LOFAR lessons learned

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LOFAR

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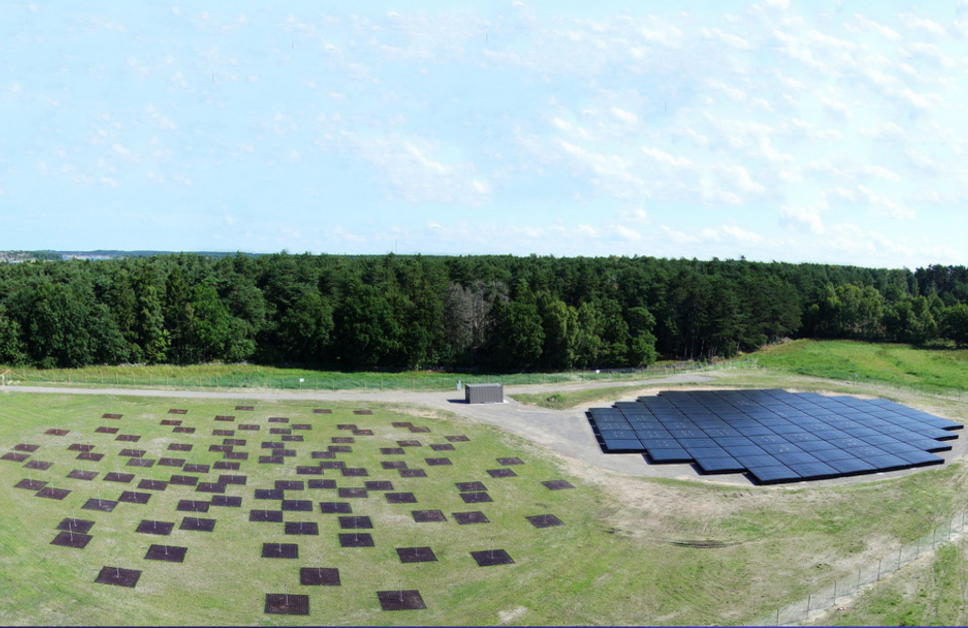

Sensitivity is key

HBA (110–250 MHz)

- Enough SNR to calibrate in 2 sec everywhere
- Ionospheric phases change at approximately 1 rad per 15 sec

LBA (10–80 MHz)

- Around 50 MHz:
- Need tens of seconds to calibrate at most locations
- Ionospheric phases change at approximately 1 rad per 5 sec

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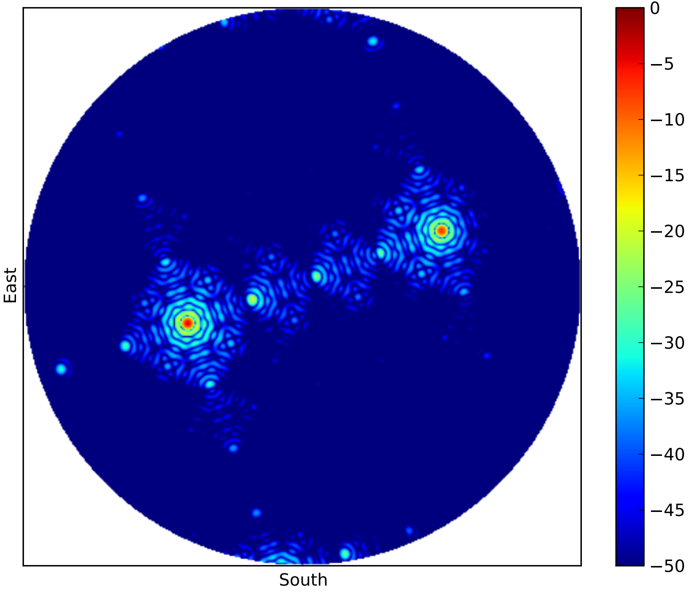
LBA

- Semi-random, spatially tapered
- Sidelobes RMS close to 1/N everywhere
- Great for all-sky single station imaging
- Sees entire sky all the time in LOFAR-NL observations
- Brightest source is usually outside primary beam

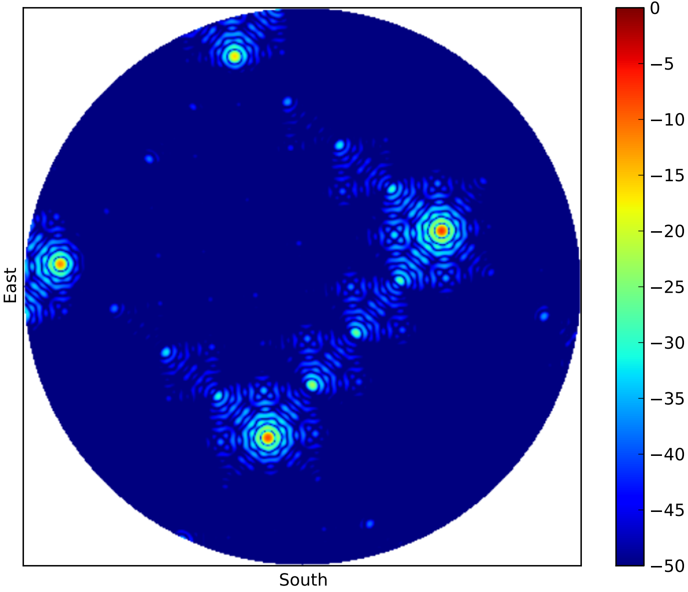
HBA

- Regular spacing, dense at bottom of band.
- Extremely low side lobes
- Brightest source is (nearly) always inside primary beam
- Extremely high grating lobes
- Rotate stations to reduce gratings in baseline beams
- Tiles are lousy for all-sky single station imaging
- Great way to get rid of distant sources in regular imaging

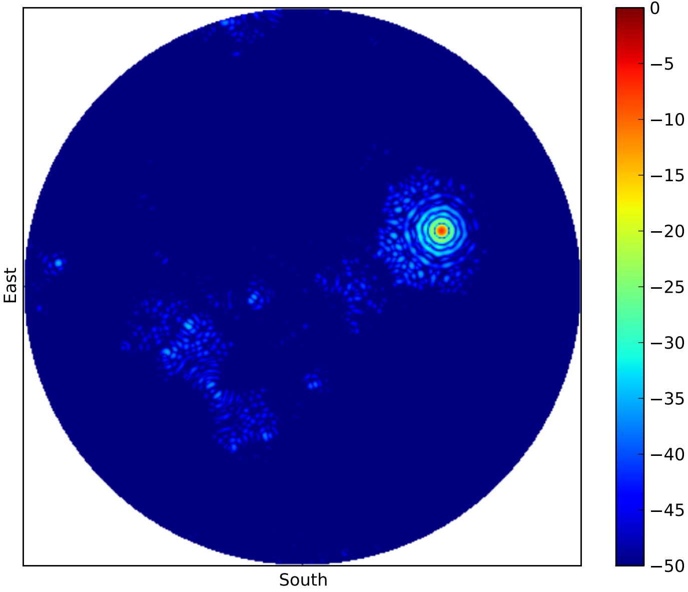
SE607 beam 240 MHz (dB)



UK608 beam 240 MHz (dB)



SE607-UK608 beam 240 MHz (dB)

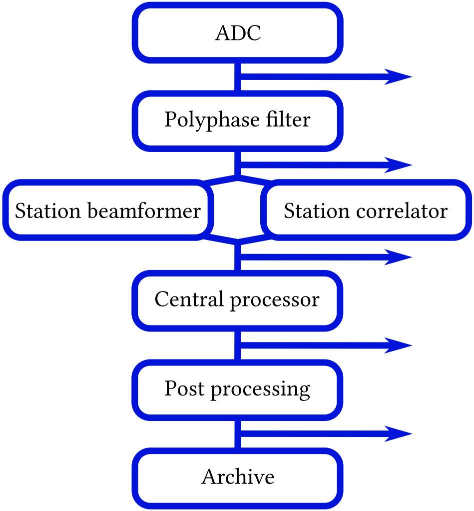


Different!

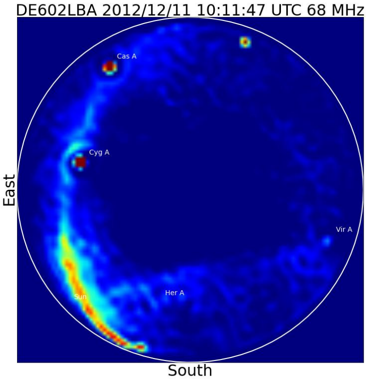
- Core: 24 times 16 = 384 dipoles
- ≈30 m diameter
- Remote: 48 times 16 = 768 dipoles
- ≈40 m diameter
- International: 96 times 16 = 1536 dipoles
- ≈55 m diameter

- VLBI OK (smearing helps)
- Wide field imaging problematic
- Hard to correct for different beams well enough
- Spatial-scale dependent flux scale variations across field(!)
- Workaround: make remotes smaller
- Beams too big for WF imaging: 3D corrections costly
- Preferred for imaging: make core stations bigger

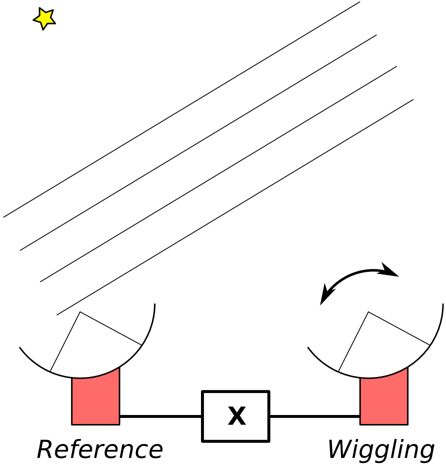
Full control / Intermediate products



- At stations: everything has CLI
- Intermediate data easily available
- At all processing stages
- Helps debugging
- Helps system comprehension
- Helps algorithm development

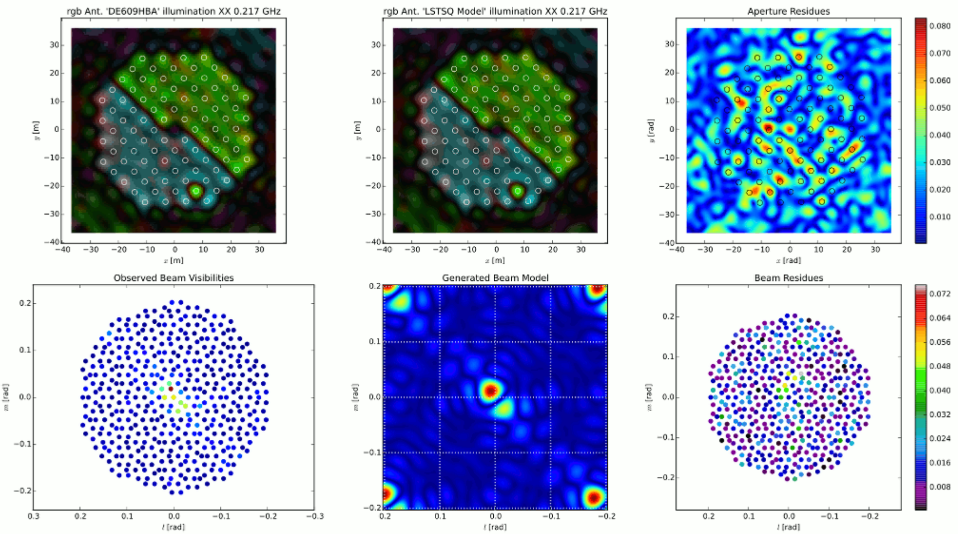


- All-sky imaging/calibration
- Multi-source sky model
- Sensitive to local RFI
- Must average over model errors (24h)
- Expensive data reduction



- Measure voltage beam pattern
- Dishes: scan target dish across cal source
- Dishes: correlate with reference station pointing at cal source
- Aperture arrays: use simultaneous multi-beaming
- Fourier transform voltage beam: aperture map!

DE609HBA



rgb Ant. 'DE609HBA' illumination XX 0.217 GHz
rgb Ant. 'LSTSQ Model' illumination XX 0.217 GHz
Aperture Residues
y [m]
x [m]
y [rad]
x [rad]
Observed Beam Visibilities
Generated Beam Model
Beam Residues
m [rad]
l [rad]

Long baselines essential for HDR imaging

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- Sky model generally best at 3–30 kλ baselines
- Calibration: mostly remote-remote and remote-core
- EoR analysis: only core-core
- Reduces DoF taken away from science data
- 5–100 km baselines required for most source subtraction
- 500+ km baselines required for subtraction of brightest sources.
- LOFAR remote uv-coverage (14 stations) too poor for complicated fields.
- SKA will do 10$\times$ better for same uv track length
- SKA LOW uv track length likely shorter because antennas more directional over most of band

Other Very Important Lessons

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- Have rudimentary, but complete observation management chain available during commissioning (from proposal to archive)
- Post processing and archiving determine observing efficiency
- Top priority: rapid data reduction/selection
- Digitize early: prevent cable delay changes before beam forming
- Do not use cross-correlations between stations that have ADC's in same subrack (or even cabinet)
- Assume at least 1 in 30 stations is not there in typical science runs
- Only purchase in bulk once final hardware has been in field for at least a full year
- Land surveyors do not know how to survey land
- 6 cm RMS surface accuracy looks like WW-I battle field
- Buzzards are a mixed blessing