MSSS (MS^3)

or

a calibration survey for LOFAR

Ger de Bruyn [1,2] & Ronald Nijboer [1]

(LOFAR calibration PS & PM)

19Mar08 / 21Aug08 /19May09

[1] ASTRON, Dwingeloo & [2] Kapteyn Institute, Groningen

LOFAR Technical Status Meeting, Dwingeloo, 19May2009

Outline

- Commissioning phases
- Why do an MS^3
- How to do MS^3 and MS^3 Products
- MS^3 array configuration and their uv-coverages
- MS^3 specifications
- Undecided issues
- Important pre-MS^3 activities

Commissioning phases

We can distinguish 3 different phases for commissioning activities:

- Before MSSS: Jun-Oct 2009 from 1 ⇒ 20 stations

- During MSSS: Nov-Jan 2010 20 stations (+ 3-5 European)

- After MSSS: Feb-Aug 2010 30 ⇒ 40 stations

Assuming start of regular LOFAR observing in Sep 2010 ?

Why do a MS^3 ?

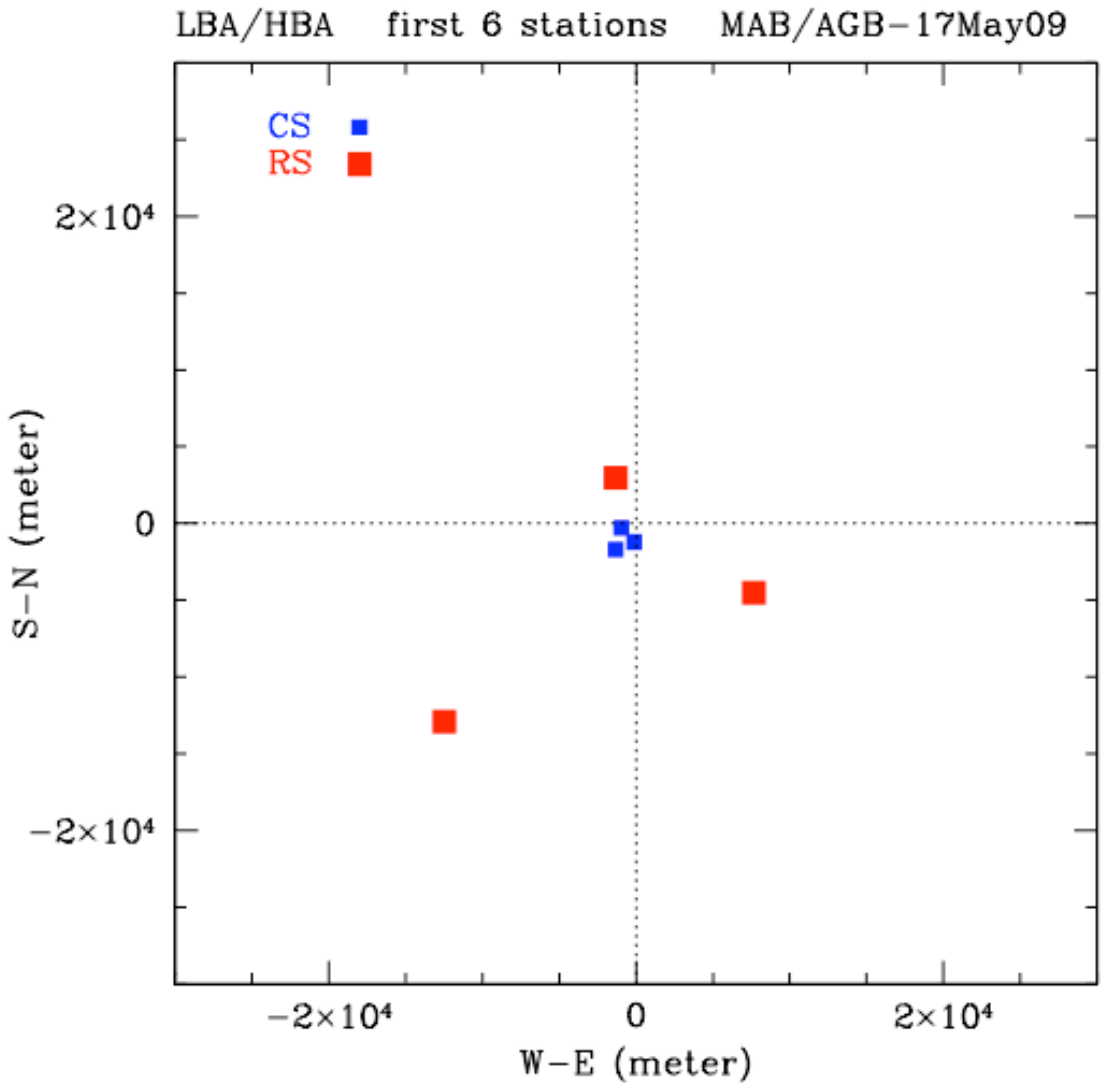
LOFAR needs a *Global Sky Model (GSM)* for the northern sky which

- has a proper flux scale
- has validated (initial) source parameters (spectrum, structure, ..)
- is astrometrically correct to better than 0.5”
- interfaces efficiently to calibration & imaging pipeline (through LSM)

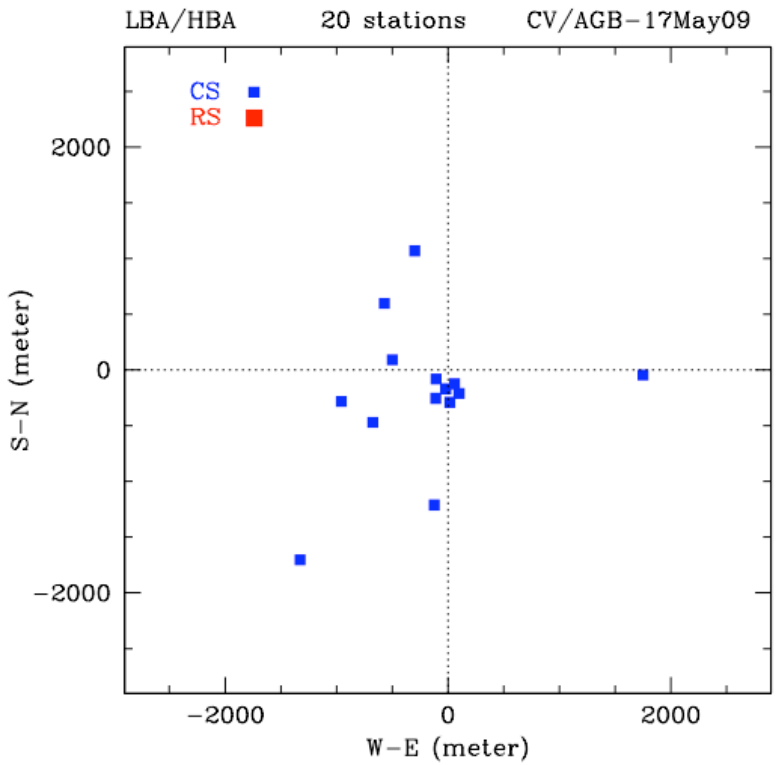
Moreover, carrying out MS^3 will

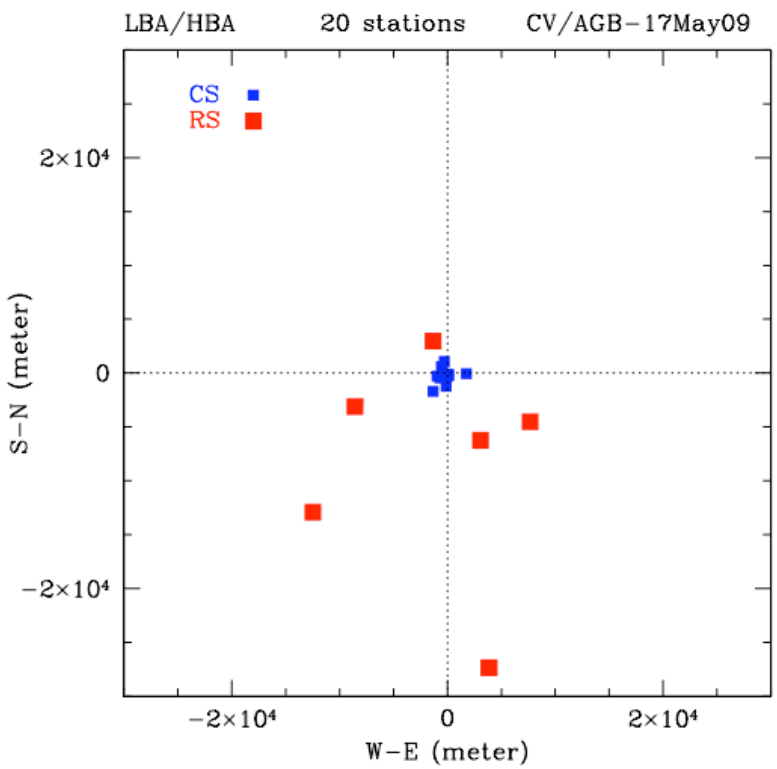
- create a ***joint focus for activities***
- integrates scheduling, monitoring, processing, calibration & imaging
- test all KSP-pipelines
- provides a field-test for storage and processing resource needs
- provide the conditions for a rehearsal of full LOFAR operations

Early array configuration: 6 stations, late Jul09 ?



MSSS configuration: 20 stations, Oct09





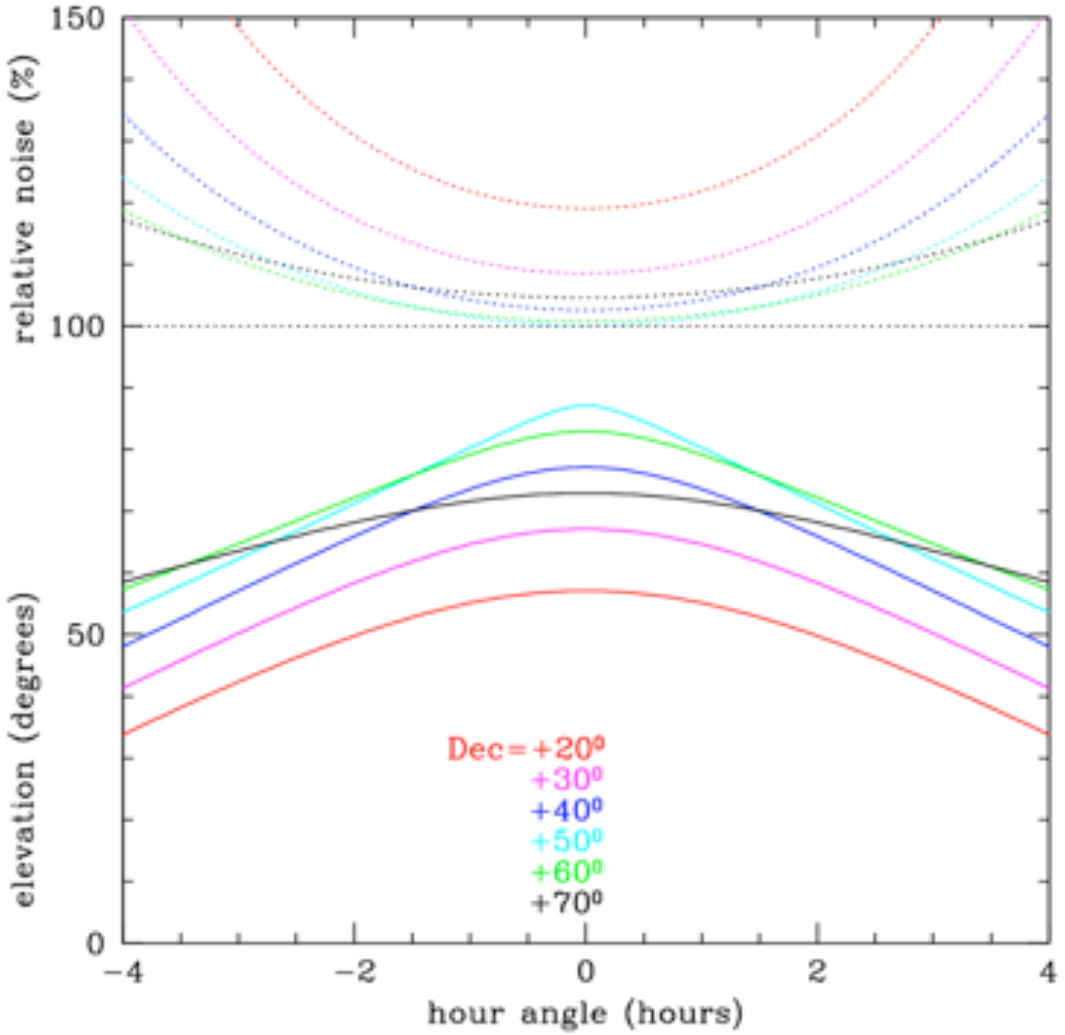
HA-range : uv-coverage vs projection

Ideallymany snapshots at widely range of hour angles, say -4h to 4h

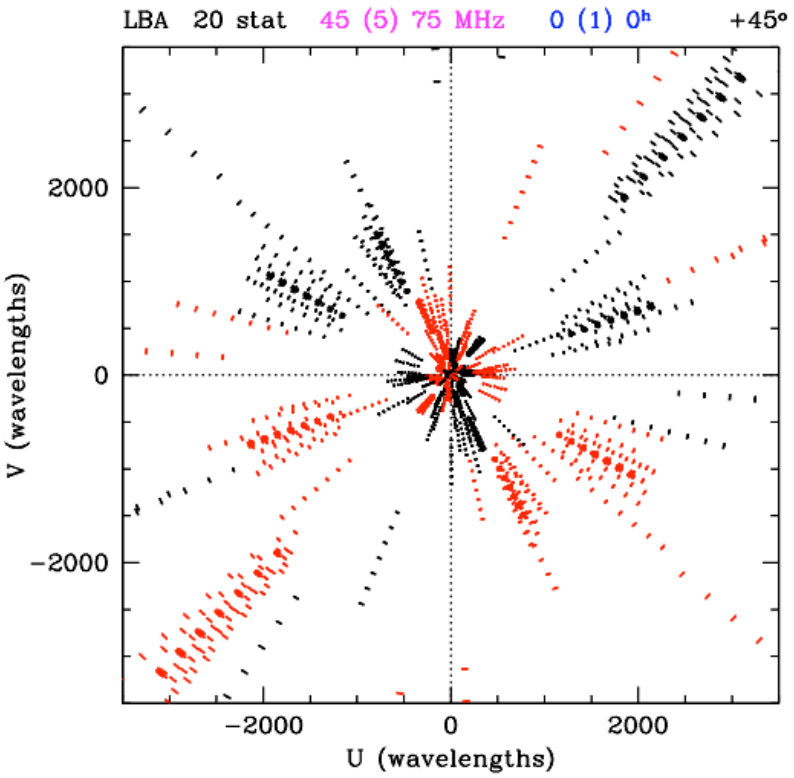
BUT

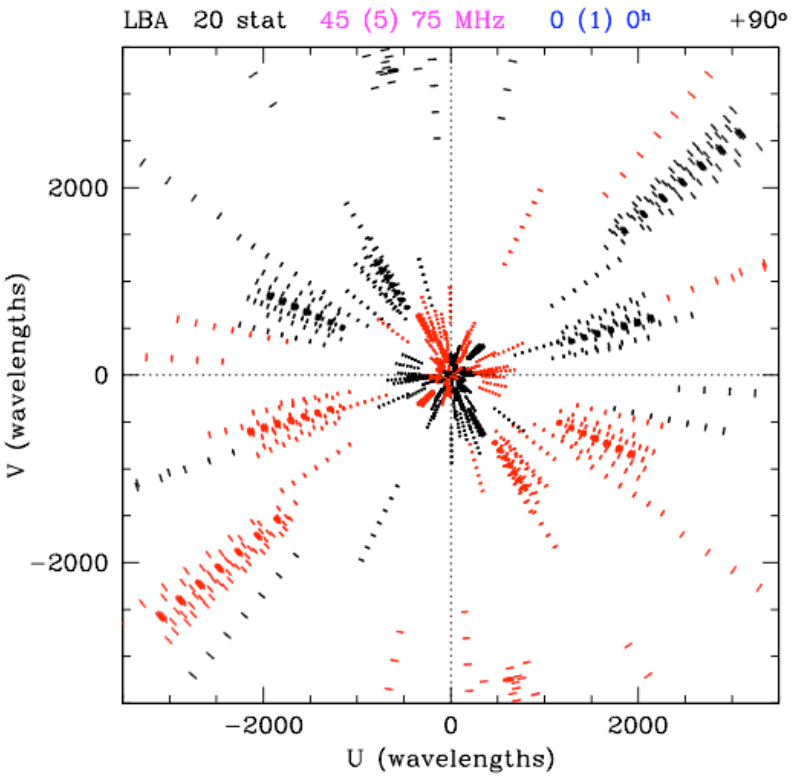
for Dec < +20^{o} severe sensitivity penalty !

$\Rightarrow$ for low Dec probably aim for snapshots within -2h, +2h HA-range



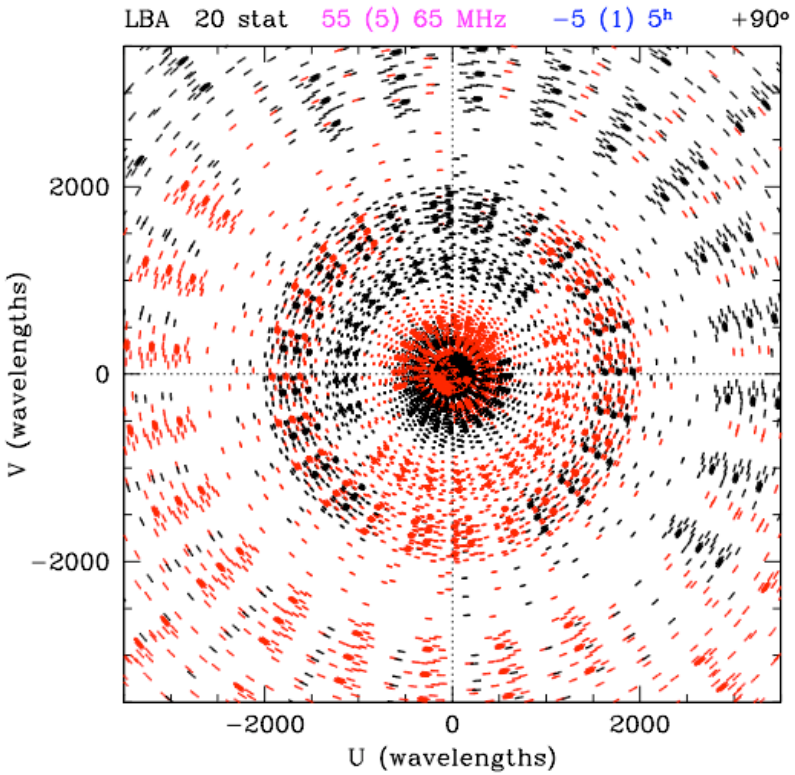
LOFAR20 uv-coverages for LBA-band

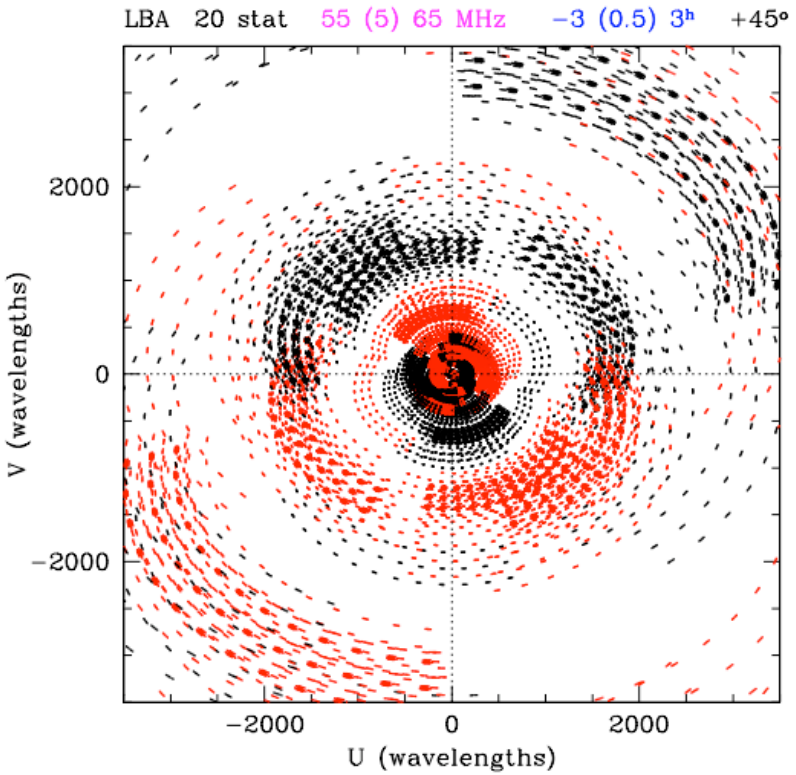




snapshot (1 cut, 5m) + very broadband (30 MHz)

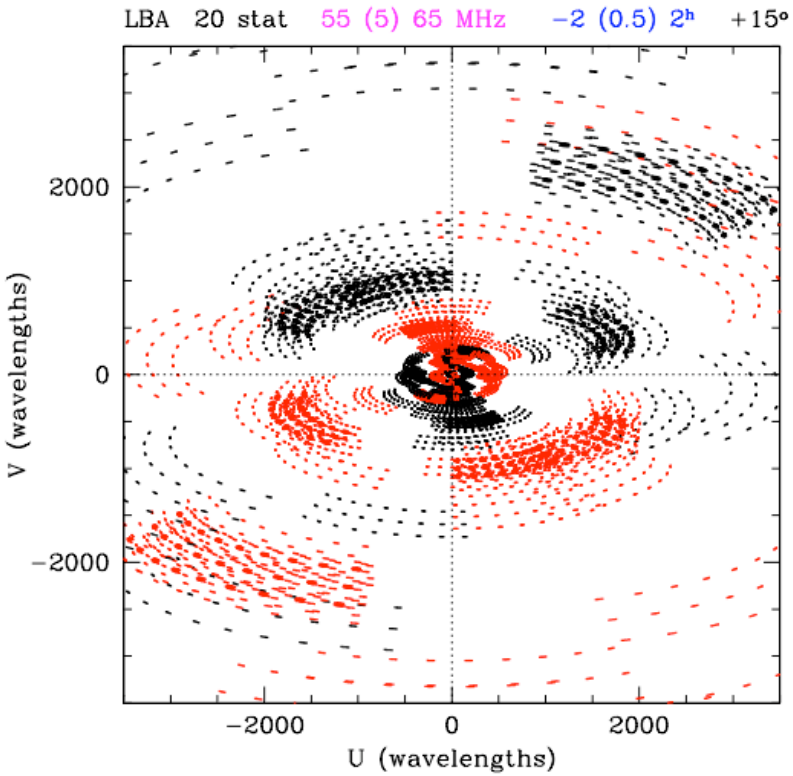
LOFAR20 uv-coverages for LBA-band

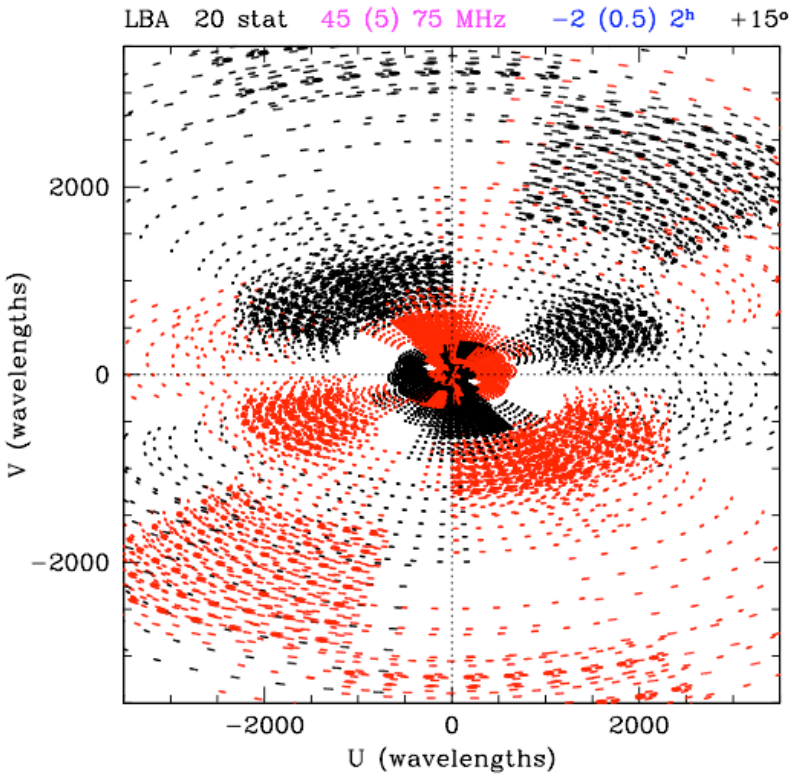




multiple cuts of 5m + broadband (10 MHz)

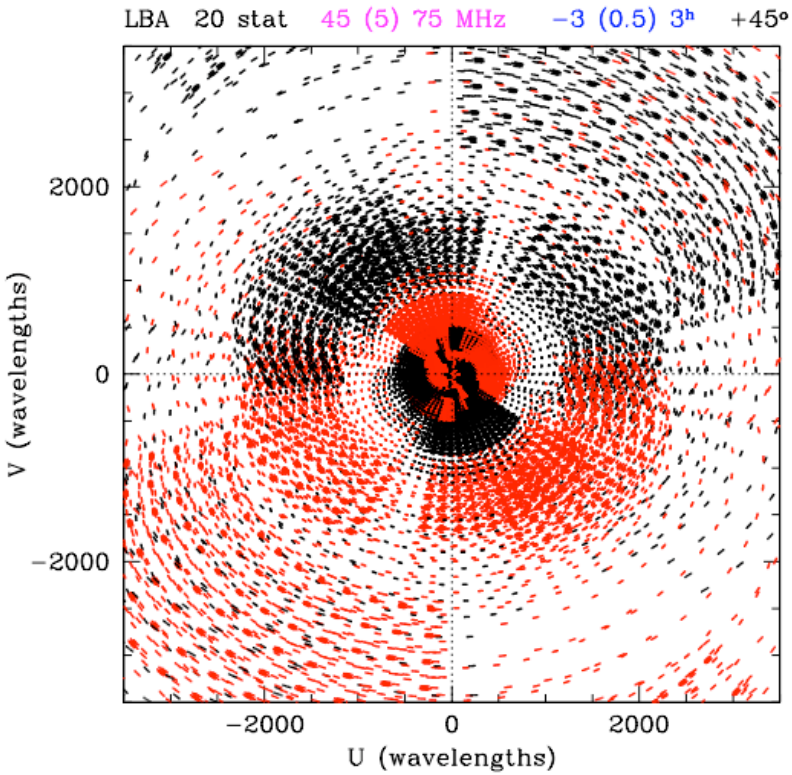
LOFAR20 uv-coverages for LBA-band

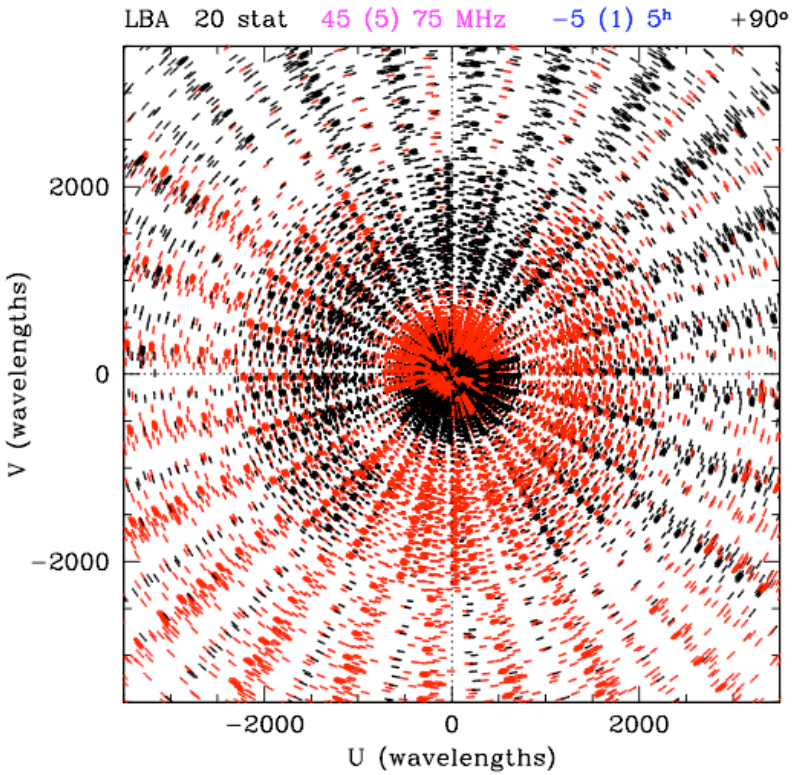




multiple cuts of 5m + broadband (10 MHz)

LOFAR20 uv-coverages for LBA-band





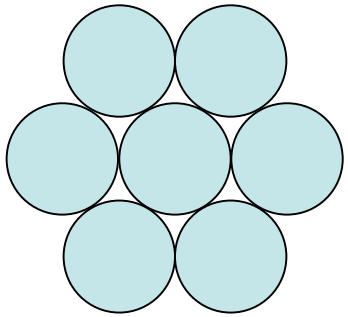
multiple cuts of 5m + very broadband (30 MHz)

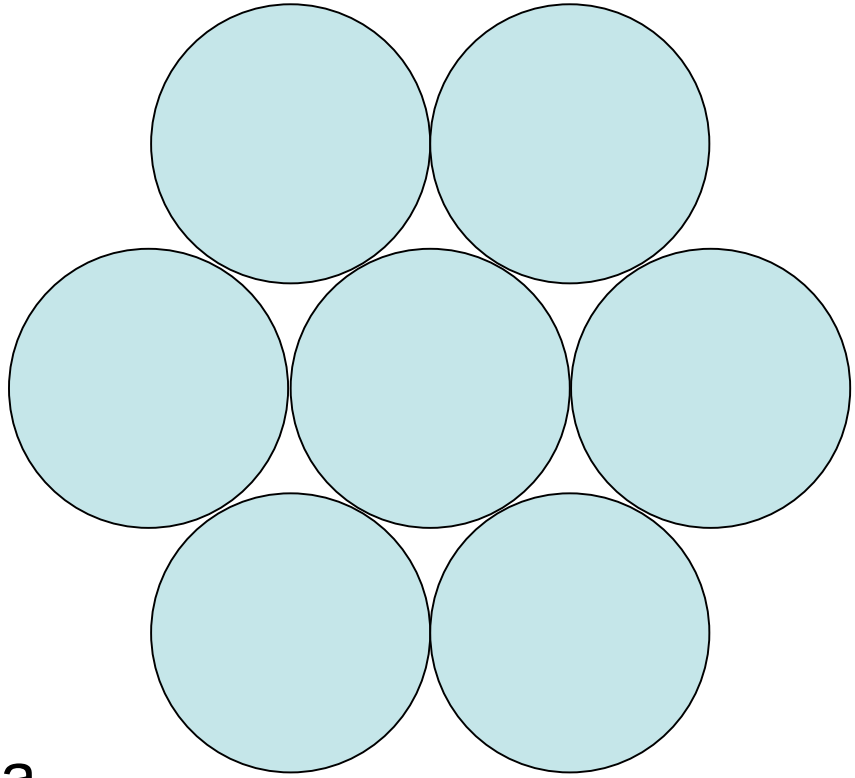
Gridpatterns, mozaicing and multi-beam issues

We assume 30m stations for both HBA-150MHz and LBA-60MHz

60 MHz: HPBW=12.5^{o} => 6.25^{o} grid in RA

150 MHz: HPBW =5.0^{o} => 2.5^{o} grid in RA





Question:

Should we conduct MS^{3} in a 7-beam observing mode?

How to do MS^3 : an initial proposal

Observations:

- 20 NL stations (13+7) => multiple snapshots for decent uv-coverage
- limit to two (broad?) frequency ranges: 60 MHz & 150 MHz
- complete in < 3 months (30% efficiency) & 'real-time' processing
- 4 beams of ~10 MHz (+ CasA beam, ~1 MHz)

Products:

- 1 million sources, of which ~ 100,000 will be high S/N (i.e. ~ 5 / □^{o})
- spectral indices for the ~ 100,000 sources seen in both bands
- structural information: ~20 - 60" PSF (~VLSS/WENSS/NVSS)
- fully tested pipelines
- arcsecond images of ~ 4,000 (?) European-LOFAR calibrator sources
- lists of polarized calibration sources for ionospheric RM-monitoring

MSSS - some basic numbers (Nijboer, March09)

	60 MHz	150 MHz
Bandwidth	8 MHz	8 MHz
Observing time per FoV	36 times 5 minutes	12 times 5 minutes
FoV	106 deg^2	19.4 deg^2
FWHM	11.6 deg	4.97 deg
PSF resolution (10 km)	82.5 arcsec	33.0 arcsec
Correlator time resolution	1 s	1 s
Correlator freq resolution	0.76 kHz	0.76 kHz
Uv data size	762 Gbyte	678 Gbyte
Post DP^3 time res.	5 s	5 s
Post DP^3 freq res.	21.3 kHz	42.6 kHz
Post DP^3 uv data size	~ 4.76 Gbyte	~ 2.12 Gbyte
# channels per image cube	Tbd	Tbd
# pixels per image plane	2048 x 2048 ?	2048 x 2048 ?
Total image size	Tbd	Tbd

Table 1: Specifications per pointing / FoV

- 2048 squared plane ~ 16.8 MByte

MSSS - some basic numbers (Nijboer, March09)

Frequency (MHz)	Area (sq. deg.)	Rms (mJy)	BW (MHz)	Sources / FoV	Int. time (hrs)	# pointings	Tot. obs. (days)	Tot. sources
60	20262	5.37	8	6062	3	609.1	19.0	1.18e+6
150	20262	0.499	8	5768	1	3346	34.9	6.14e+6

- # sources @ 5 σ thermal noise
  - Multiple freq. planes & 30 σ: few times1e+5
- Total obs. Time (100% eff.): 53.9 days or 7.7 weeks
- At 50% eff.: 15.4 weeks or 3.4 months

- Not taken into account:
  - Nyquist sampling yields another factor 1.5 in sensitivity
    - (or 2.25 in observing time)
  - Tapering of HBA stations for near sidelobe reduction

MSSS - some basic numbers (Nijboer, March09)

	60 MHz	150 MHz
Total # fields (2 pi steradian)	609	3346
Total observing time (100% eff., using 4 beams)	456.75 hr	836.5 hr
Total # sources	Tbd	Tbd
Total uv data size	466 Tbyte	2.27 Pbyte
Total post DP^3 uv data size	~ 2.9 Tbyte	~ 7.1 Tbyte
Total image data size	Tbd	Tbd

Table 2: "All sky" specifications

- 1 freq. plane: 16.8 MByte x 3955 = 66.4 GByte

Assumptions/choices and their consequences

— ~ 3 months total in (say) Nov09 - Jan10 ⇒ mostly nighttime
Hence RA ~14h - 22h region will have to be done mostly in daytime !

— required uv-coverage and (relative) sensitivity are based on mnay cuts
If efficiency 50% ⇒ 9 x 5m (HBA) and 36 x 5m (LBA)
Efficiency determines number of cuts. Will become clear after 1 month.
Should we observe each field more than once (also yields variability data)

— 30m HBA and LBA stations in core ?
Should we space-taper RS in NL to 30m ?
⇒ Nyquist grid of 2.5^{o} (150 MHz) and 6^{o} (60 MHz)

— Only one longish baseline (28 km) high sidelobes !
⇒ probably require imaging with strongly tapered array (~ 10km?)

— Room for some simulations !!

Preparing for MS^3

Some important still largely undecided (?) issues, with significant consequences (there arec many many more!) :

- use of bandwidth synthesis in imaging: How wide can we go ?
- number of calibration and deconvolution loops ?
- MSSS requirements on ionospheric modeling
- intrinsic polarization (RM-synthesis ?) in both HBA and LBA ?
- participation of European stations: 3 - 8 ? (see next talk)

Compact sources ? Daytime observing and IPS!

European baselines : 800 km

=> 400 kλ at 150 MHz => 0.5” fringe

=> 160 kλ at 60 MHz => 1.25” fringe

During daytime compact sources with sightlines within ~ 45^{o} from Sun will be affected by scintillation due to the Inter Planetary Medium (IPM). This causes amplitude fluctuations on timescales of seconds ! Only sources that contain structure <1” will scintillate

A program to identify IPS scintillating sources, with core or superstation data, would be an interesting TRANSIENT and SolarSystem KSP program during MS^{3} . They could find out which compact sources are suitable for European scrutiny !