LOFAR Calibration

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ASTRON

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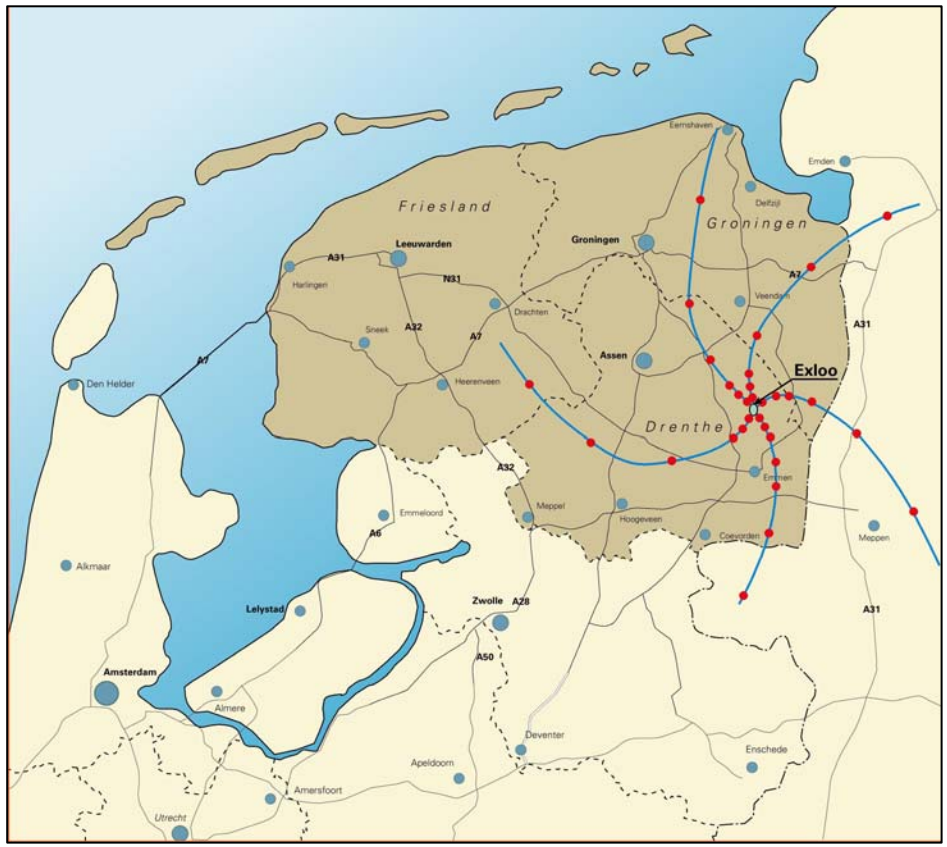
- Radio Telescope
- Low Frequency Array
- 30 – 240 MHz
- 32 core and 45 outer stations
- longest baseline: 100 km
- 96 Low Band and 96 High Band Antennae per station



LOFAR Antennae

LBA: 30 – 90 MHz

HBA: 120 – 240 MHz

Data flow

RCU Board
A/D
Beamformer
RSP Board
Filter
Filter
Filter
Filter
Σ
Output control
GbE
Backplane & RF Shield
Distributed Beamforming
WAN
Station GbE switch (24 ports)
RSP board 24
WAN fibre connections
Station 77
GbE switch fabric (231 outputs)
Central Processing Facilities
Sync.
Buffering
Delay
Correlator / Beamformers (Blue Gene /L)
Ionosphere Calibration RFI Mitigation
Storage
calibration
Image creation
User applications
Archive Export and GRID

Calibration Challenges: the data

Raw visibilities at full resolution: ~ 6.5 TByte

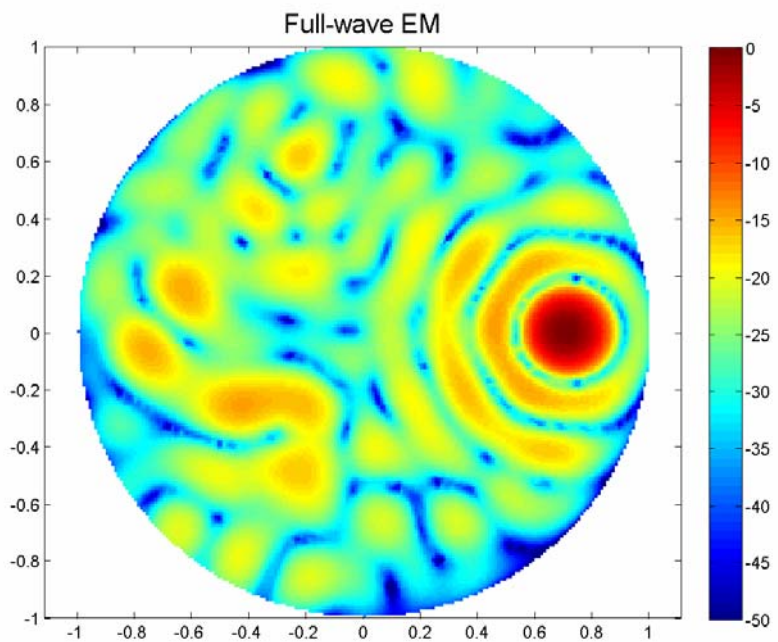
- 5 hr. = 18000 sec.
- 77 stations = 2926 baselines
- 1 beam = 4000 1kHz channels
- 4 correlations

- Image cubes can be 250 GBytes
- Correlation using a ~34 TFlop/s Blue Gene/L Supercomputer
- Off-line post-processing using a 500 node cluster and part of the Blue Gene/L (~10 TFlop/s)

Calibration Challenges: the stations

- the variability of the station beams (in time and frequency as well as over stations)
- instrumental polarization: X and Y voltage beam differ
- high station beam sidelobes

LOFAR Calibration
=
All Sky Calibration!

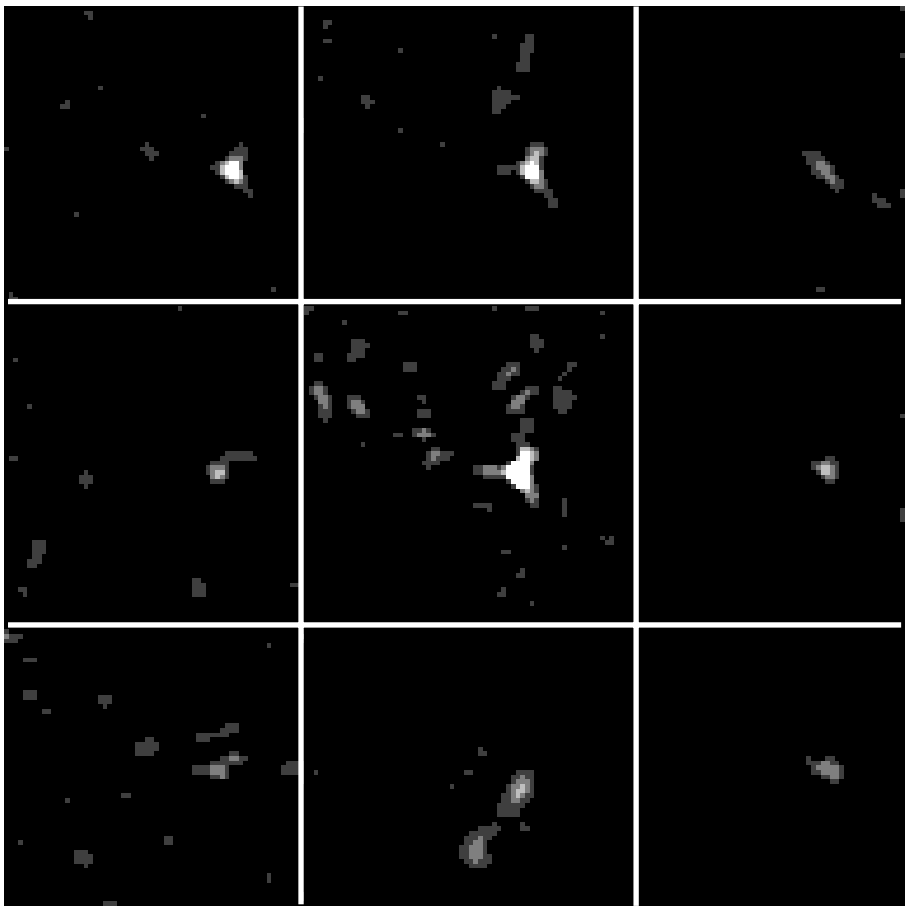


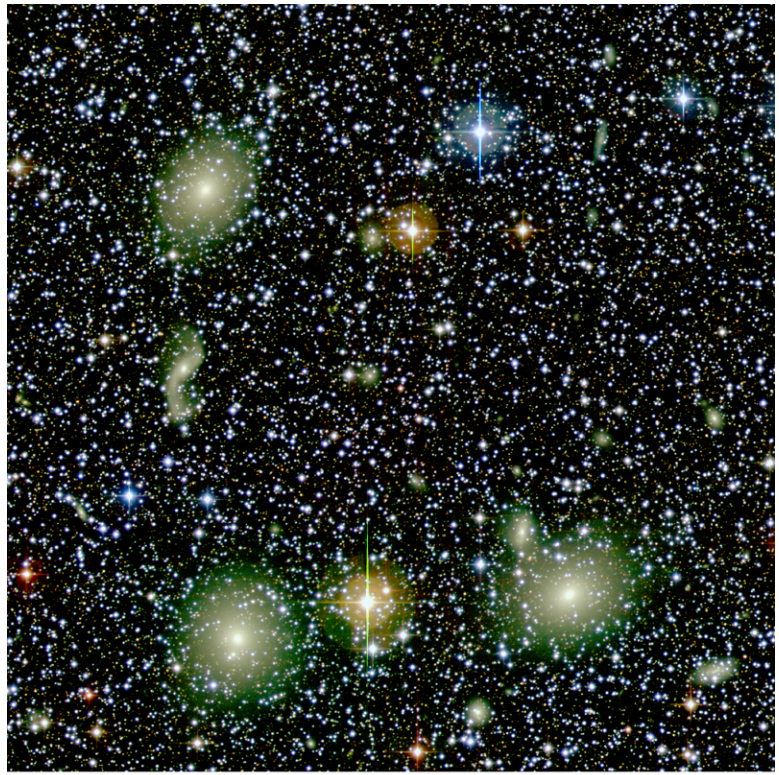
LBA Station beam @ 30 MHz

Calibration Challenges: the sky

pathological ionosphere

(74 MHz VLA; Lazio)





View towards the Great Attractor (Detail)
(MPG/ESO 2.2-m + WFI)

ESO PR Photo 46d/99 (21 December 1999) © European Southern Observatory

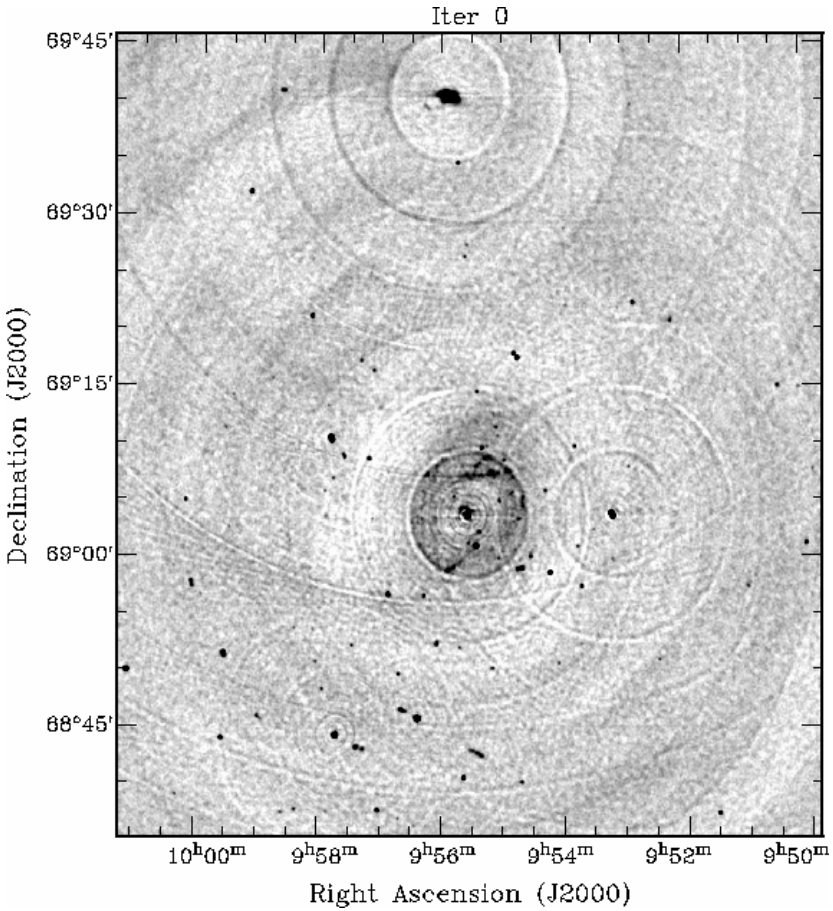
crowded fields

Calibration Principles

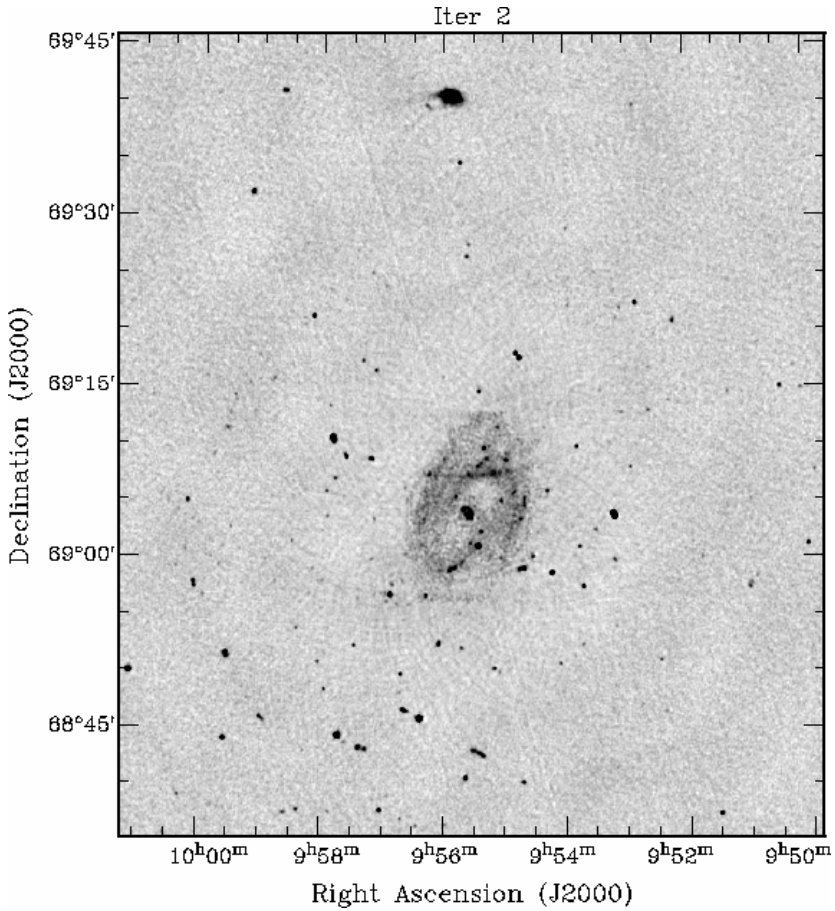
$$\vec{V}_{ij}(u,v) = \sum_k \int df \int dt \left(J_{ik} \otimes J^*_{jk} \right) S \vec{I}_k$$

- Generalized Self-Cal using the Measurement Equation:
  - Instrumental model
  - Ionospheric model
  - Sky model
- Full treatment of Polarization
- Calibration for Image Plane Effects
  - ionosphere
  - beam
- Calibration is the ability to subtract (foreground) sources from the (visibility) data

Image Plane Effects



standard selfcal entire field



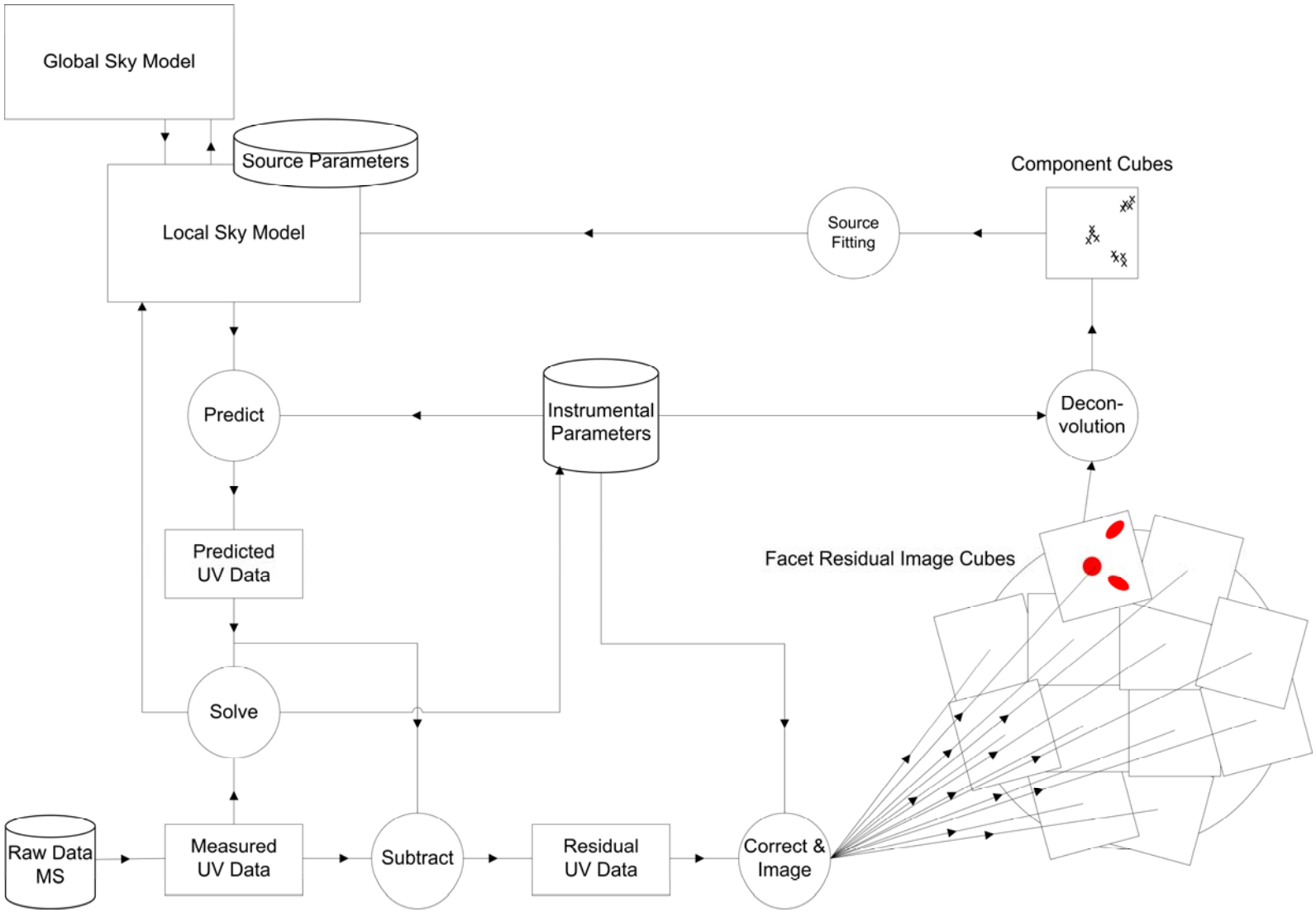
2-patch peeling (miriad)

(Result by Tom Oosterloo)

Calibration Strategy

- Start with an initial sky model
- Coarse Calibration
  - Bandpass division
  - Flagging
  - Gain calibration and fitting of ionospheric phase model
- Calibration of image plane effects: Major Cycle
  - Cat. I Peeling & additional flagging
    - Estimation of station voltage beams
    - Estimation of Ionospheric Faraday rotation
  - Subtraction of Cat. II sources
  - Data correction and imaging per Facet
  - Deconvolution & correction for (averaged) image-plane effects
  - Source updating and source extraction

Major Cycle


Global Sky Model
Source Parameters
Local Sky Model
Source Fitting
Component Cubes
Predict
Instrumental Parameters
Decon-volution
Predicted UV Data
Facet Residual Image Cubes
Solve
Raw Data MS
Measured UV Data
Subtract
Residual UV Data
Correct & Image

Concluding remarks

- LOFAR Calibration is more general than for the traditional radio telescopes
  - Station beams and ionosphere are image plane effects
  - Full polarization needs to be considered
- All tricks of the trade need to be applied
- New tricks need to be learned
  - BBS: Optimised software system for bulk data reduction
  - MeqTree: Flexible software system for experimentation and development of algorithms and strategies
- LOFAR Calibration will be quite some work
- But we'll get there … in the end

- For first data see Poster P4.24 by Adriaan Renting