Field-based Ionospheric Calibration

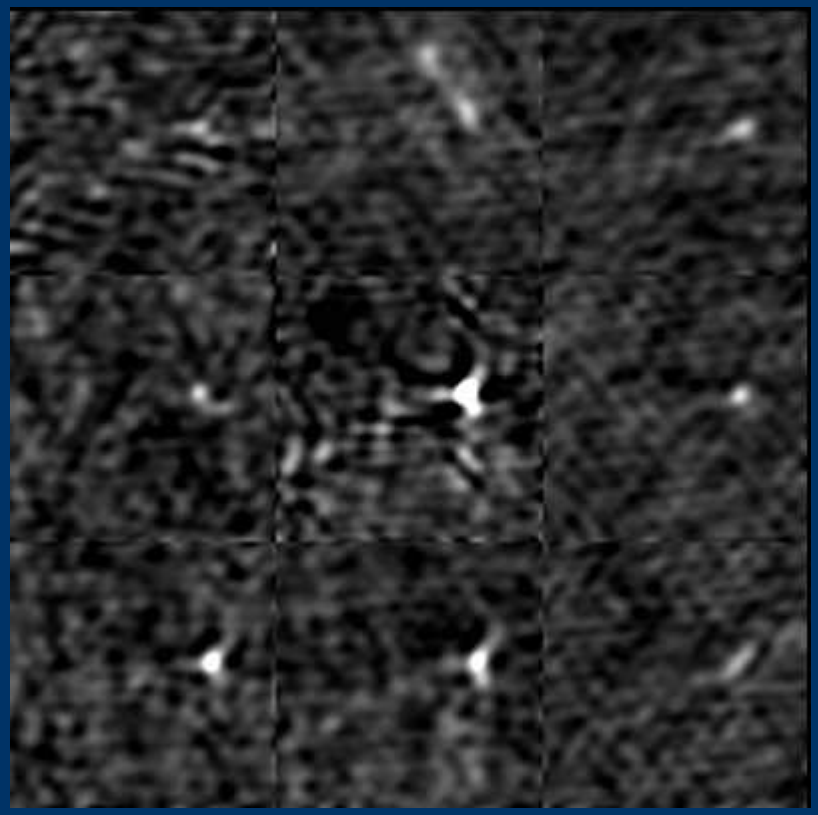
Bill Cotton, NRAO

- Overview of isoplanatism problem
- Description of Field-based calibration
- Limitations of technique

Isoplanitism

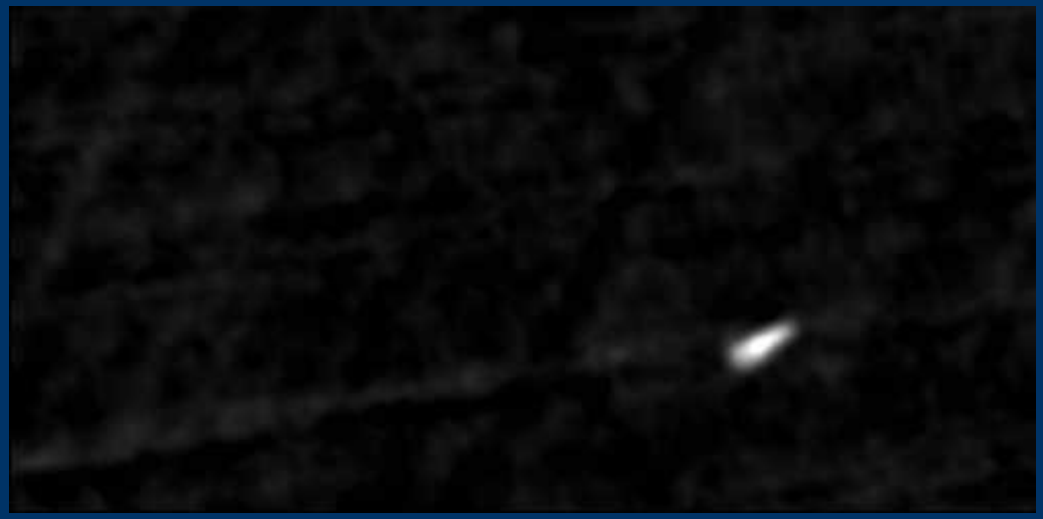
- At low frequencies ionospheric effects vary across the field of view
- Three regimes:
  1) Constant gradient across FOV
     all sources have same position shift
  2) Variable gradient across FOV
     different sources have different shifts
  3) Higher order phase variations across FOV
     sources defocused
- Self-calibration works in regime 1)
- Field-based calibration works in regime 2)
- Ionospheric correction may be needed up to 1 GHz

Time lapse movie of sources



Mosaic of 9 individual sources in 2 min intervals
Shows variable refraction and occasional defocussing

Time lapse movie of Virgo A



Sequence of 2 min snapshots of Virgo A into dawn

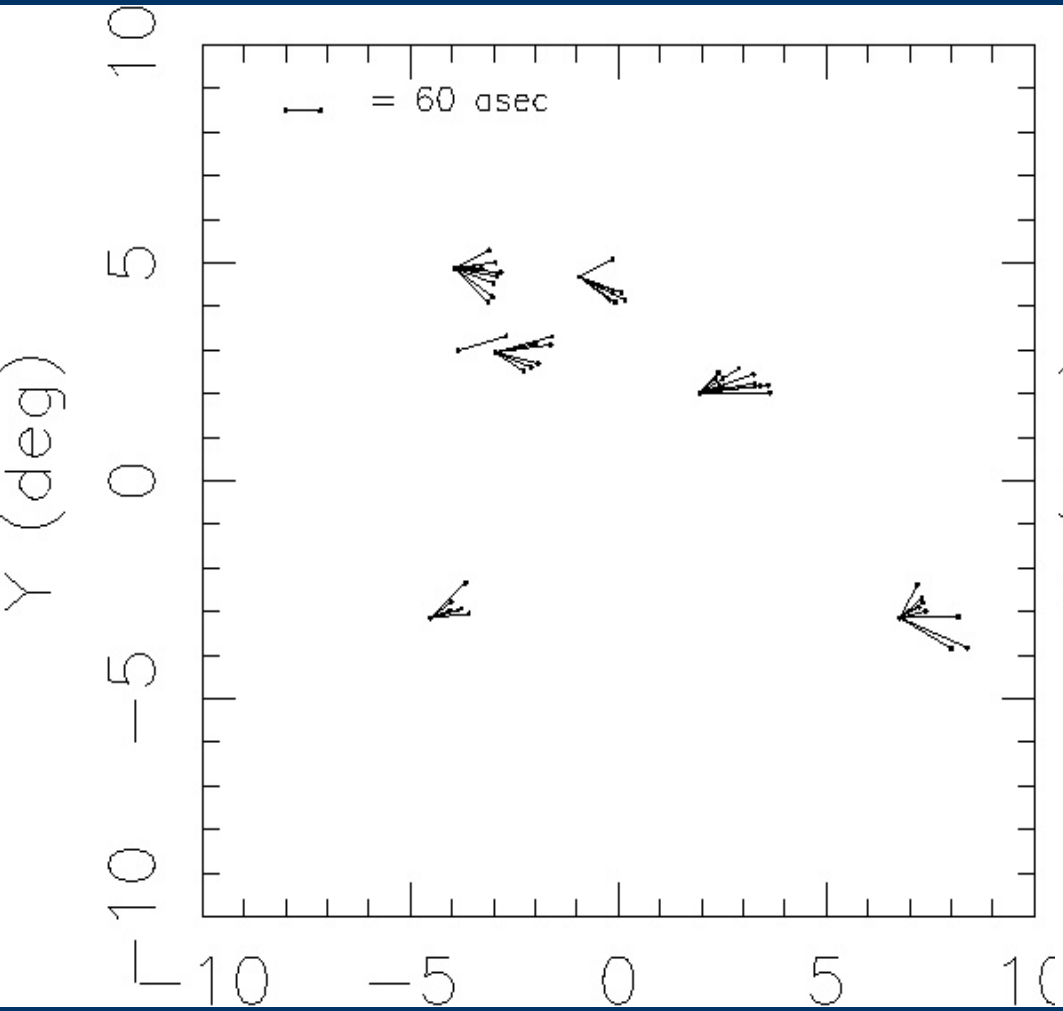
Field-based Calibration

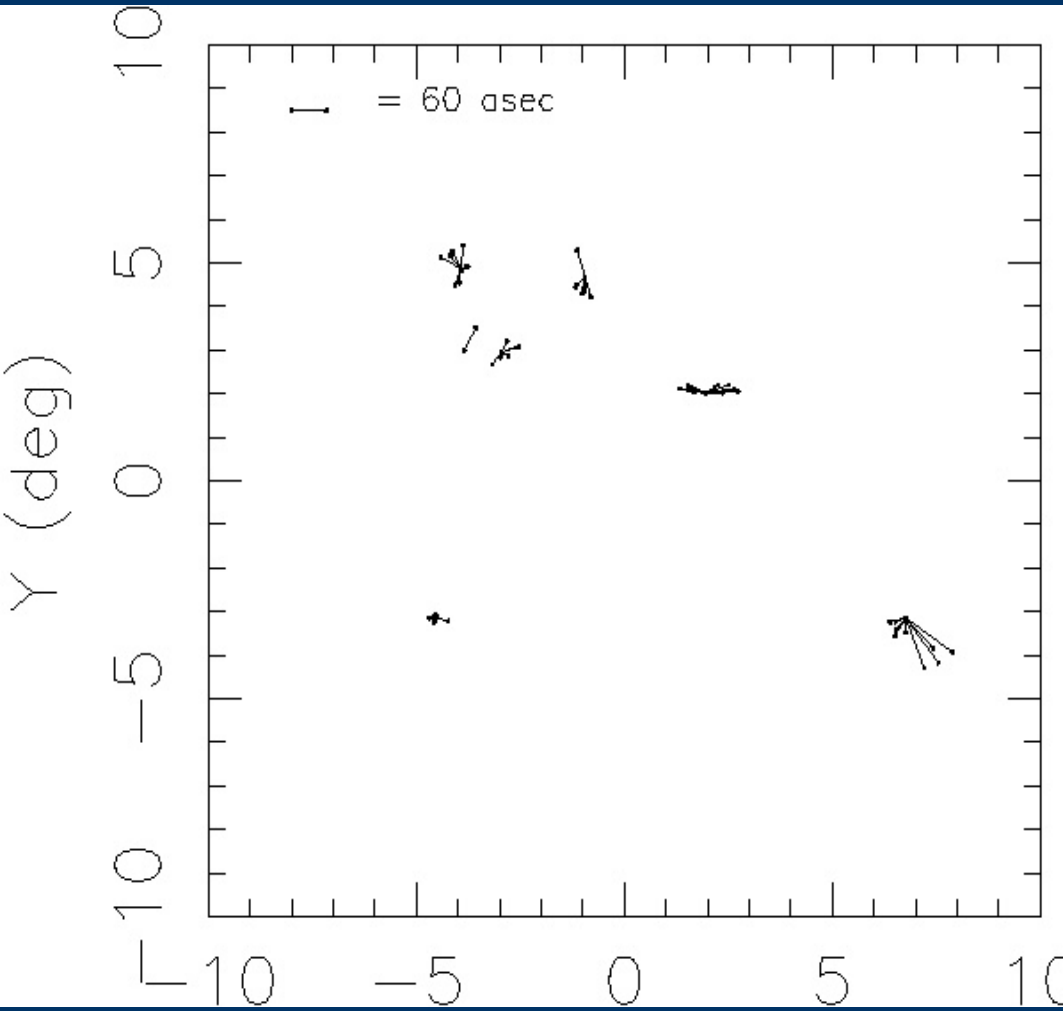
- Assumes phase screen across array projected from any direction is a linear gradient
- Positions of sources will be shifted but they will be undistorted
- Position offsets of bright sources in snapshots measure the phase gradients
- Fit ionospheric phase screen model to measurements of the gradient
- Use ionospheric model to dedistort sky in imaging

Field-based Calibration cont'd

- Ionospheric screen modeled with time sequence of low order Zernike polynomials
- Imaging uses Fly's Eye technique:
  - Facet size smaller than isoplanatic patch size
  - Evaluate ionospheric model at each facet center
  - Apply calibration appropriate to each facet center
- In subtracting CLEAN model from data, the position of each component is given a time dependent offset determined from the ionosphere model
- Implemented in Obit (http://www.cv.nrao.edu/~bcotton/Obit.html)

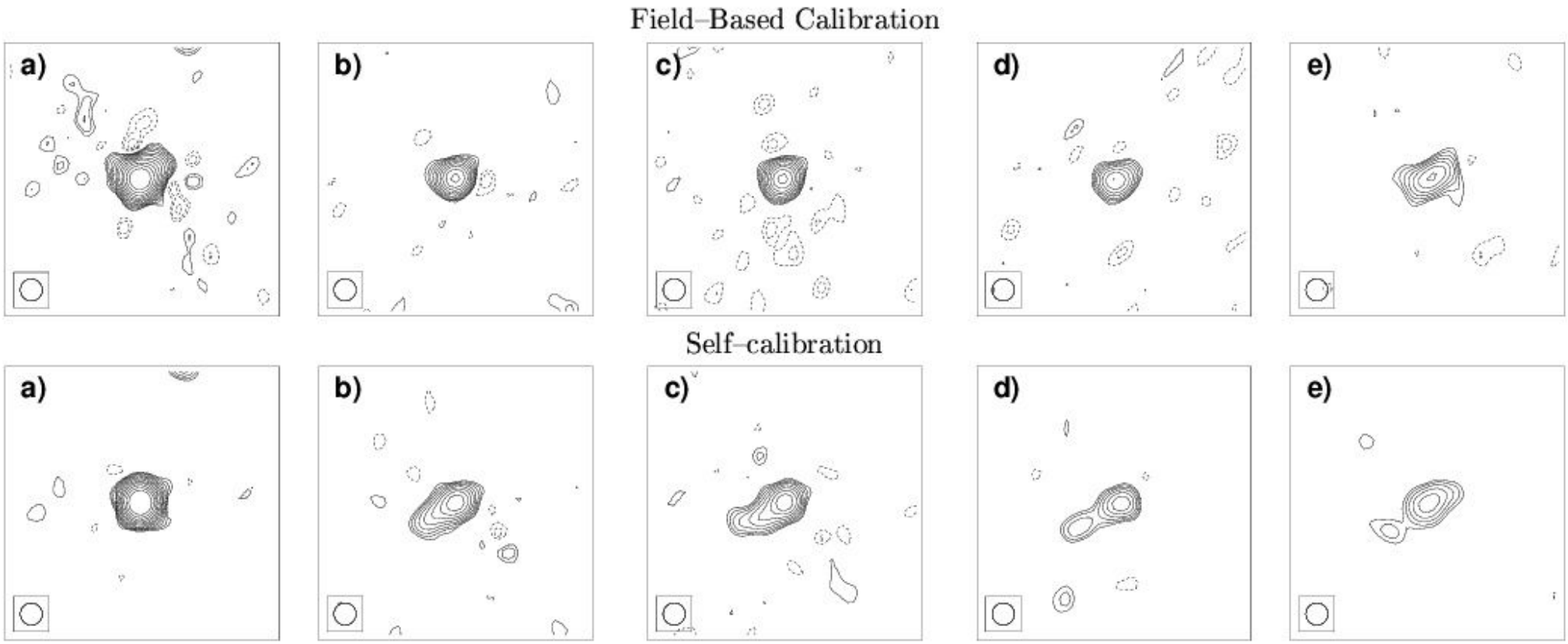
Example, VLA 74 MHz





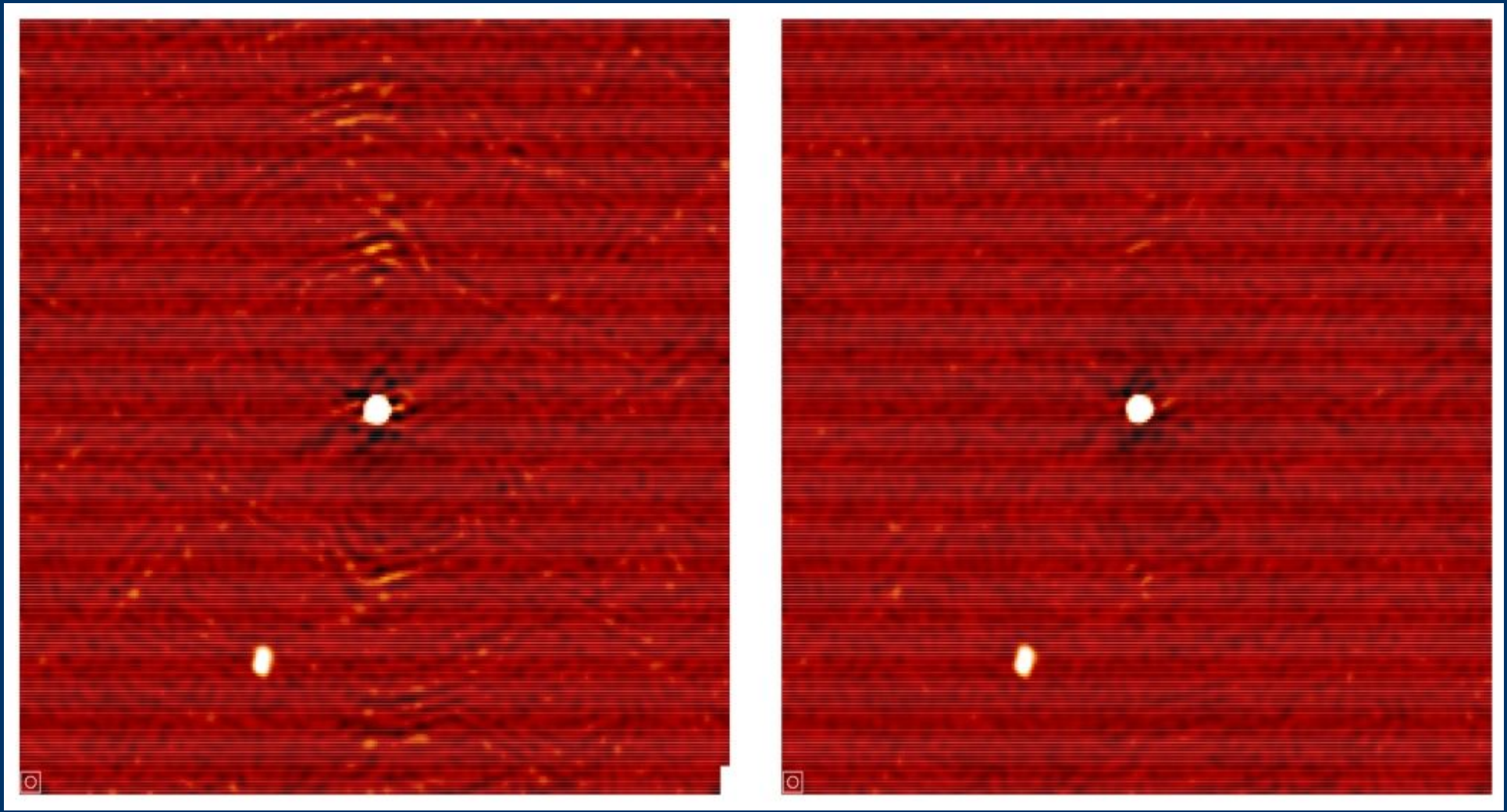
Time sequence of apparent position shifts (right) and after correction by fitted model

Example, VLA 74 MHz imaging



Comparison of source images using field based calibration and self cal, ordered by distance from a), the dominant source in the field

Example, VLA 327 MHz imaging



Comparison of self-cal (right) and field-based cal (left)

Limitations of Field-based Calibration

- Assumes linear gradient over array in any given direction
- The ionosphere is highly variable
- Fraction of the time the method is applicable depends on frequency, resolution, geomagnetic latitude.
- LOFAR & LWA will need higher order calibration much (all?) of the time, higher frequencies may be OK.
- SPAM technique by H. Intema at Leiden looks like a promising next step