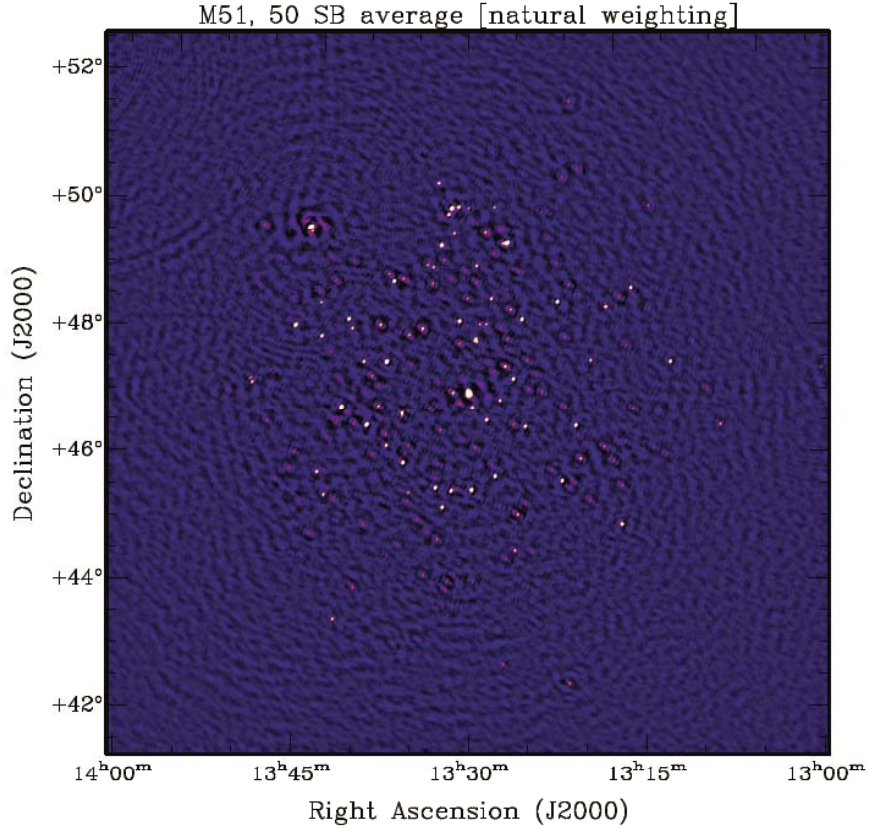
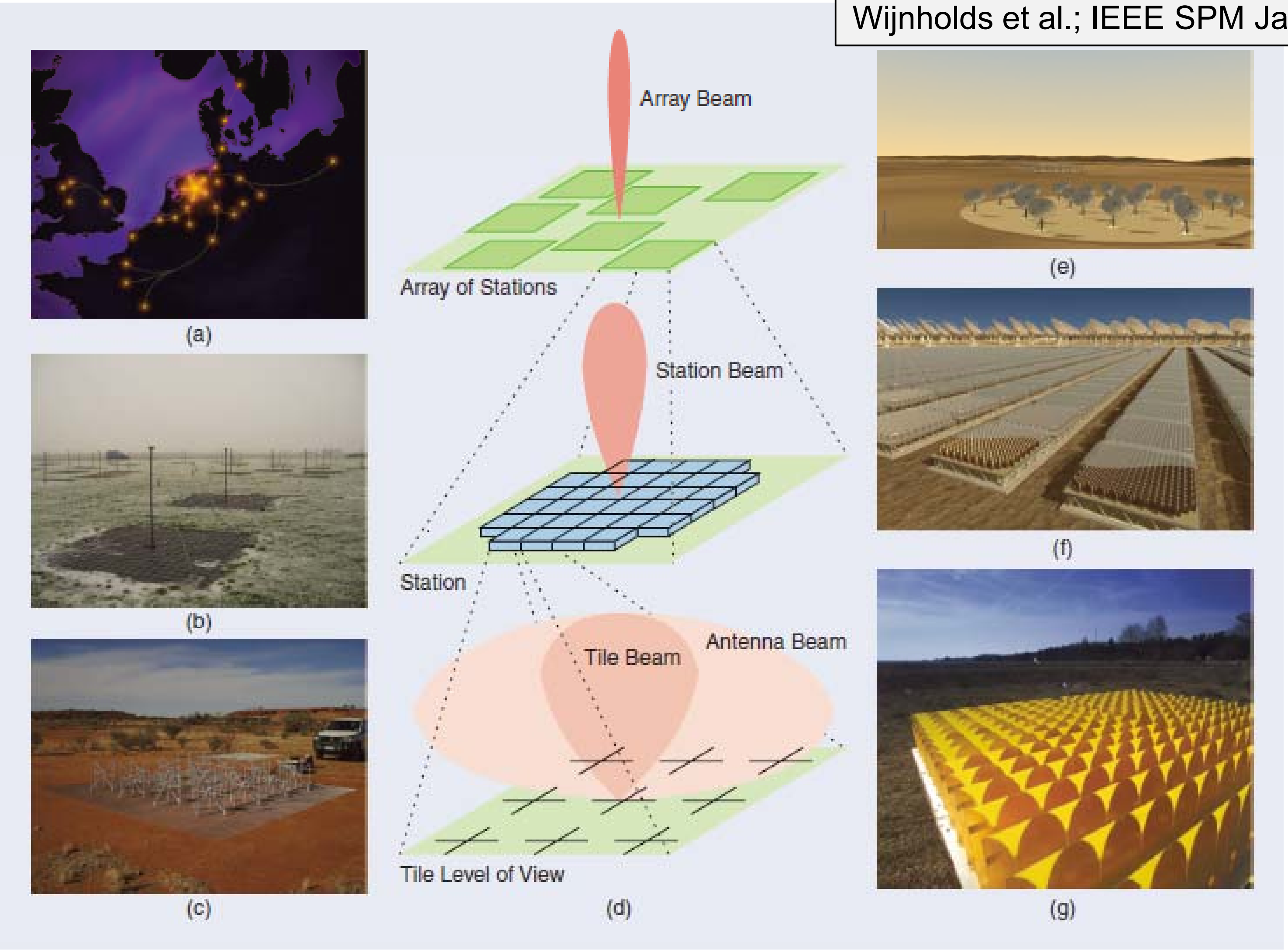
Wide Field Imaging



R.J. Nijboer

Hierarchical (primary) beams

Wijnholds et al.; IEEE SPM Jan. 2010



LOFAR: wide FoV

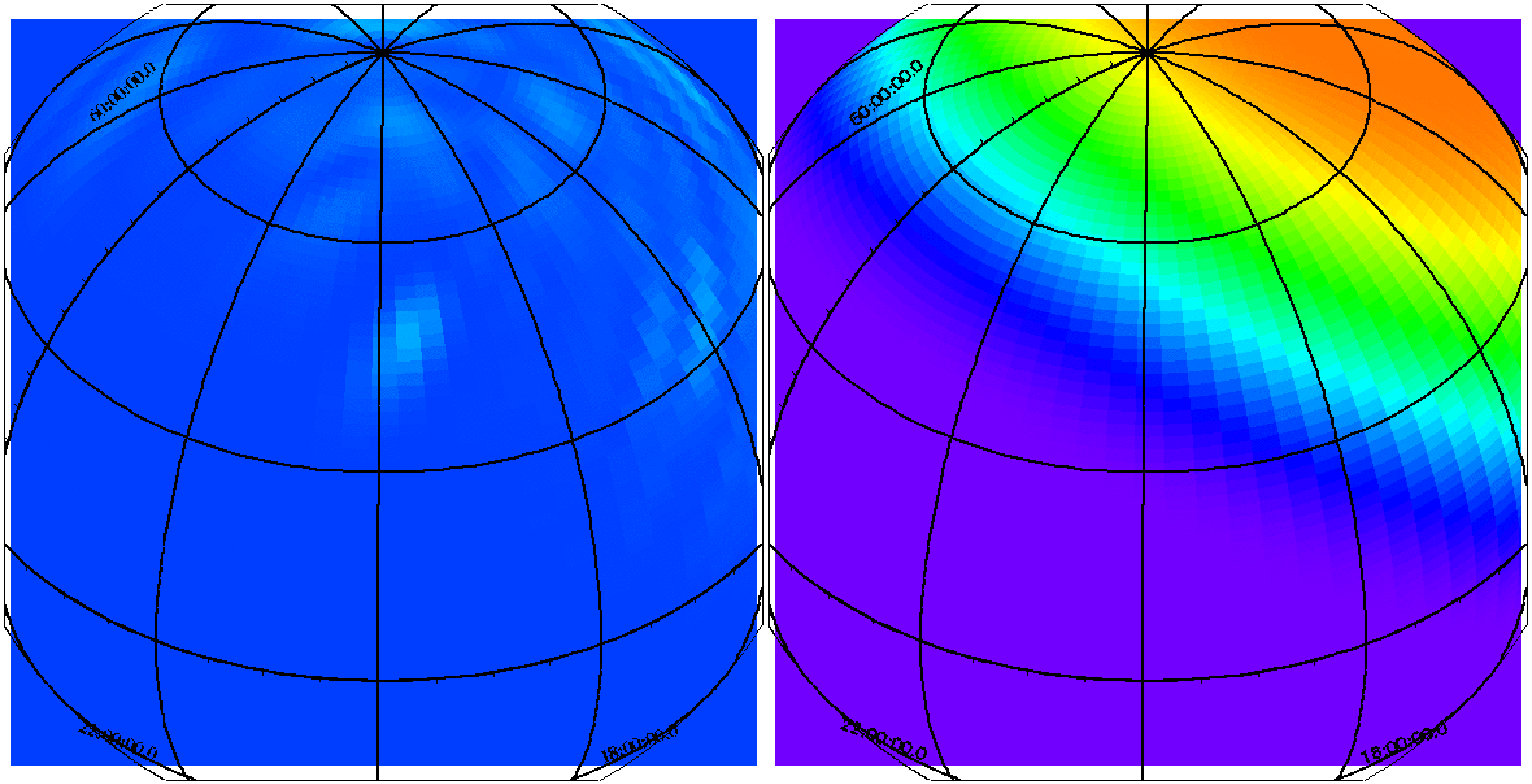
Freq (MHz)	λ (m)	Stat. diam. D (m)		FWHM (deg)		FoV (sq.deg.)	
15	20.0	32.3	81.3	46.2	18.3	1676	263
30	10.0	32.3	81.3	23.1	9.16	419	65.8
45	6.67	32.3	81.3	15.4	6.10	186	29.3
60	5.00	32.3	81.3	11.6	4.58	105	16.5
75	4.00	32.3	81.3	9.24	3.66	67.0	10.5
120	2.50	30.8	41.1	6.06	4.54	28.8	16.2
150	2.00	30.8	41.1	4.84	3.63	18.4	10.3
180	1.67	30.8	41.1	4.04	3.02	12.8	7.18
210	1.43	30.8	41.1	3.46	2.59	9.40	5.28
240	1.25	30.8	41.1	3.03	2.27	7.20	4.04

WSRT 1400 0.21 25 0.63 0.31

Low Band: 30 MHz – 80 MHz

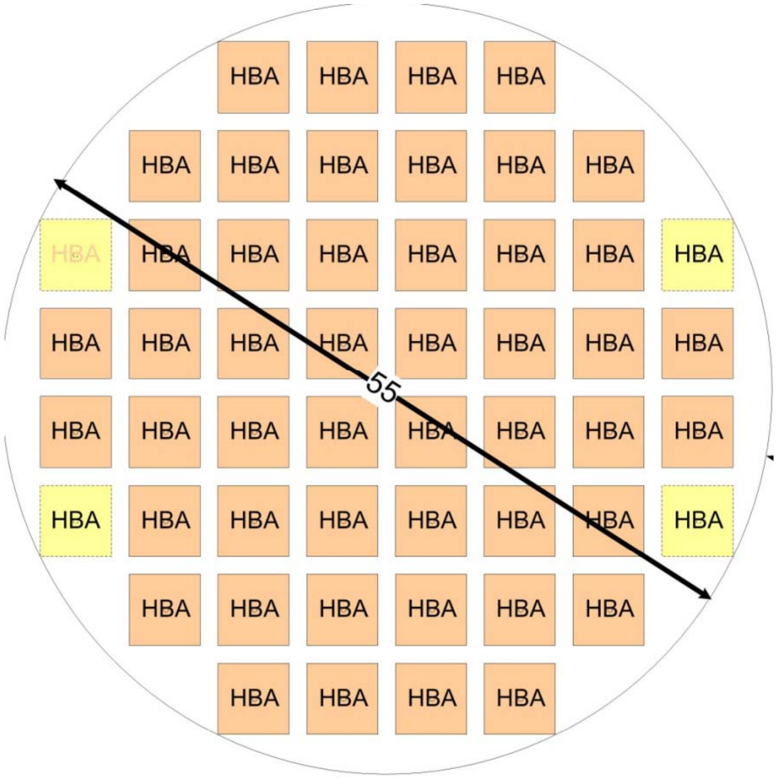
station beam

dipole beam

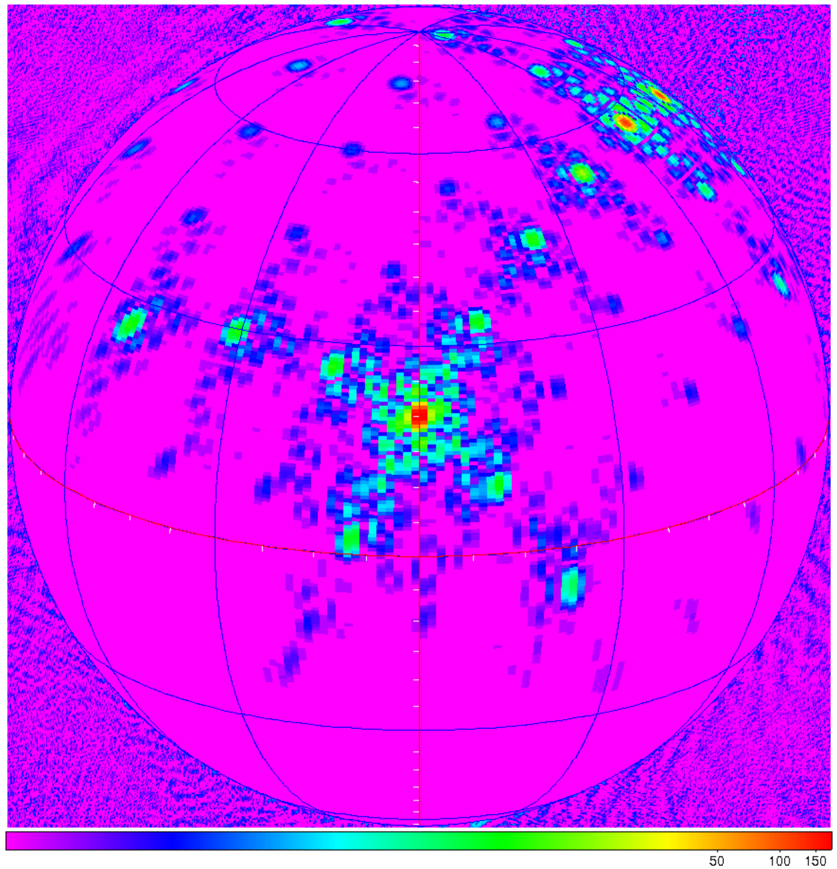


Sarod Yatawatta

High Band: 120 MHz – 240 MHz



station beam

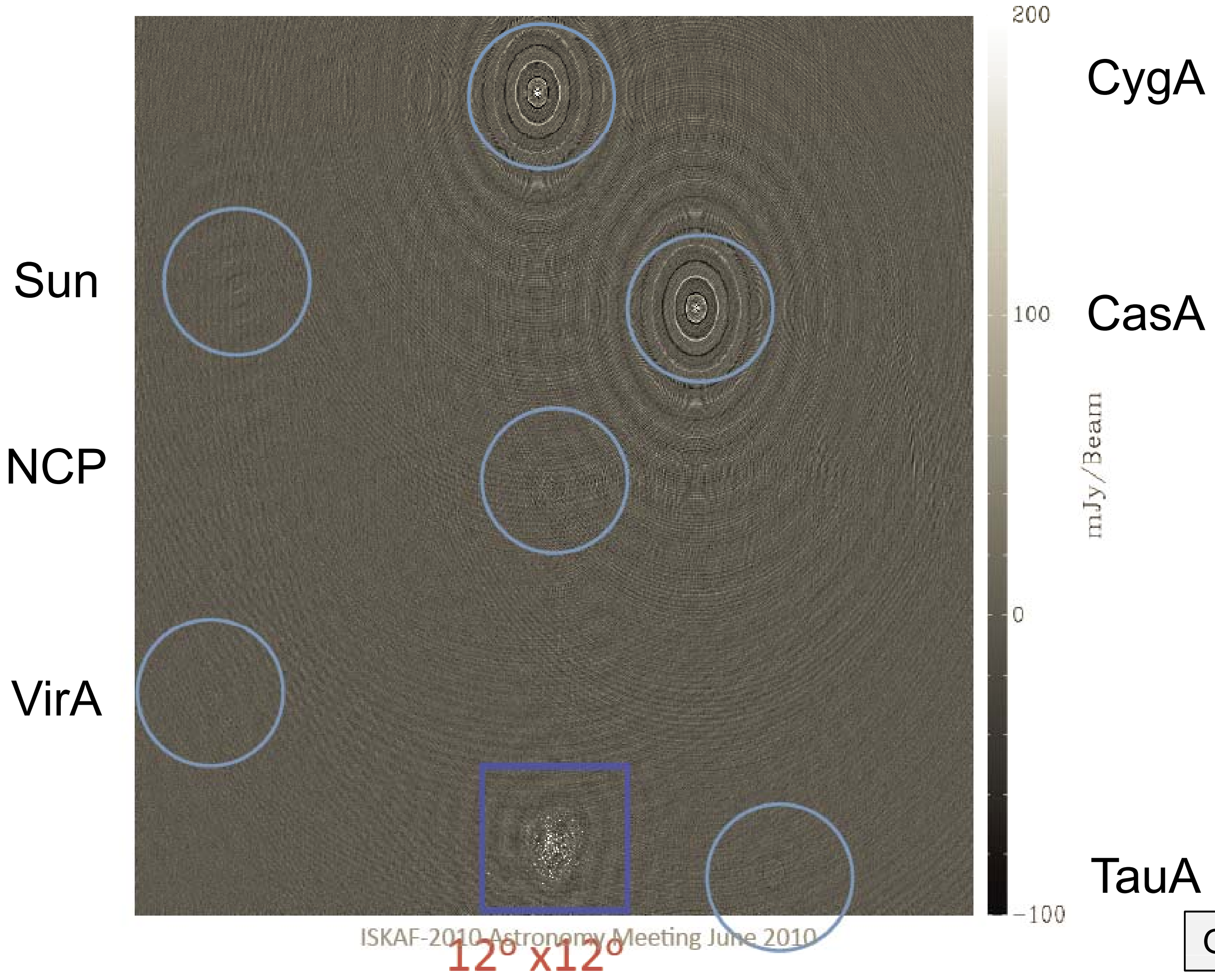


Sarod Yatawatta

LOFAR Imaging is All Sky Imaging

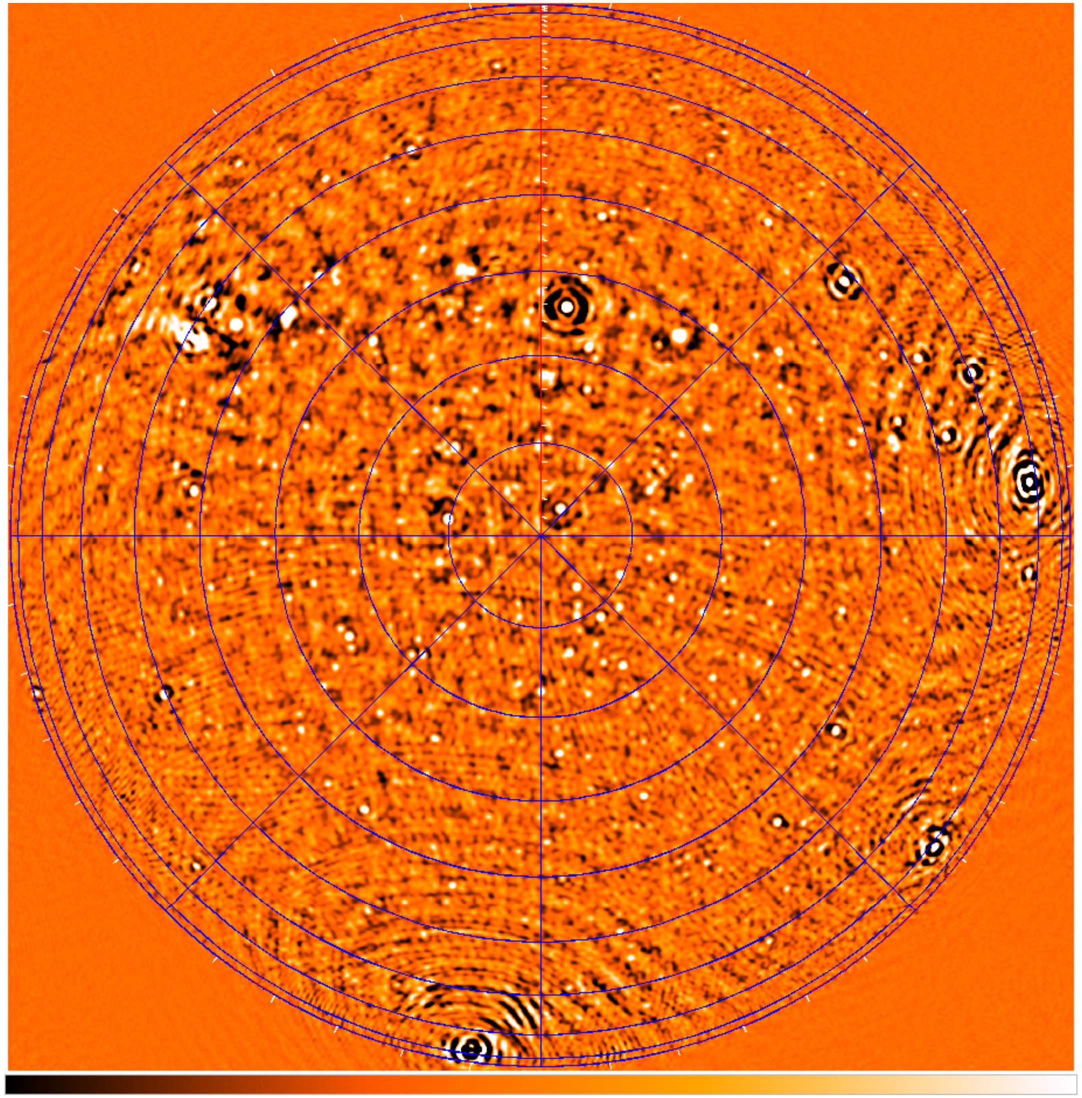
- Sources (A-Team) contaminate through sidelobes
  - Stronger on shorter baselines
- Stations have been rotated to average out far sidelobes
- Dipoles have been “rotated back” to preserve polarization response
- Time varying beams

WSRT 150 MHz; 3C196



Ger de Bruyn

LOFAR Core Station 1: NCP



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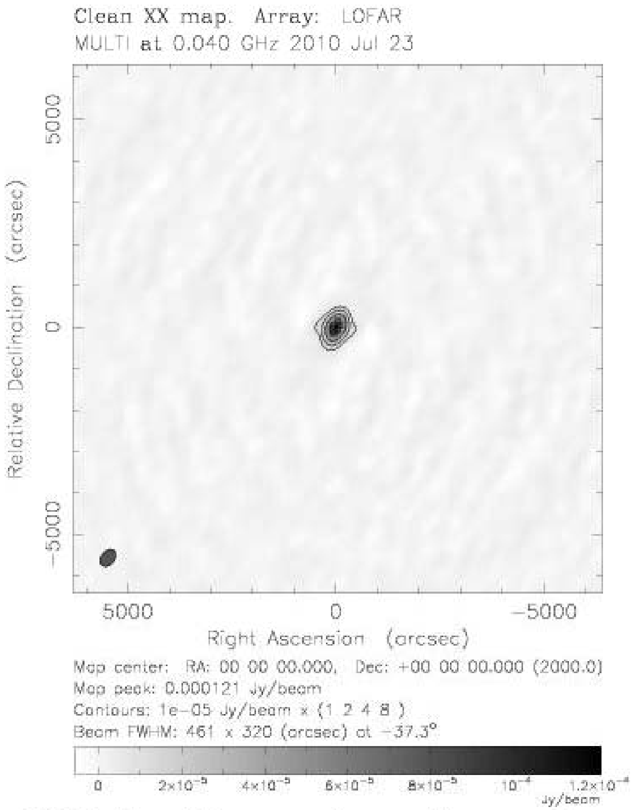
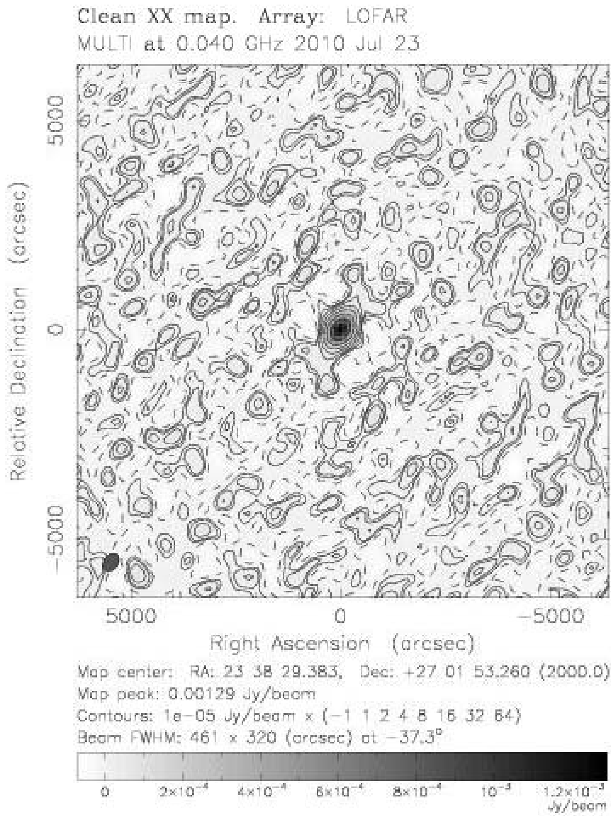
3C465

3C465 – LOFAR LBA – Imaging Busy Week 7



With directional–gain correction and subtraction of CygA and CasA in BBS



Without correction

Neal Jackson

LOFAR wide field imaging

- After subtraction of contaminating sources outside the field of fiew …

- The field of fiew must be corrected for
  - Non-coplanar baselines (w-term) effect
  - Station voltage beam
  - Ionosphere: phase and Faraday rotation

Different correction methods

- Snapshots: divide out PB per snapshot
  - Applicable when all PBs are equal and sky is non-polarized
  - How to deal with ionosphere?
- Facets: correct for center of facet
  - Many facets needed?
  - W-projection within facet
  - Image deconvolution “complicated”
- Convolutional methods
  - W-projection for non-coplanar baseline effect
  - A-Projection for PB
    - LOFAR PB is time dependent!
  - Could this work for ionospheric correction?

What is available in software?

- Cimager and CASA imager in LOFAR pipeline
  - CASA imager designed for interactive use
  - Cimager designed for streaming processing

- Both imagers can image in facets
- Both imagers contain w-projection algorithm
- Neither correct for LOFAR primary beams or ionosphere

- Initial implementation of PB and ionospheric correction in progress
  - In a facet based approach
  - On a longer time-scale in convolutional approaches
- More research is needed
  - Especially for computational performance

Imaging Equation

$$V(u,v,w) = \int \left[\frac{A(l,m) e^{j2\pi w\left(\sqrt{1-l^2-m^2}-1\right)}}{\sqrt{1-l^2-m^2}} \right] I(l,m) e^{j2\pi(ul+vm)} dl dm$$

$$V(u,v,w) = \tilde{G}(u,v,w) \otimes V(u,v)$$

$$\tilde{G}(u,v,w) = \int \frac{A(l,m) e^{j2\pi w\left(\sqrt{1-l^2-m^2}-1\right)}}{\sqrt{1-l^2-m^2}} e^{j2\pi(ul+vm)} dl dm$$

V(u,v) is the 2D Fourier transform

$$V(u,v) = \int I(l,m) e^{j2\pi(ul+vm)} dl dm$$

A denotes image plane effect: PB and / or ionosphere

Tim Cornwell / Sanjay Bhatnagar

W-projection

$$V(u,v,w) = \tilde{G}(u,v,w) \otimes V(u,v)$$

$$\tilde{G}(u,v,w) = \int \frac{e^{j2\pi w\left(\sqrt{1-l^2-m^2}-1\right)}}{\sqrt{1-l^2-m^2}} e^{j2\pi(ul+vm)} dl dm$$

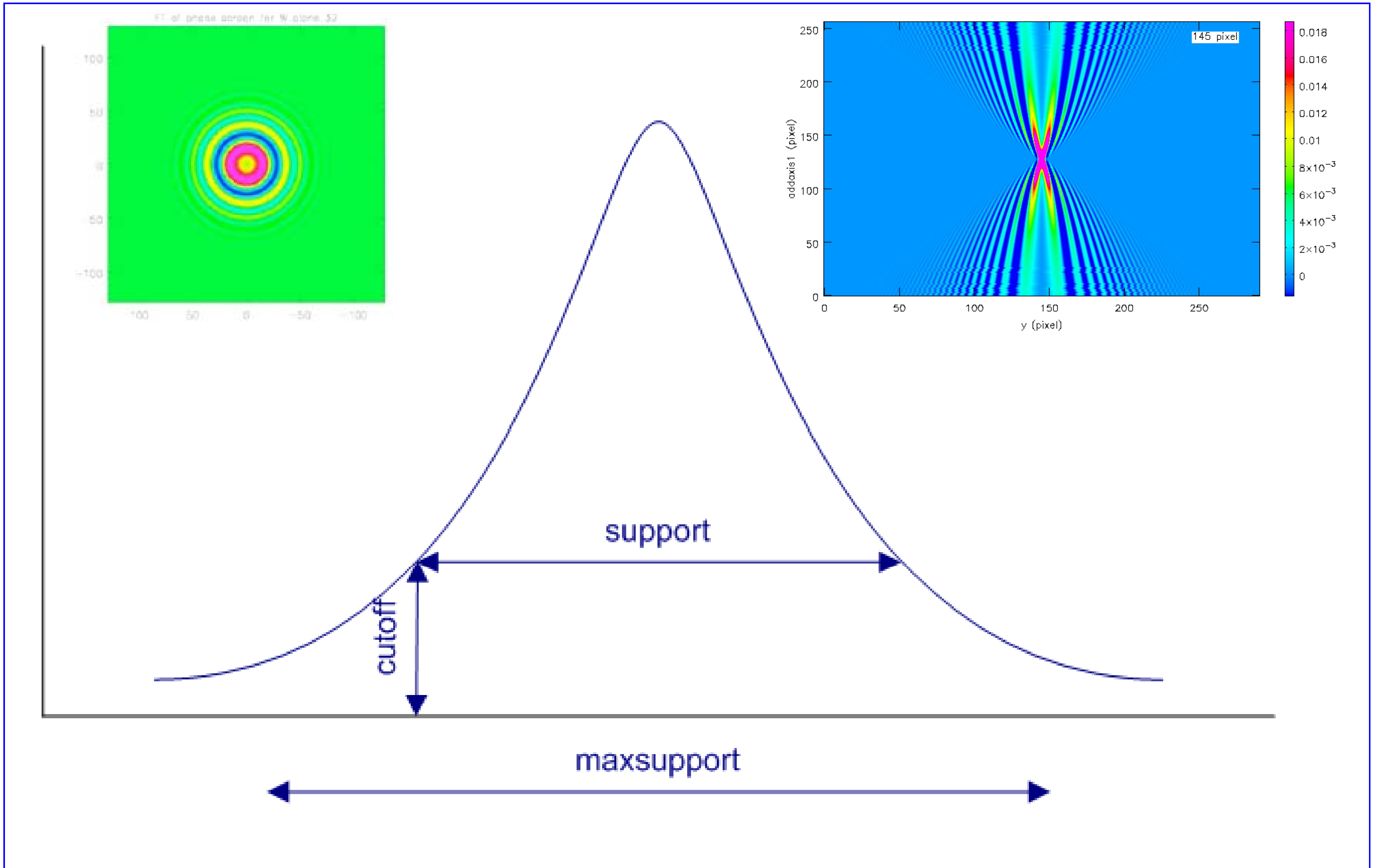
$$\tilde{G}(u,v,w) \approx e^{j\pi w(u^2+v^2)}$$

- Precalculate a table of convolution functions as a function of *w*
- Gridding: convolve each visibility with the appropriate w-dependent convolution function. Then FFT.
- De-gridding: FFT image to uv grid. Convolve grid points with appropriate w-dependent convolution function to get off the grid.

Parameters

Parameter	Type	Default	Value	Description
wmax	Double	35000.0	B/λ	Largest allowed absolute value of the w term in wavelengths. An exception will be thrown if the dataset contains w-term exceeding this value (*W scaling error: recommend allowing larger range of w*). Note that the MS contains uvw coordinates in meters!
nwplanes	Int	65	λ B / D^2	Number of w-planes. Number of w planes must be an odd positive number. For the WProject gridder this scales up the number of convolution functions calculated. For the WStack gridder this is the number of grids maintained. You may (and will) run out of memory for a large number of w planes, especially for the stacking algorithm.
oversample	int	8		Oversampling factor. Convolution functions will be computed for this number of pixels per uv-cell.
maxsupport	int	256		The largest allowed support size in pixels. The grid used to compute the convolution function (before the support is searched and the appropriate inner part of the grid is extracted) is initialised to have the size equal to the smallest of maxsupport and the image size. WProject uses maxsupport x maxsupport grid at the moment regardless of the image size.
cutoff	double	1e-3		Cutoff in determining support. Must be greater than 0.0 and less than 1.0. The support is searched starting from the edge of the image inwards. As soon as the value of the convolution function exceeds cutoff times the peak, the distance from the centre (the largest value of two coordinates is used) becomes the support size. At the moment, we use a single value of the support, which is the largest across all family of convolution functions stored in the cache. The smaller the cutoff, the larger the support size and the more accurate gridding is performed.
limitsupport	int	0		Upper limit of support. If the determined support size happens to be greater than this value, the support will be capped to this value. This limit is applied after the convolution functions are calculated, before an inner part of the grid is extracted to be stored in the convolution function cache. The default value of 0 indicates no limit is imposed.

Determining the convolutional support size



Summary

- LOFAR Imaging is all sky imaging
- Contaminating source contributions outside the FoV must be subtracted from the uv-data
- The FoV must be corrected for
  - W-term
  - Primary beam
  - Ionosphere
- W-projection and facet imaging available in CASA and Cimager
- Methods to correct for Primary Beam and Ionosphere are under development