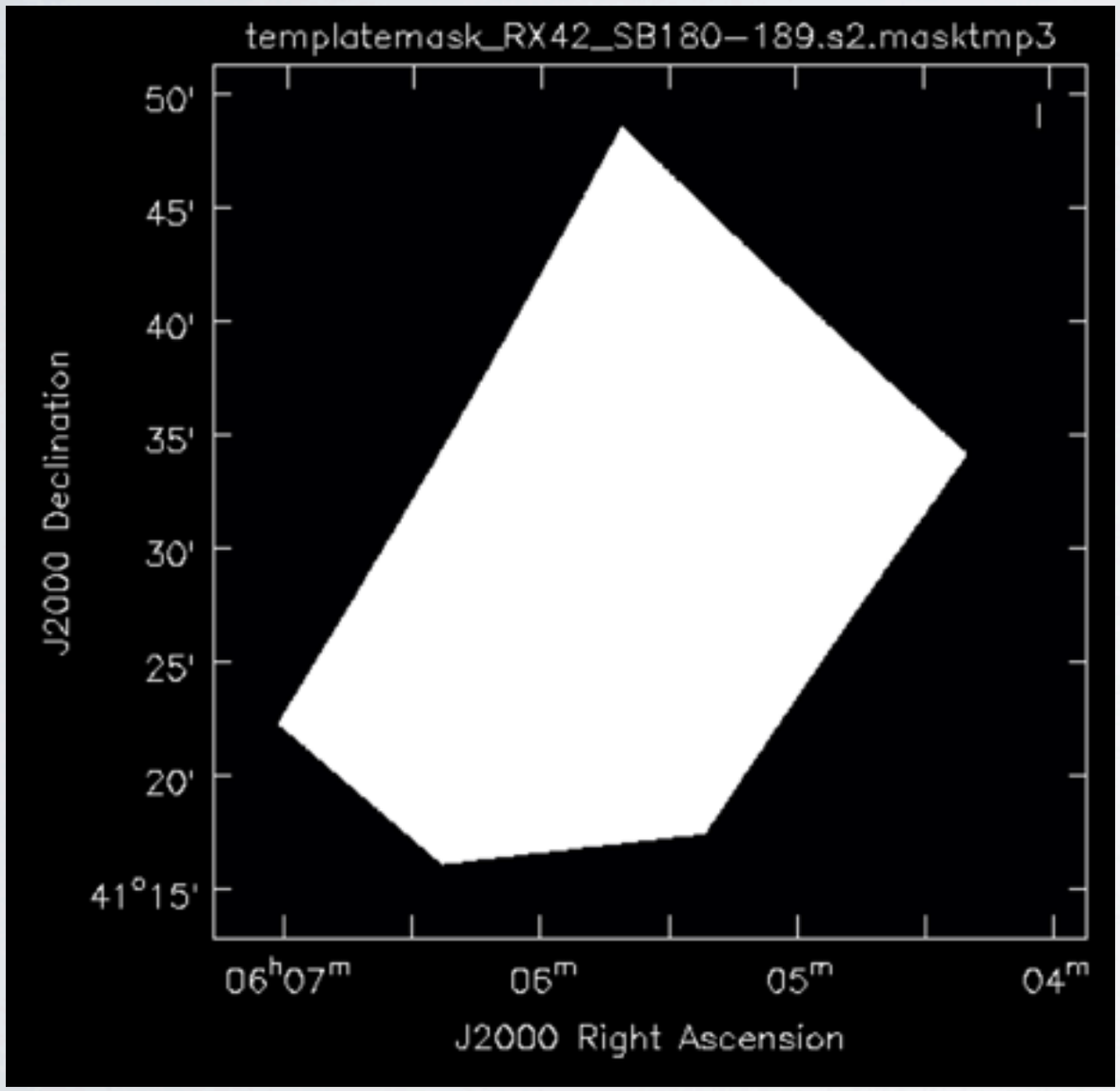
phaseshift + average, but less averaging than compared to the DDE selfcal cycle as imaged area is larger now

- Imaging + Masking
  - wsclean (A. Offringa) / casapy

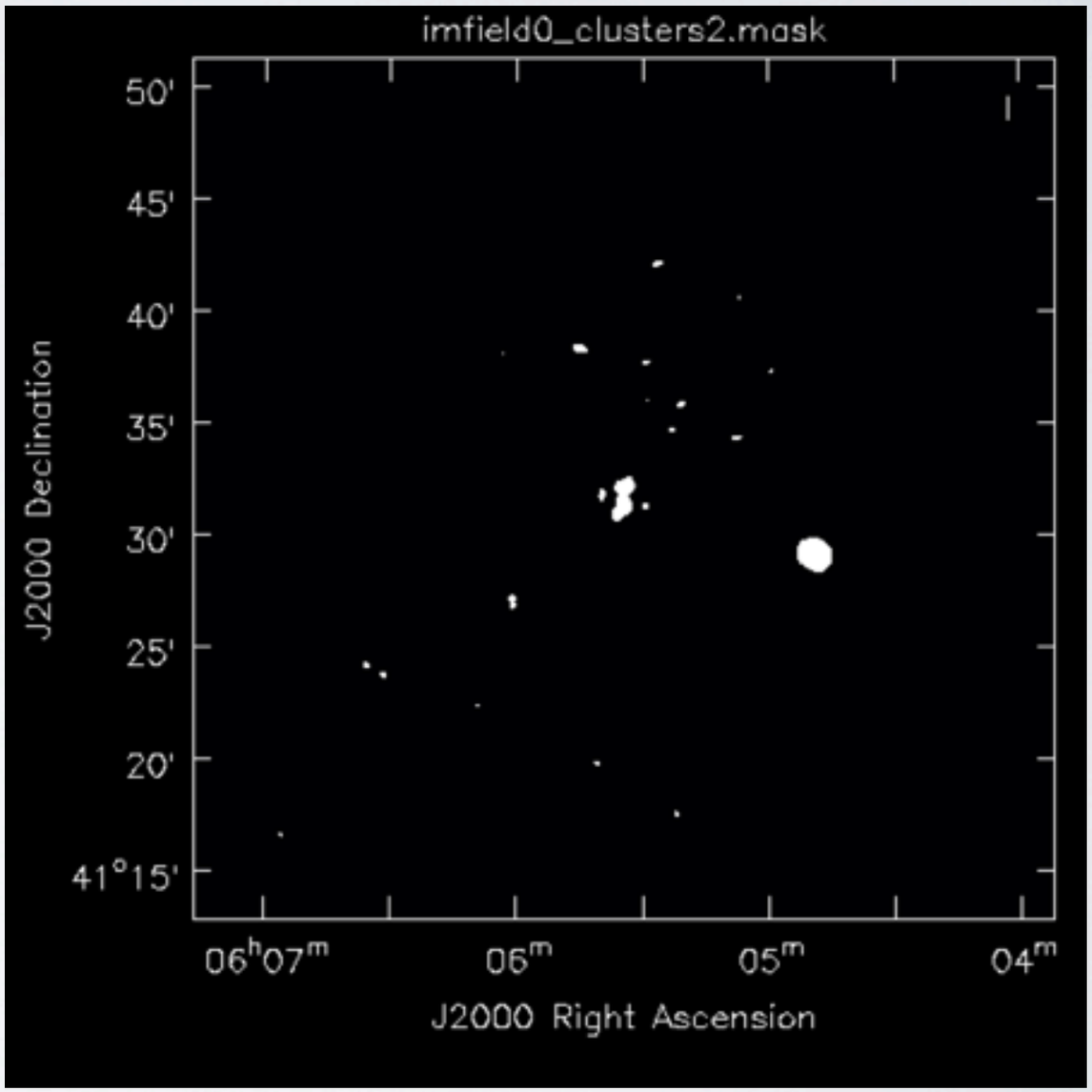
- FFT subtract on “full” resolution data



FACET IMAGING

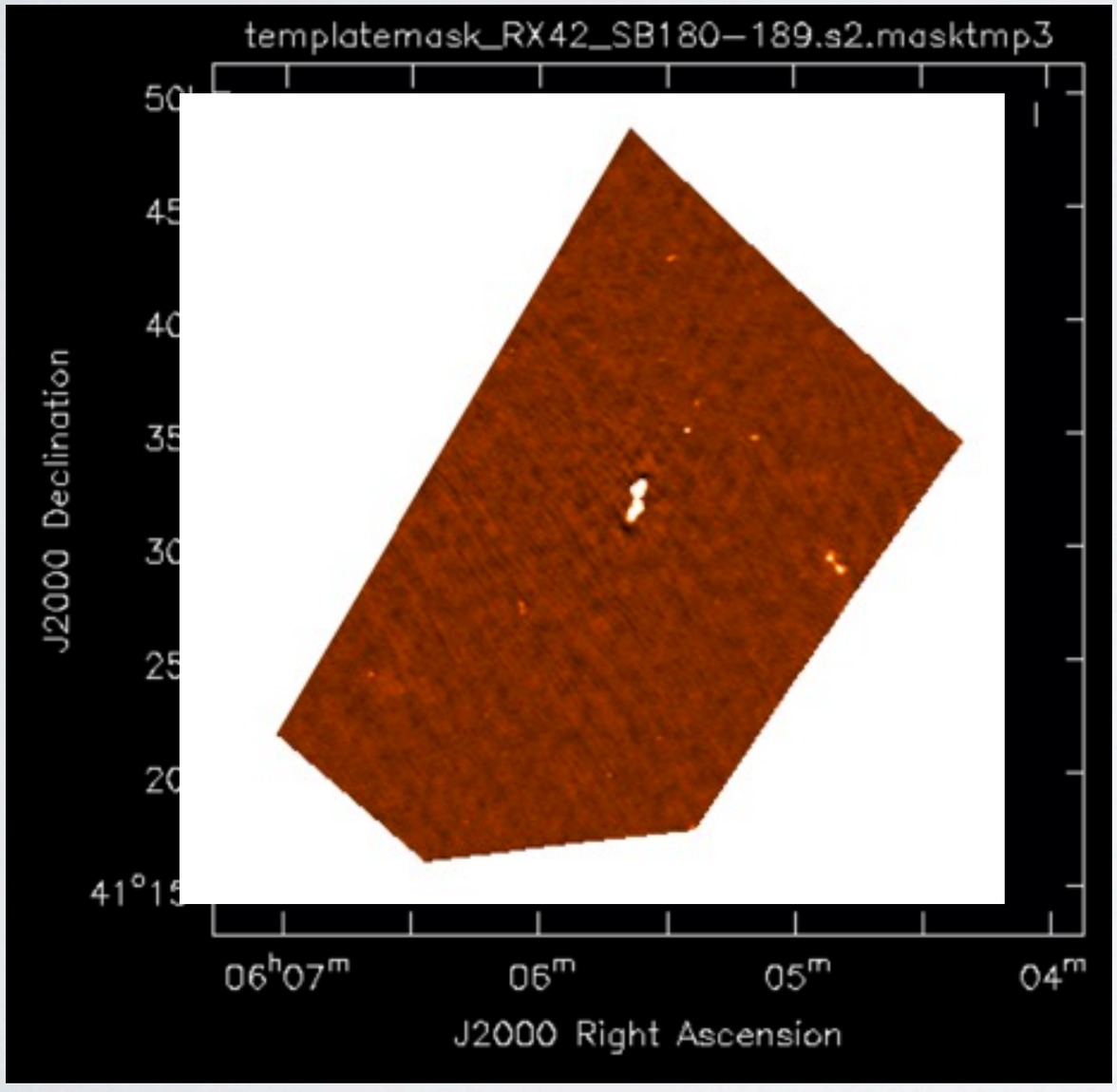


facet boundary

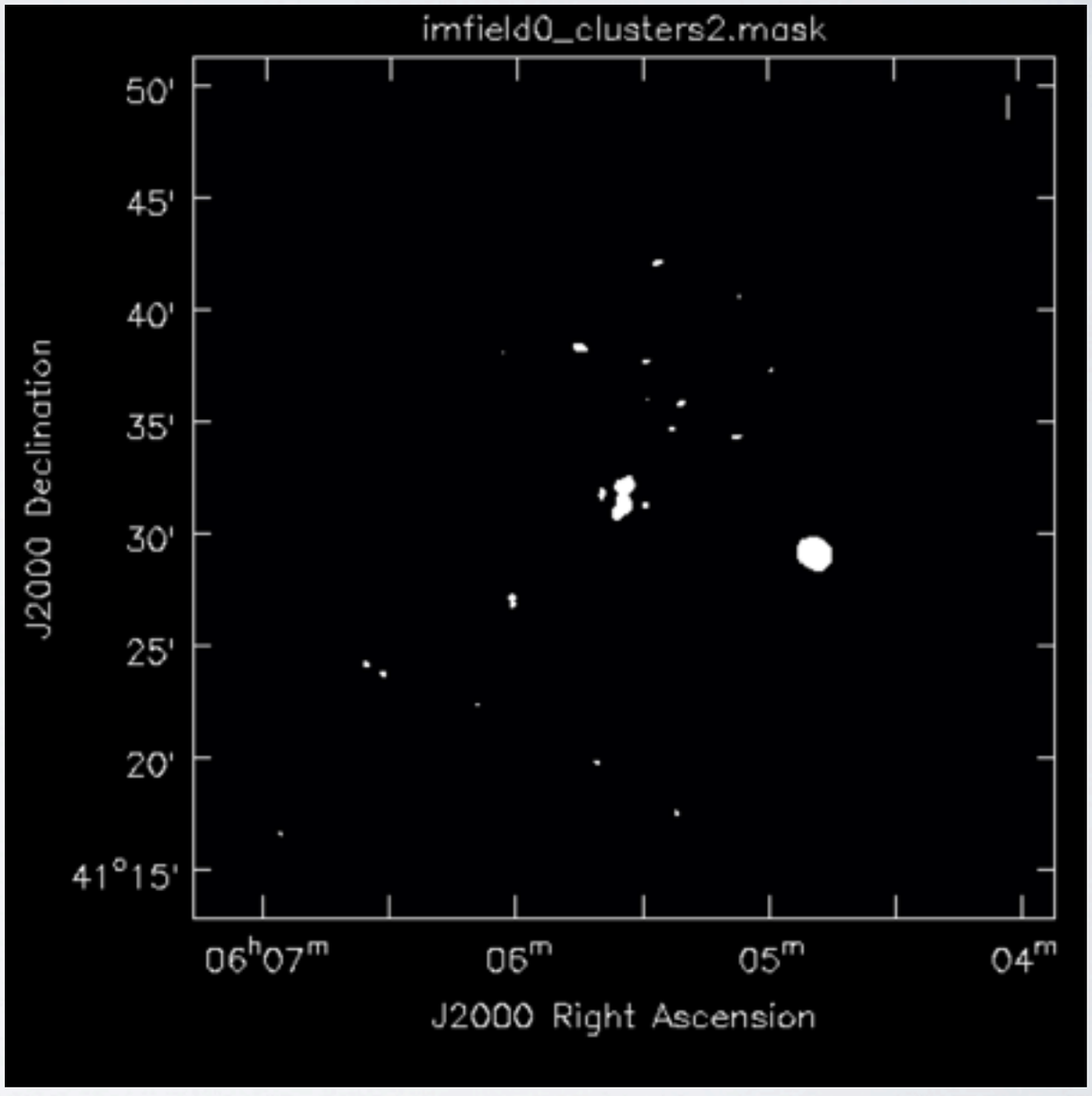


clean mask

FACET IMAGING

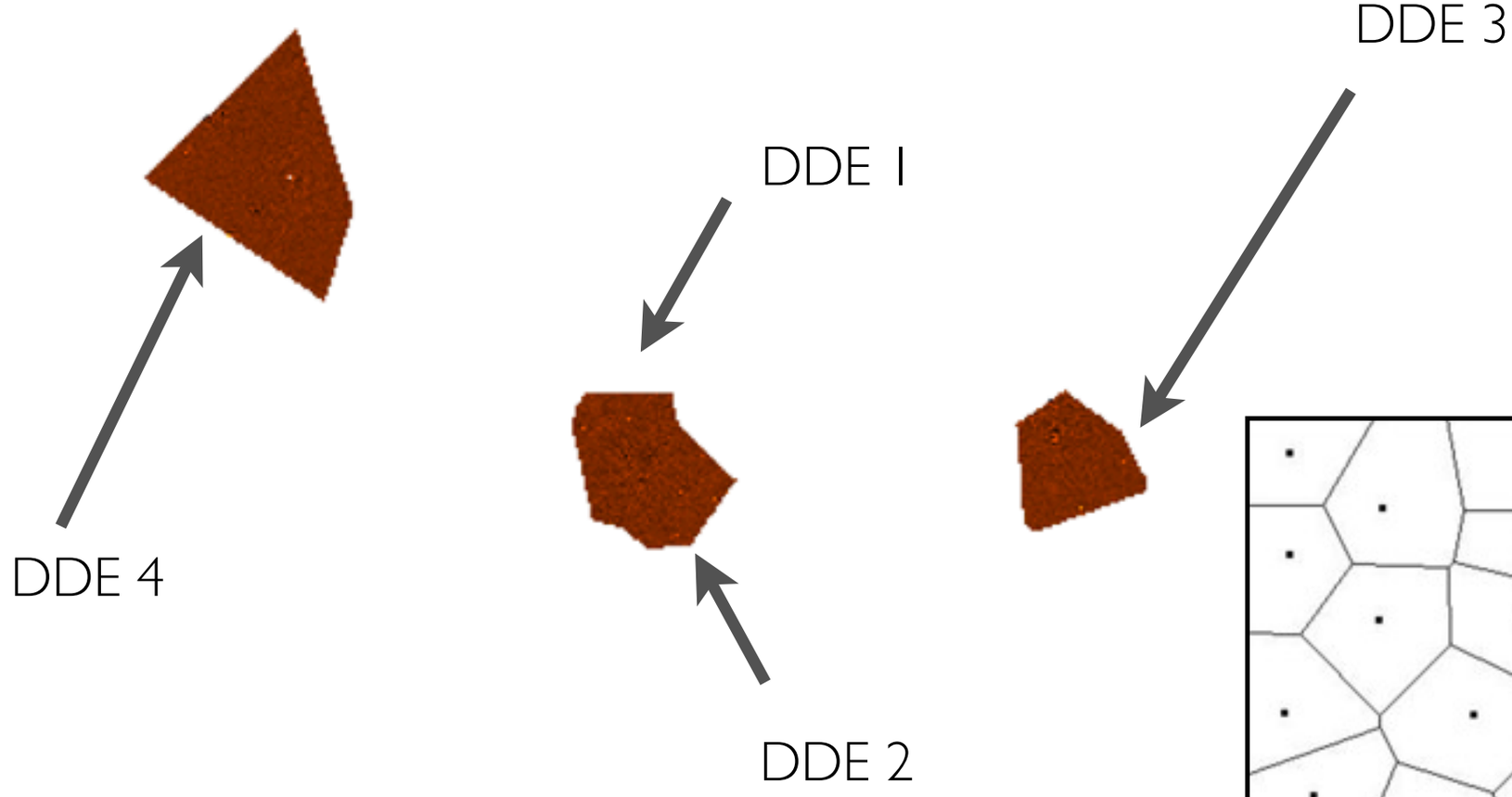


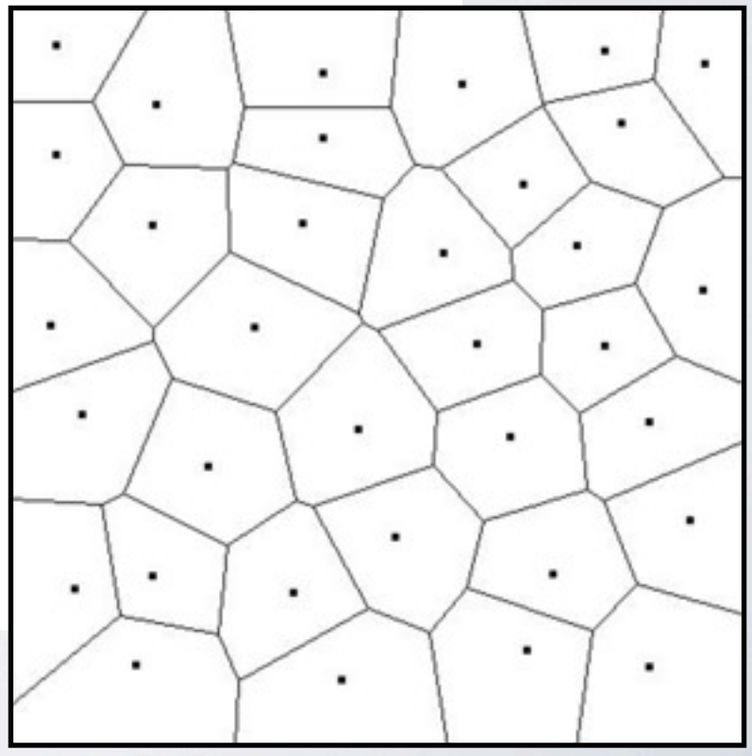
facet boundary



clean mask

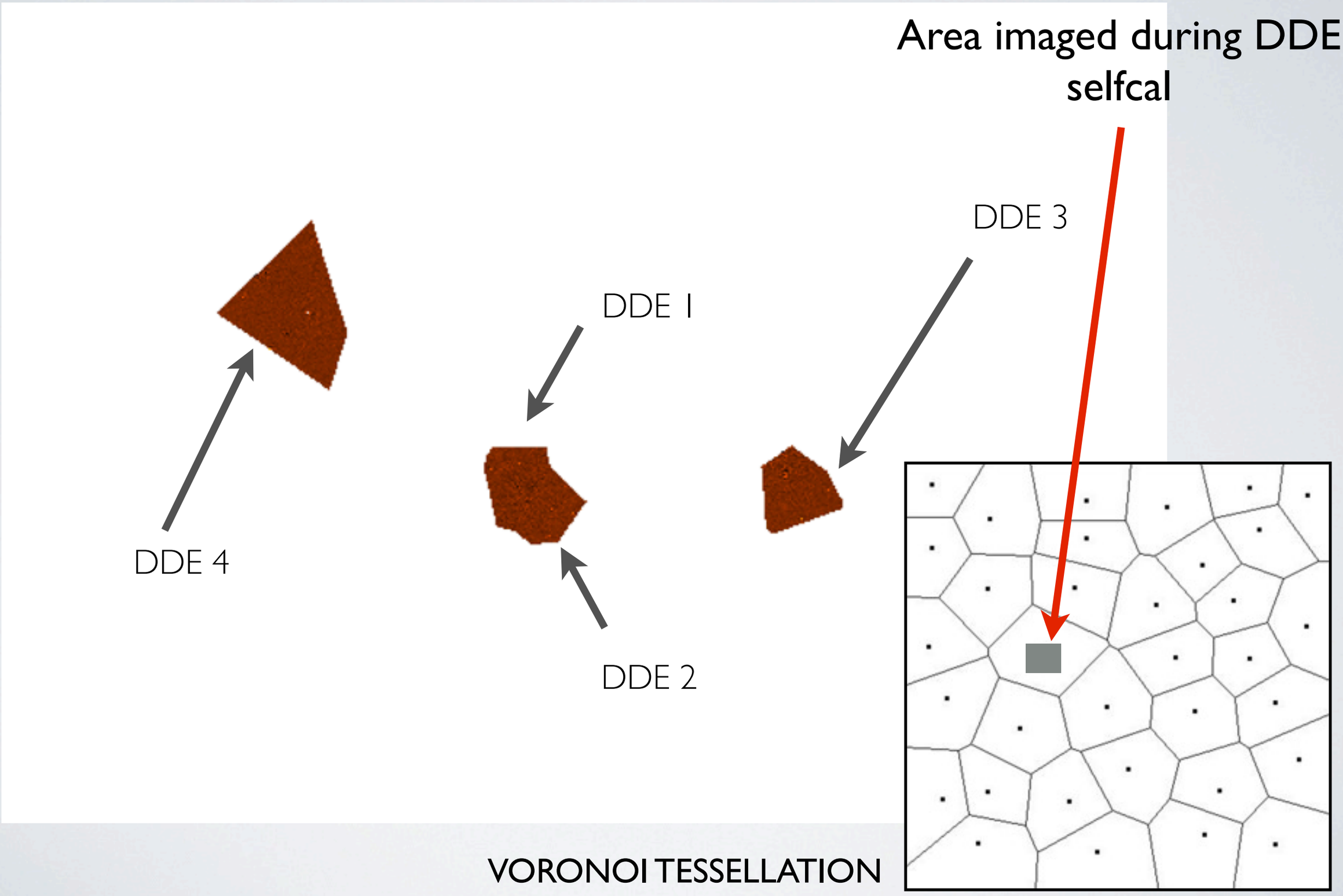
AFTER 4 DDE CYCLES



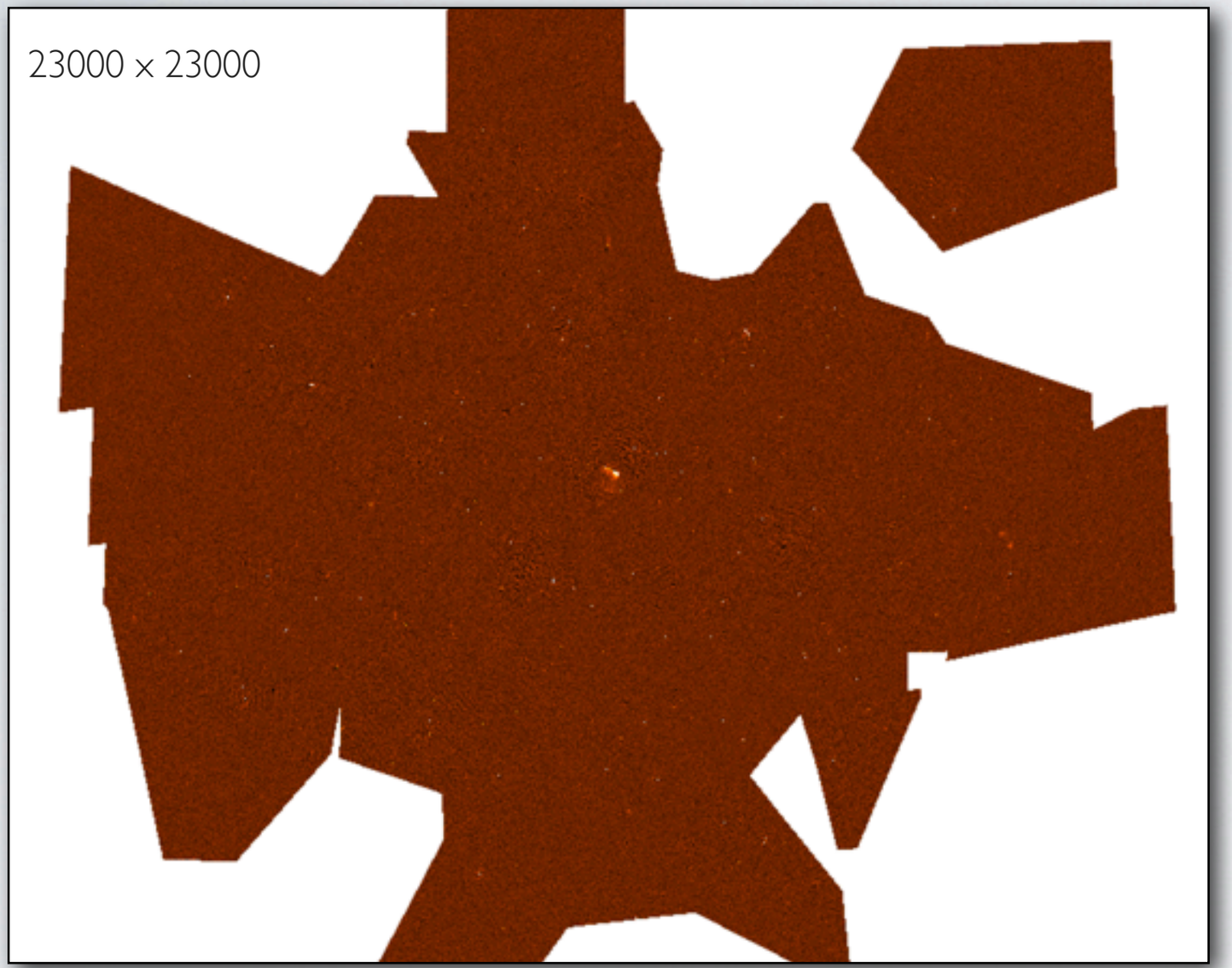


VORONOI TESSELLATION

AFTER 4 DDE CYCLES



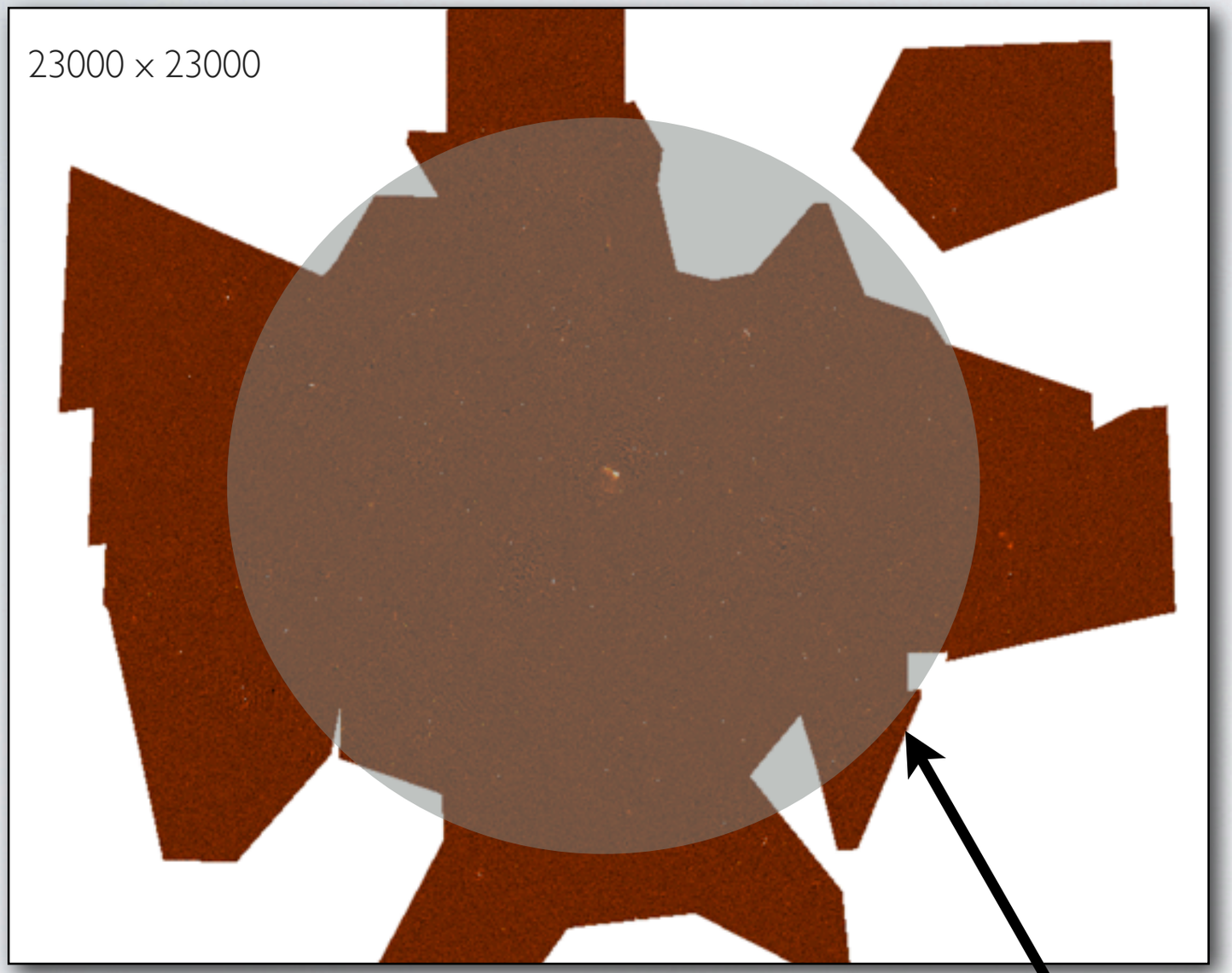
AFTER ~40 DDE CALIBRATORS



Primary beam correction

- Take the average primary beam (computed by awimager) and divide

AFTER ~40 DDE CALIBRATORS



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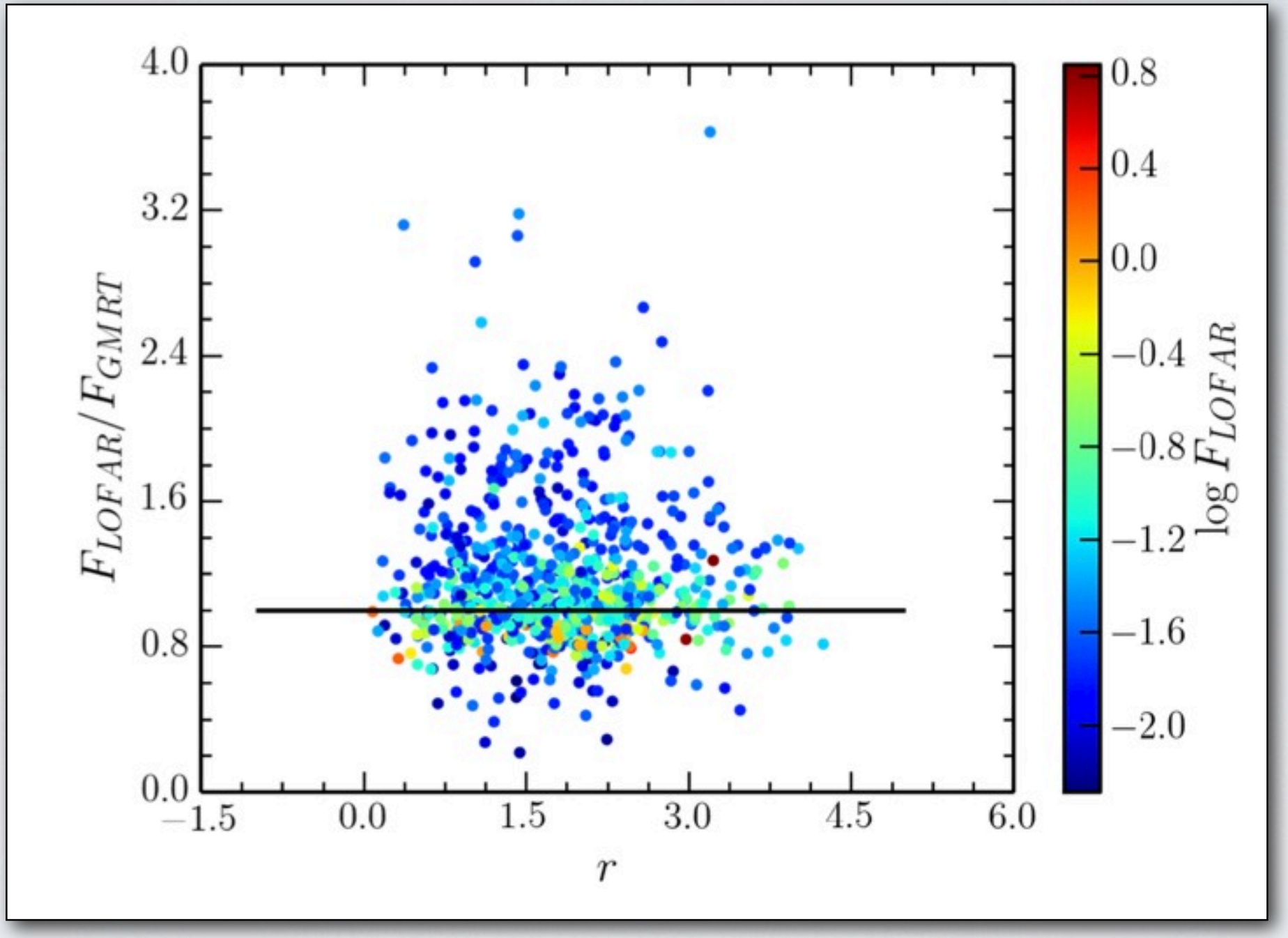
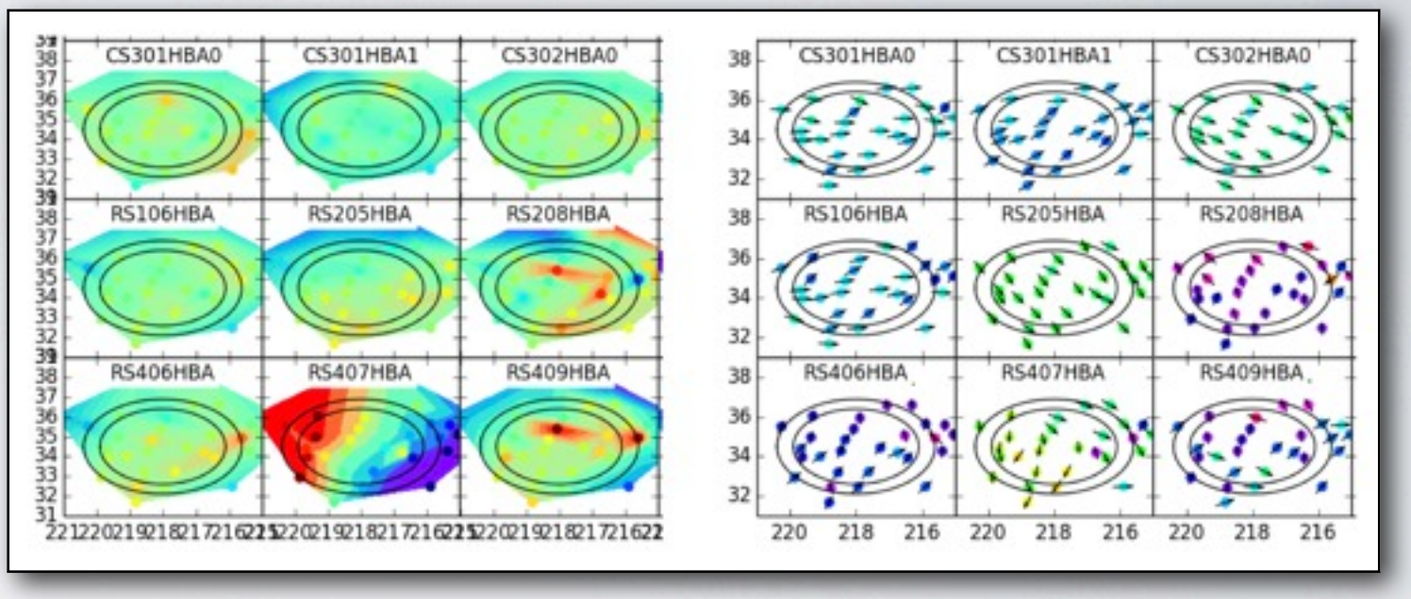
FLUXSCALE

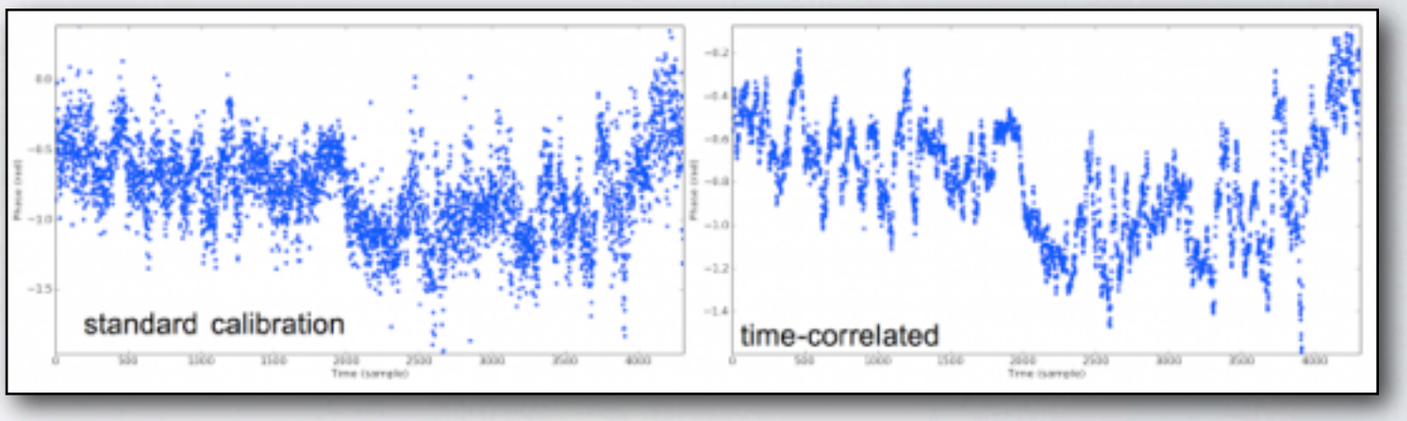


Bootes field (Wendy Willams)

ONGOING & FUTURE WORK

- Tier-2 depth (optimistic...)
- Tier-3 depth ?
- Amp+phase screens
- Stefcal + time-correlation
- All-sky issues: Automatization
  - User interaction
  - Calibration stability
  - Computing power (probably doable...)
- LBA





CODE

- Development version (Reinout, Wendy, Martin, Pepe)
  - Experimental options https://github.com/tammojan/facet-calibration/

Tested on ~15+ fields (by ~10 users)

- low-DEC
- bright source in FoV (3C295)
- complex diffuse emission (10-15 arcmin in size)
- deep field(s)
- field close (8 degr) to CasA

- FACTOR (CITT version, David Rafferty)
  - Code clean up
  - More parallelization
  - Pipeline/user friendly

https://github.com/revoltek/factor

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