Ionospheric Modeling: Comparing BBS with SPAM

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Low Frequency Observations: Problems Caused by Ionosphere

- Observing through the Ionosphere:
  - Ionosphere is very extended, inhomogeneous, partially ionized medium
  - Has a time- and frequency-dependent refractive index
  - Varies across the FoV of each antenna
  - These effects cause off-axis sources to shift around, smearing them in the final image (see Cyril's movie)

Adapted from talk of Huib Intema

The Ionosphere

- Partially ionized gas layer between ~50 and ~1000 km
- Mainly ionized by the Sun through UV and short X-ray
- Free electron density varies with space and time; electron density peaks at 300 km height:
  - TEC is the total number of electrons present along a path: 10^{16} electrons/ m^2 = 1 TEC unit
- Global large-scale variations are largest in amplitude (day↔night, solar storms; factor 10–100 variation in TEC)

Adapted from talk of Huib Intema

Ionosphere at low

- Radio waves experience a variable refractive index along their path through the ionosphere
- Propagation delay is the dominant effect causing a time & direction-dependent phase error per antenna
- The resulting differential phase errors in visibilities cannot be corrected for by applying a single calibration table
- Calibration needs to be incorporated into

Adapted from talk of Huib Intema

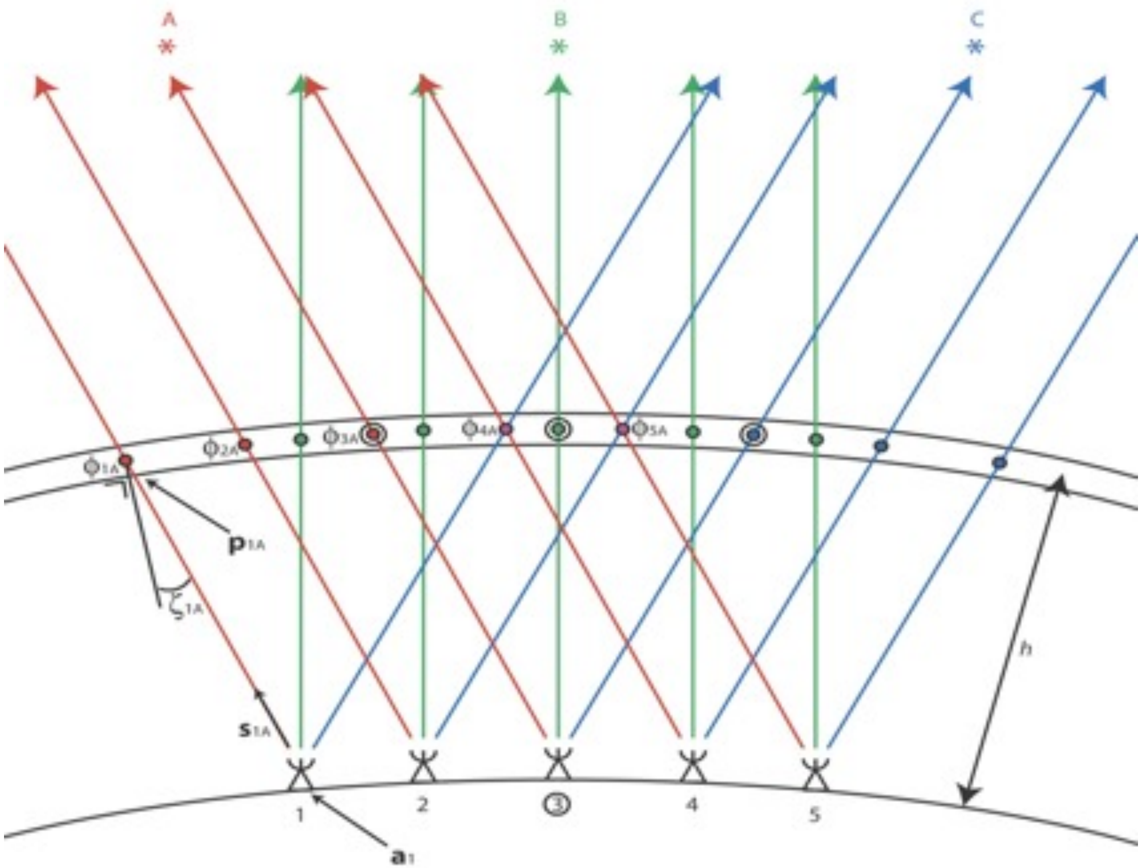
SPAM Recipe (**S**ource **P**eeling & **A**tmospheric **M**odeling)

Implemented by Huib Intema, based on work by van der Tol & van der Veen (2007) assuming that the Ionosphere model is a single-layer turbulence model

- Obtain instrumental phase calibration from calibrator observations
- Obtain initial calibration and sky model (e.g., through self-cal.)
- Subtract sky model from visibilities while applying calibration
- Peel calibrator sources to find phase solutions in different directions
- Project viewing directions on an ionospheric screen
- Fit a phase screen to the solutions

Adapted from Huib Intema / Bas van der Tol

SPAM single layer geometry



Huib Intema et al.

BBS (**B**lack**B**oard **S**elfCal) Ionosphere Implementations

- An implementation in BBS has been made by Maaijke Mevius.
  - No peeling, fits phase screen directly to visibilities
  - Fits Total Electron Content (TEC) values instead of phase
- Bas van der Tol has implemented the SPAM routine using BBS
  - Uses directional gains to obtain phases
  - Uses wide bandwidth of LOFAR to separate TEC and clock phase effects
  - Uses TEC phases to fit a phase screen using SPAM method
  - Resulting ionospheric effects can be removed

Compare BBS to SPAM

- To verify that directional gain in BBS is working as expected, we can use data that have also been run through SPAM
- Dataset: GMRT 153 MHz observation of A2256
  - We have (from Huib Intema) the phase (peeling) solutions from SPAM in 84 facets
  - Use BBS to calibrate the same data using the same model using directional gain

BBS vs. SPAM

- To make the fairest comparison, use SPAM/AIPS CLEAN components for BBS sky model (~8000 in total)
- Use “patches” in BBS to group the sources by facet
- Calibrate, then subtract all sources except those in facet of interest
- Use directions gains to find phase solutions for facet

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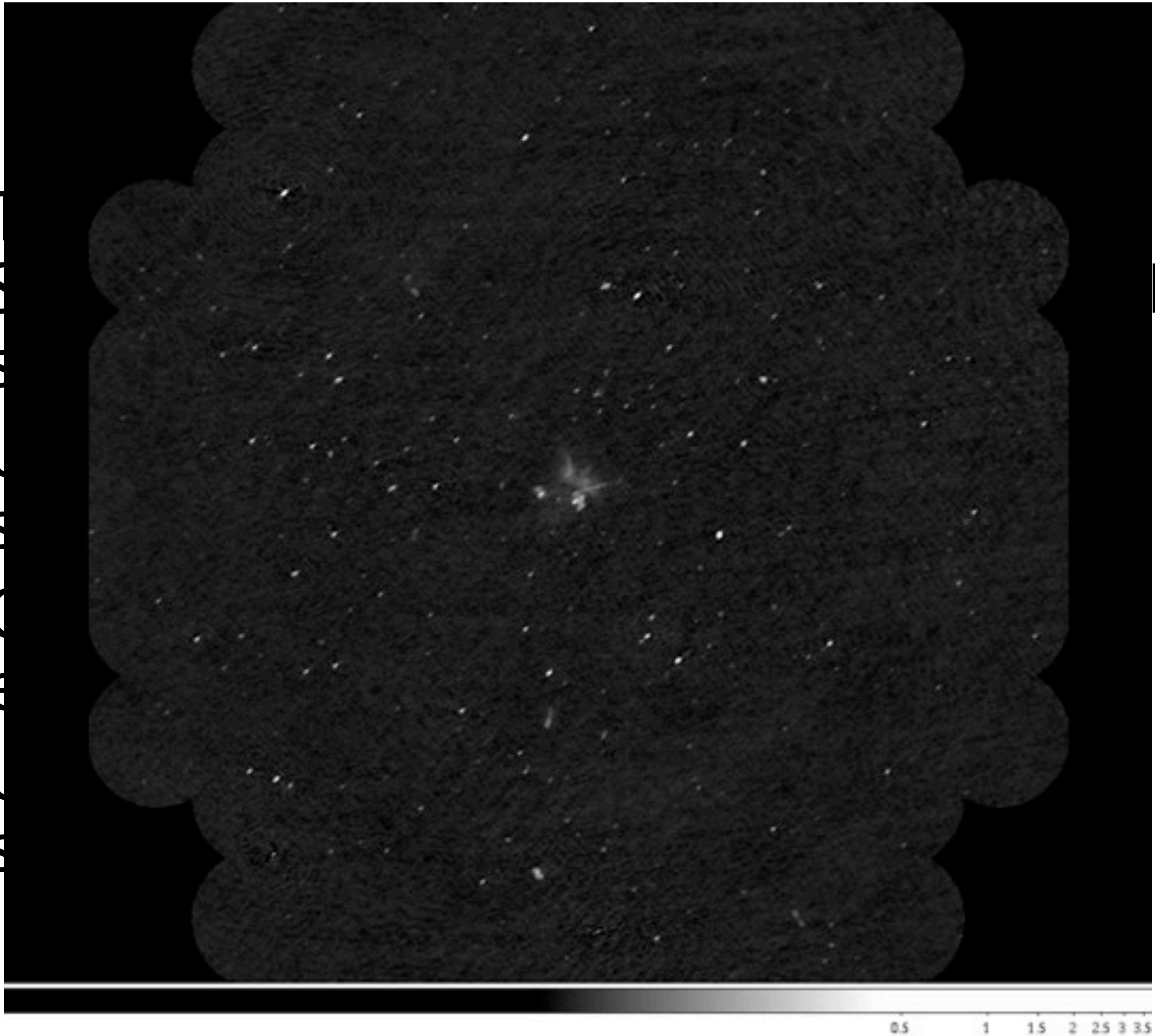

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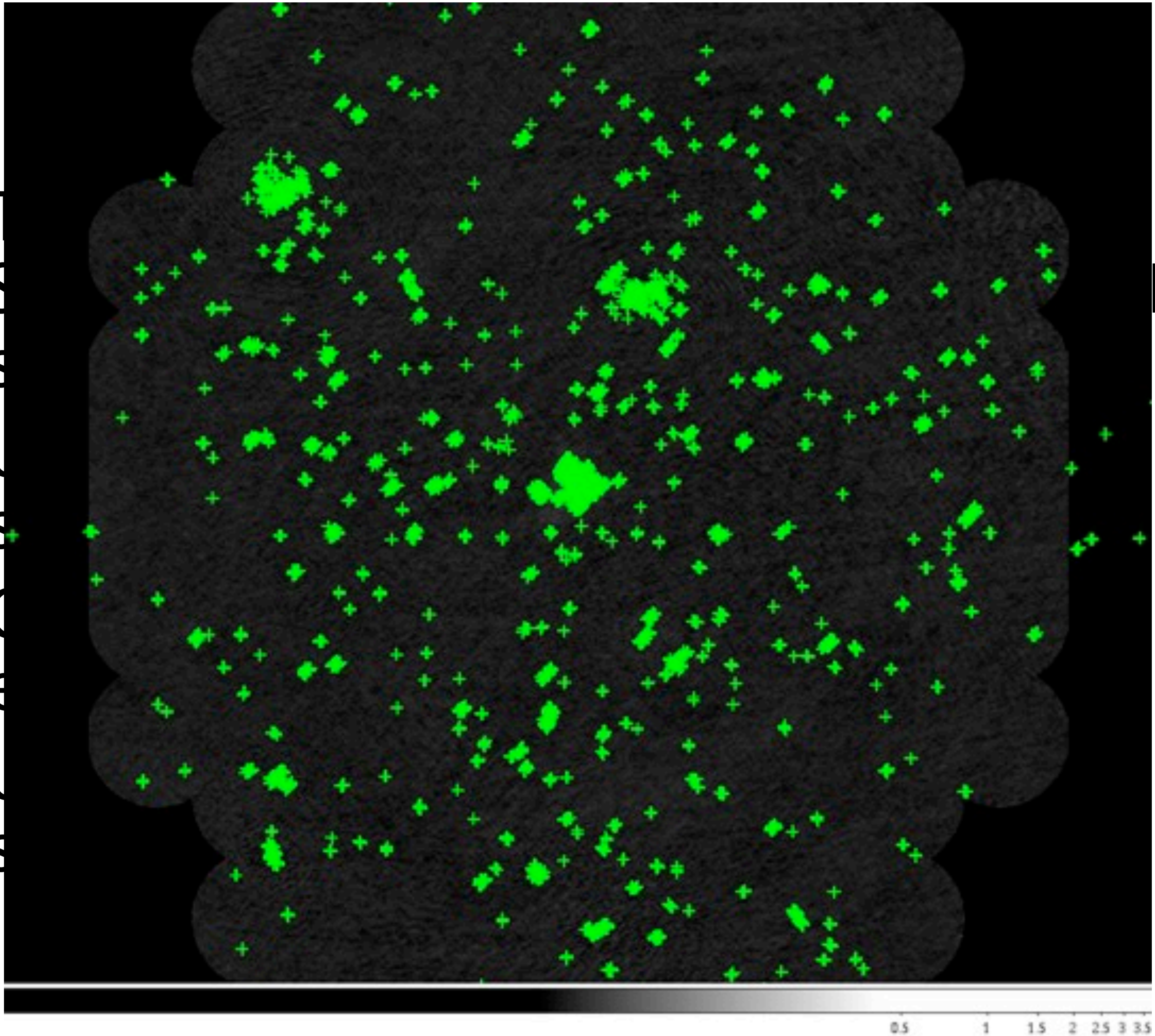

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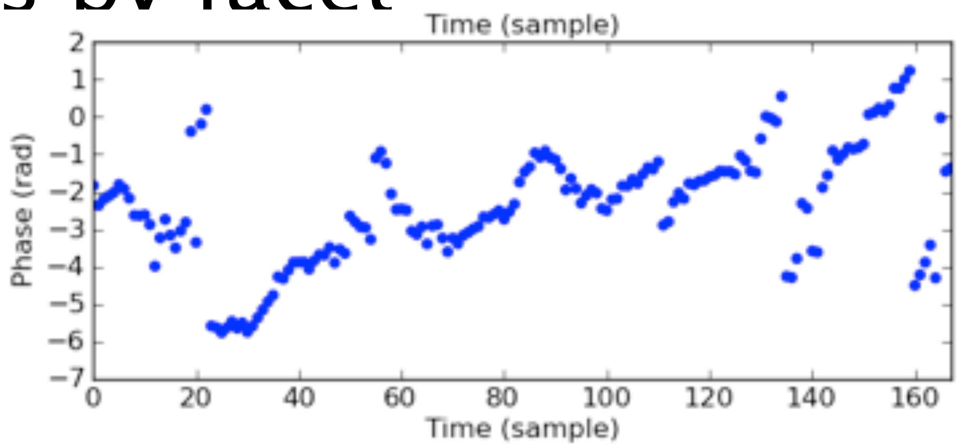

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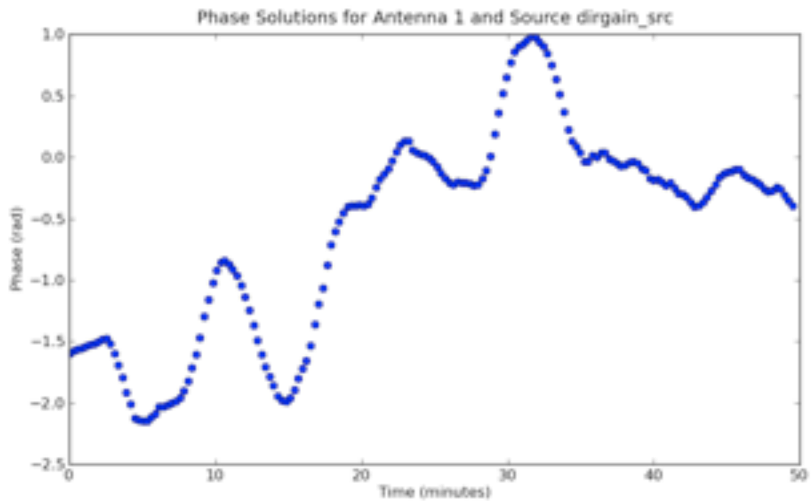

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