Recent imaging results from TKSP commissioning

(SS433 + Bell Transients)

Jess Broderick
(University of Southampton)

Martin Bell
(University of Southampton)

John Swinbank, Valeriu Tudose, Dan Calvelo, Dan Plant,
Richard Plotkin, David Cseh, Jason Hessels, Evert Rol,
Bart Scheers, Rob Fender, Ralph Wijers
and the LOFAR Transients KSP

Transients KSP imaging commissioning

- PSR B0329+54 zenith field (HBA; Bell, Broderick)
- SS 433 / W50 (HBA and LBA; Broderick)
- Cygnus X-1 and Cygnus X-3 (HBA; Tudose, Calvelo, Plant, Cseh)
- GRS 1915+105 (HBA; Plotkin)

  + several other fields....

- Use the data from these fields to develop a transients imaging pipeline (trip). Images are then passed on to the transients detection pipeline (trap; Evert Rol's talk).

PSR B0329+54 Field (possible transients)

* 11 x 12 hour observations

* 3 x 6 hour observations

* Mean freq. ~150 MHz

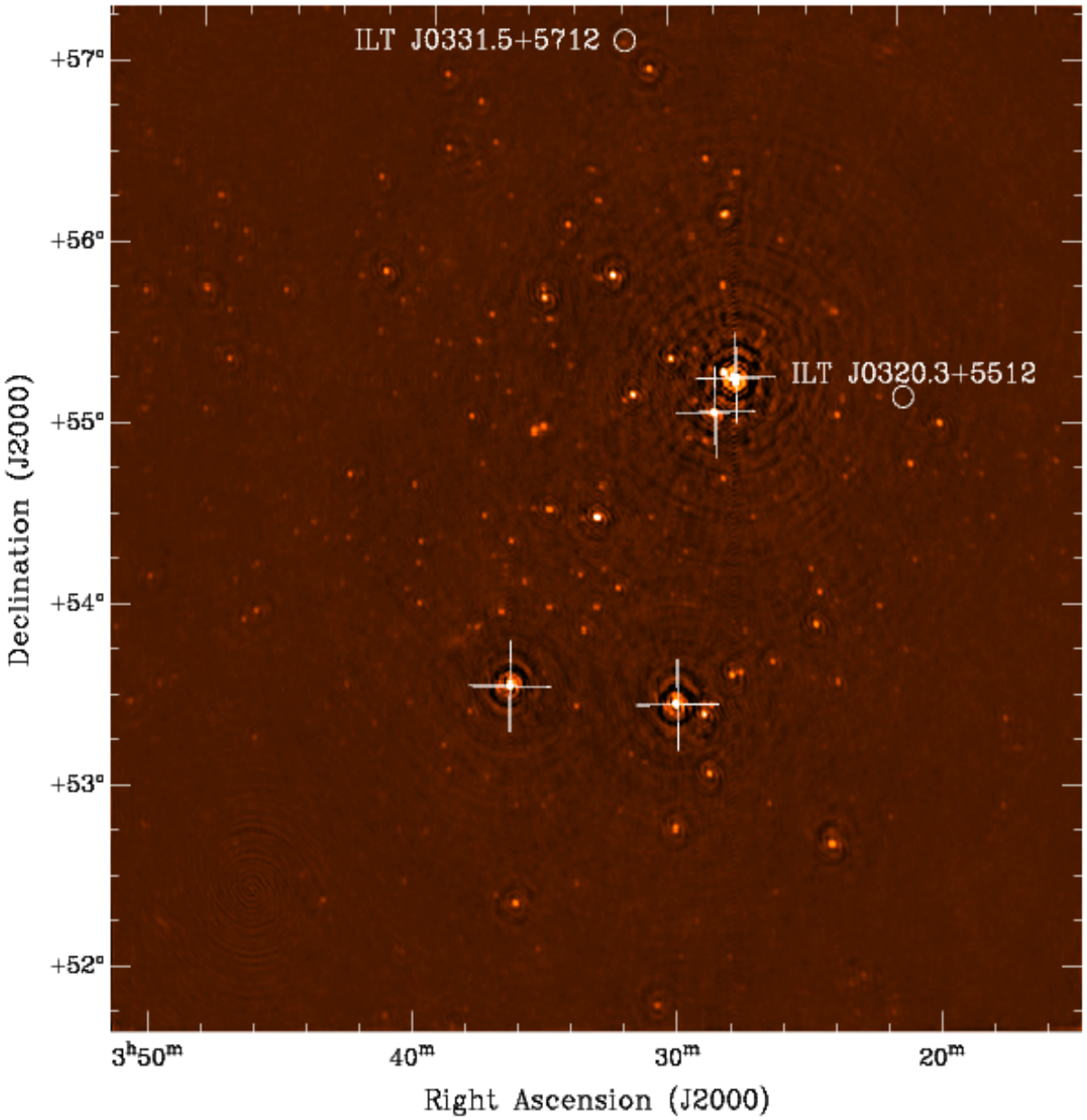
* 7 – 20 stations (using HBA_DUAL config.)

* ~20 deg^2 FOV

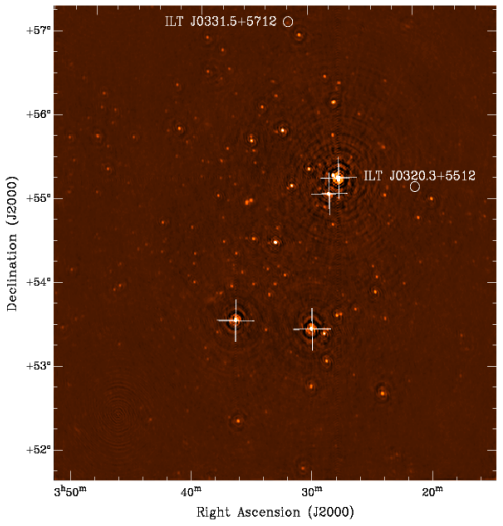
* Cadence ~ weeks and months

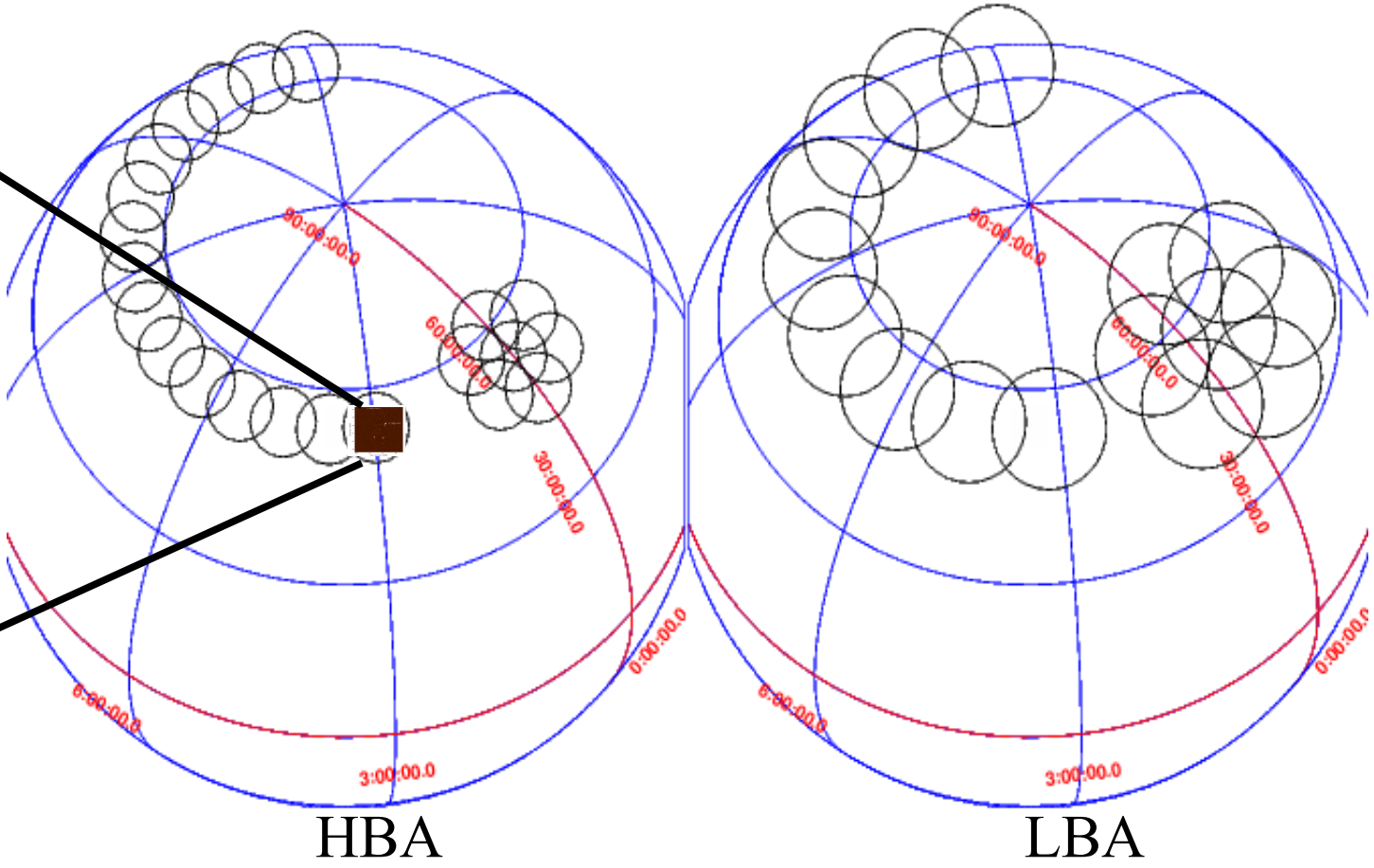
* Noise ~ 15 mJy/beam

* One full year of monitoring

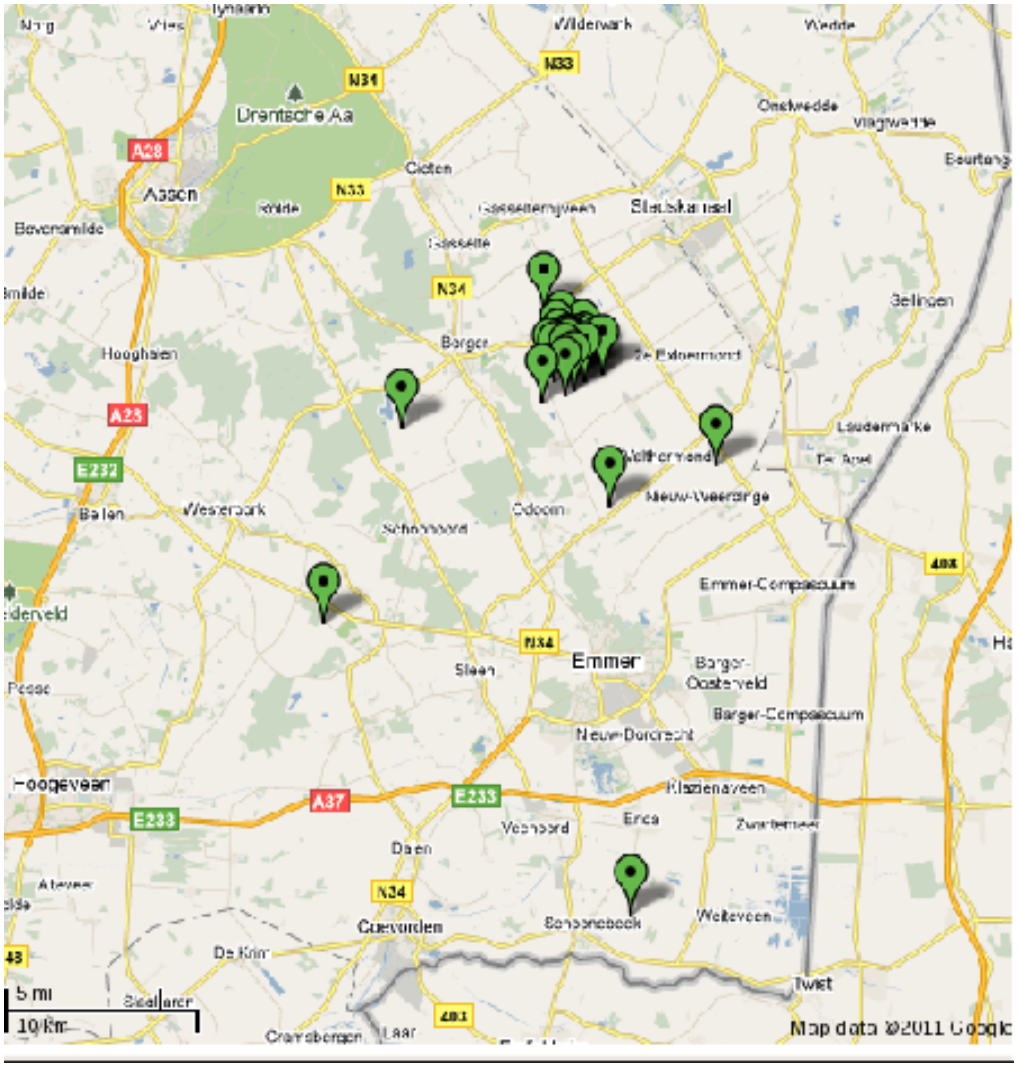


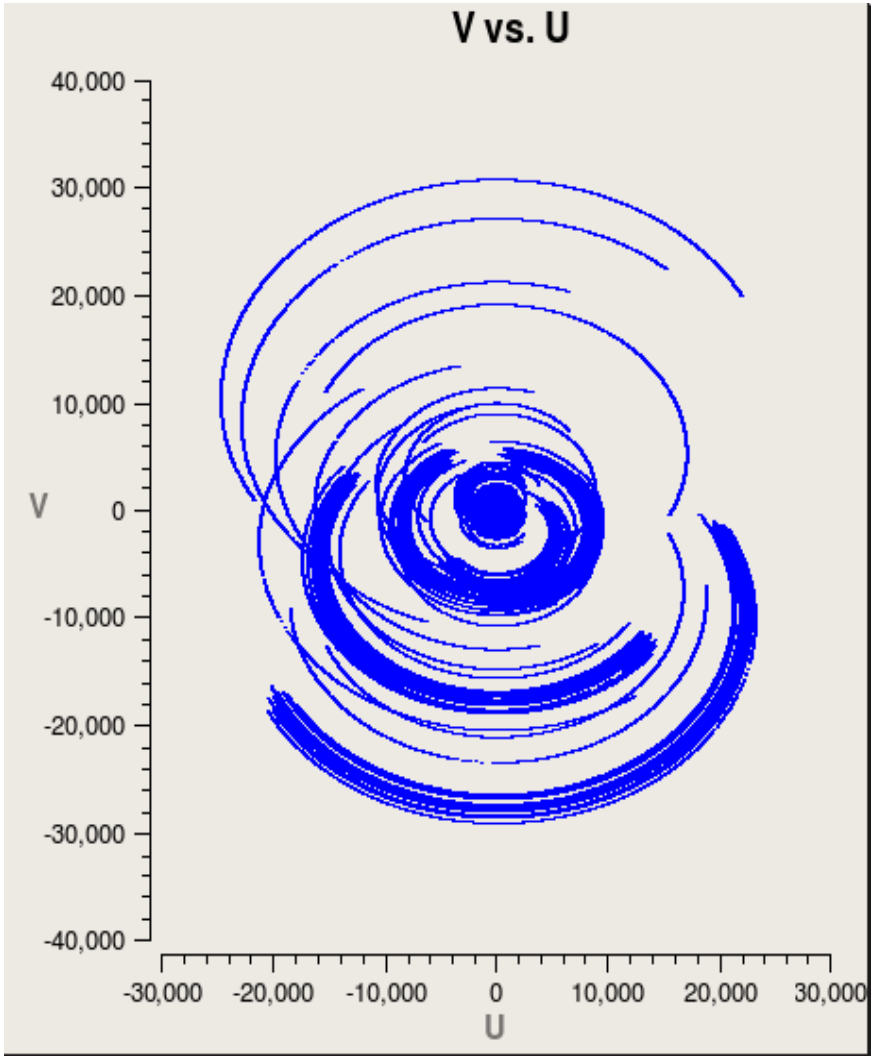
Commissioning the RSM





Typical station locations / *uv* plot





Progress

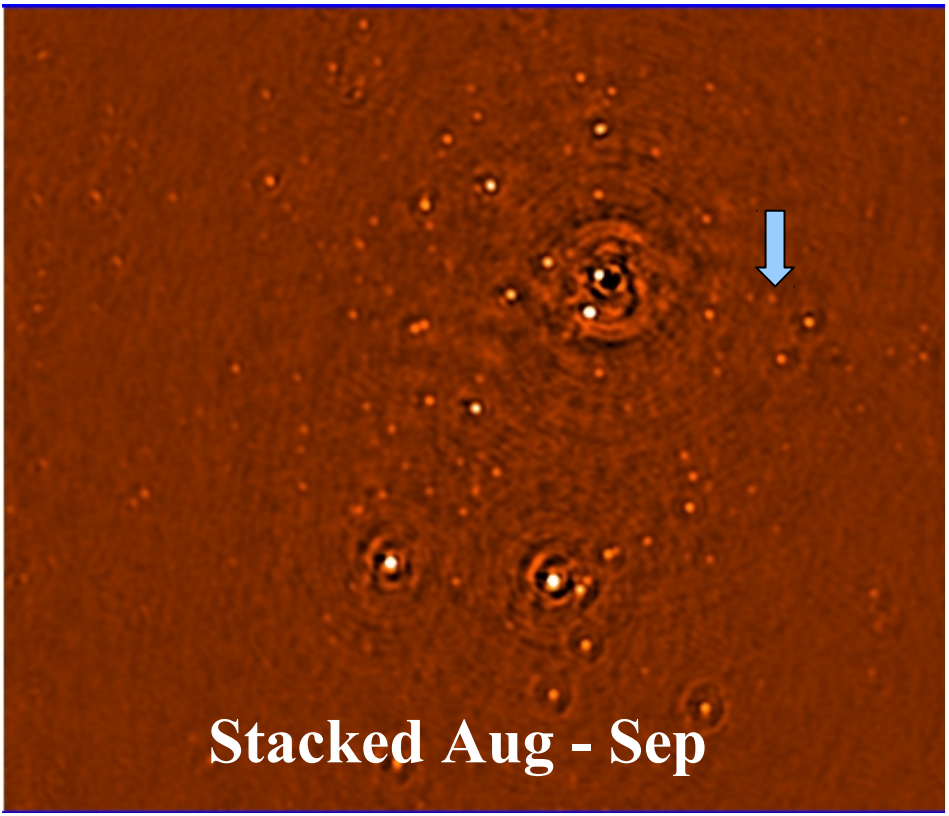
Table 5.1: Transient commissioning observations obtained with the LOFAR High Band Array. # Channels gives the number of channels each sub-band was divided up in. The Image RMS column gives the noise calculated in the same region of the map for each image.

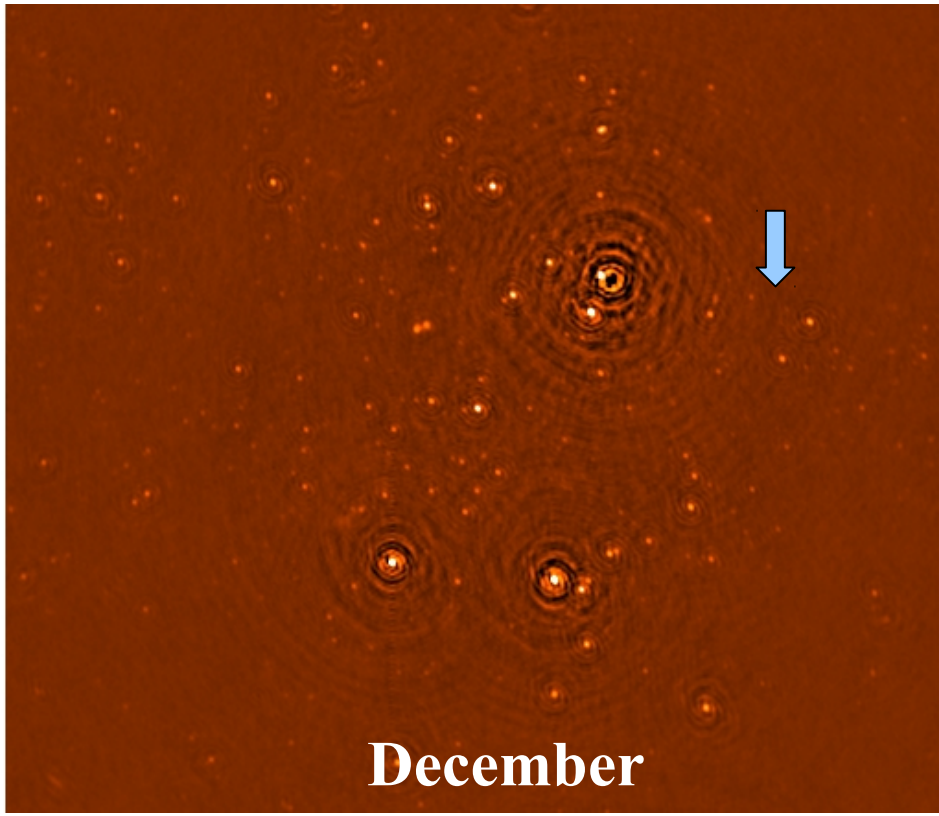
Obs. Date	Obs. ID	Int. Time (Hours)	# Stations	# Channels	Success	Image RMS (mJy)	Comments
2010-04-09	L2010_06928	12	17	256	Yes	21.5	
2010-08-13	L2010_09851	12	16	16	Yes	20.5	
2010-08-14	L2010_09852	12	16	16	No	–	Image reduction failed
2010-08-15	L2010_09870	5	14	16	No	–	Image fidelity is bad
2010-08-20	L2010_09936	12	14	16	Yes	16.5	
2010-08-21	L2010_09948	12	14	16	Yes	22.9	
2010-08-27	L2010_20033	12	15	16	Yes	16.1	
2010-09-19	L2010_20473	12	14	16	No	–	Image reduction failed
2010-09-25	L2010_20613	12	13	16	Yes	20.4	
2010-10-02	L2010_20673	12	20	16	Yes	7.2	
2010-10-10	L2010_20851	12	15	16	Yes	12.3	
2010-12-03	L2010_21641	12	25	64	Yes	3.5	
2011-03-19	L2011_24435	6	38	32	Yes	7.9	See comment A

[A] *This observation used a three second interval in the integration time, to reduce data volumes. All other observations used one second.*

(Bell, PhD thesis)

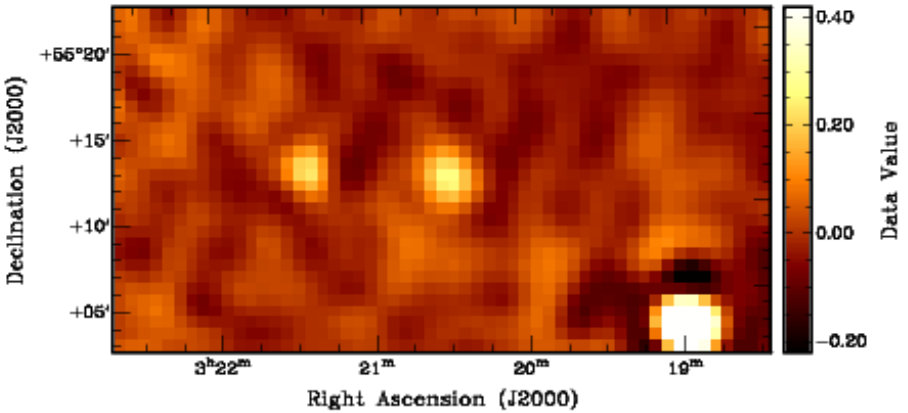
Transient search



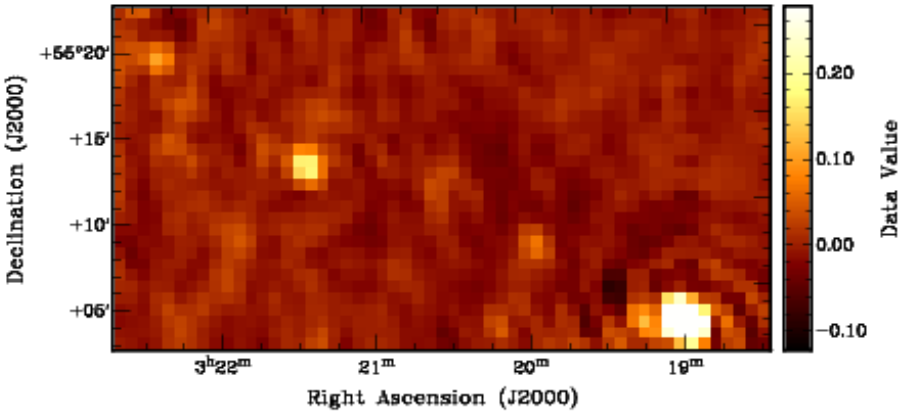


ILT J0320.3+5512 (Bell #1)

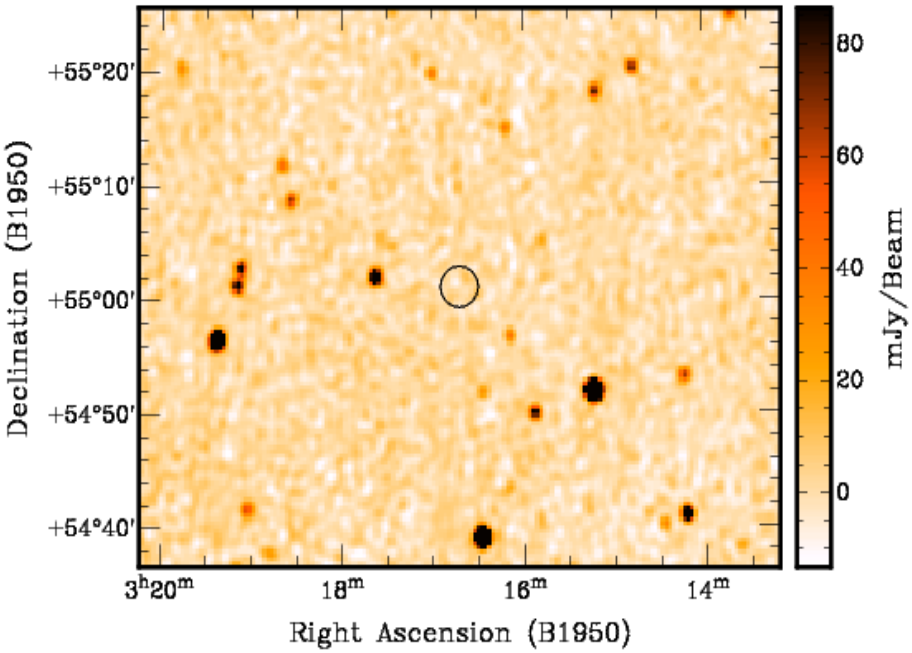
Stacked LOFAR Summer



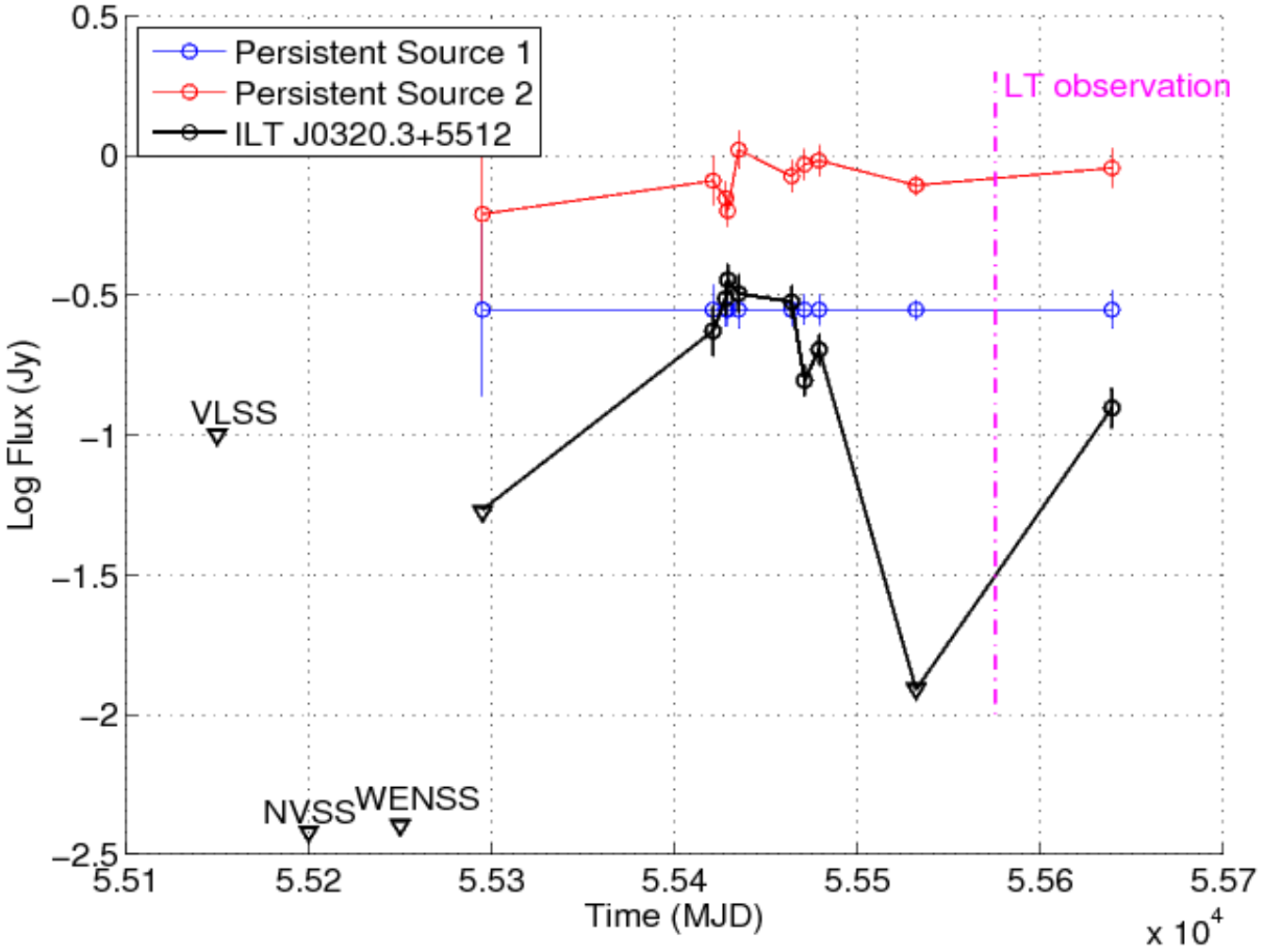
Stacked LOFAR December



WENSS (325 MHz)

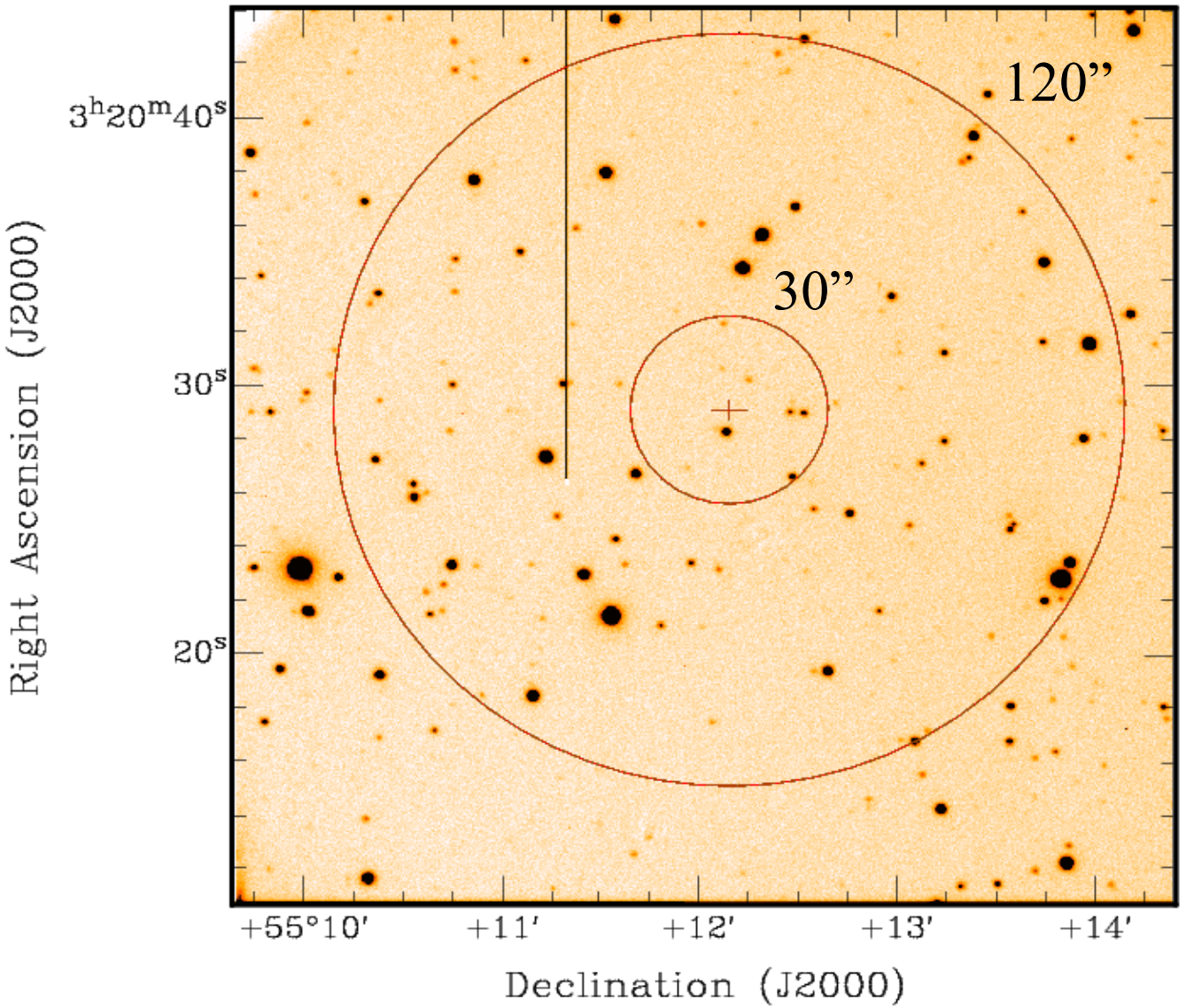


ILT J0320.3+5512 (Bell #1)



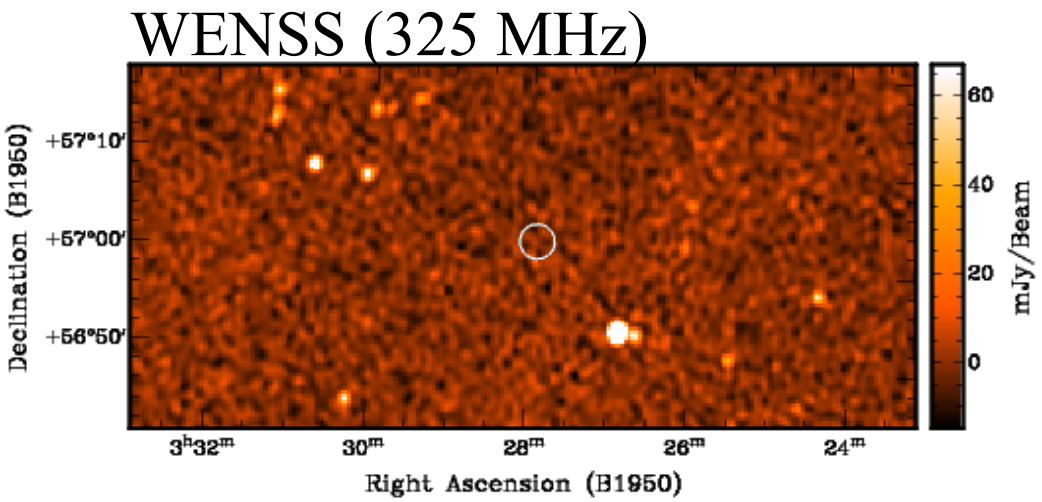
ILT J0320.3+5512 (Bell #1) – LT optical follow-up

Courtesy D. Bersier



* Liverpool telescope *r* band observations (in 2011 Jan). No new optical sources; no sources show significant variability.

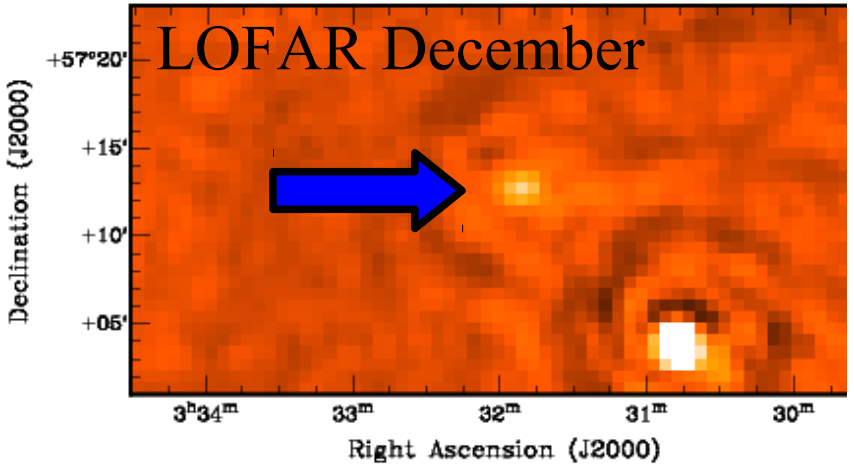
ILT J0331.5+5712 (Bell #2)

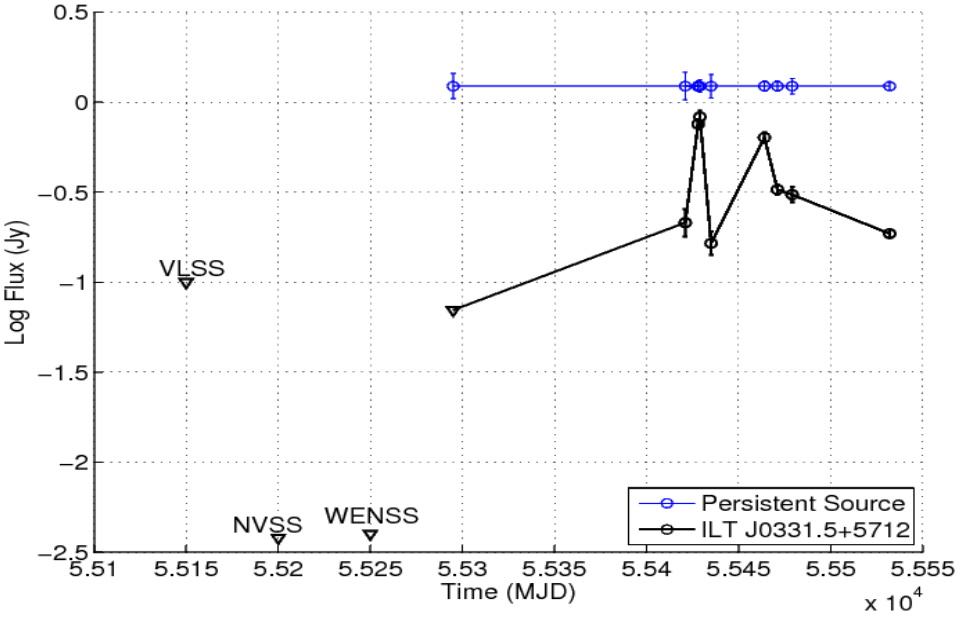


*Not detected in April 2010 observation.

*Observed 'on' in all subsequent observations.

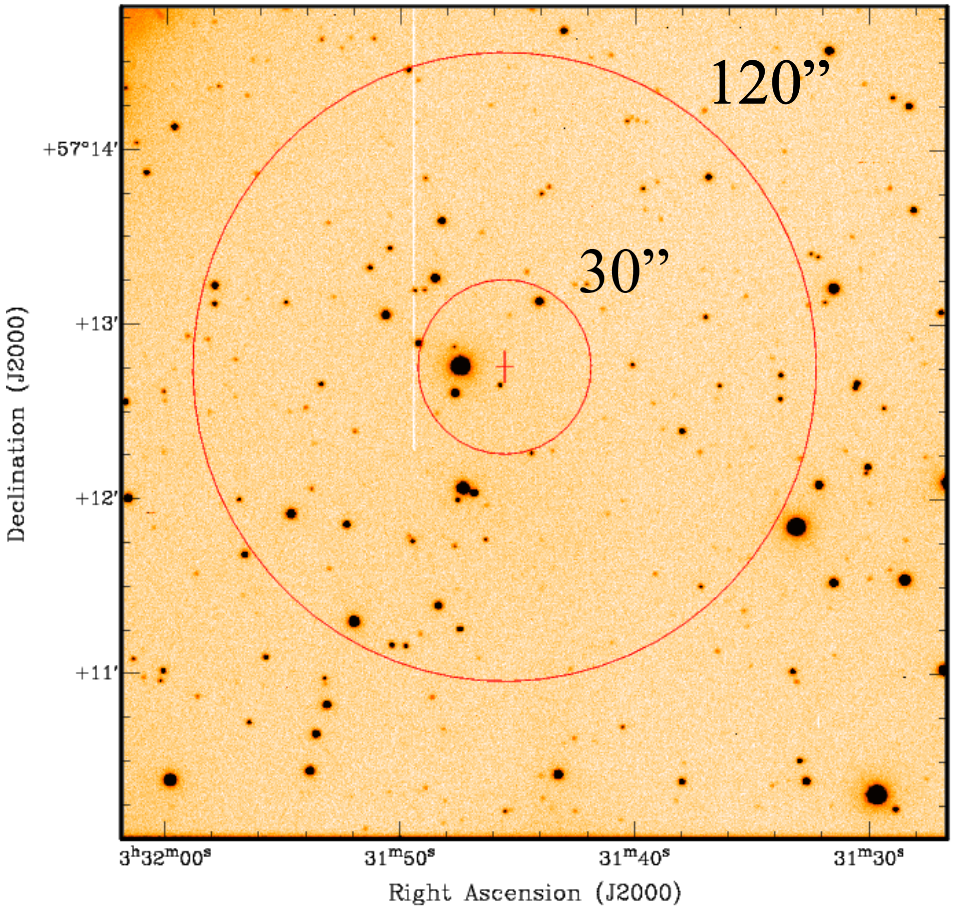
*Triggered WSRT ToO.





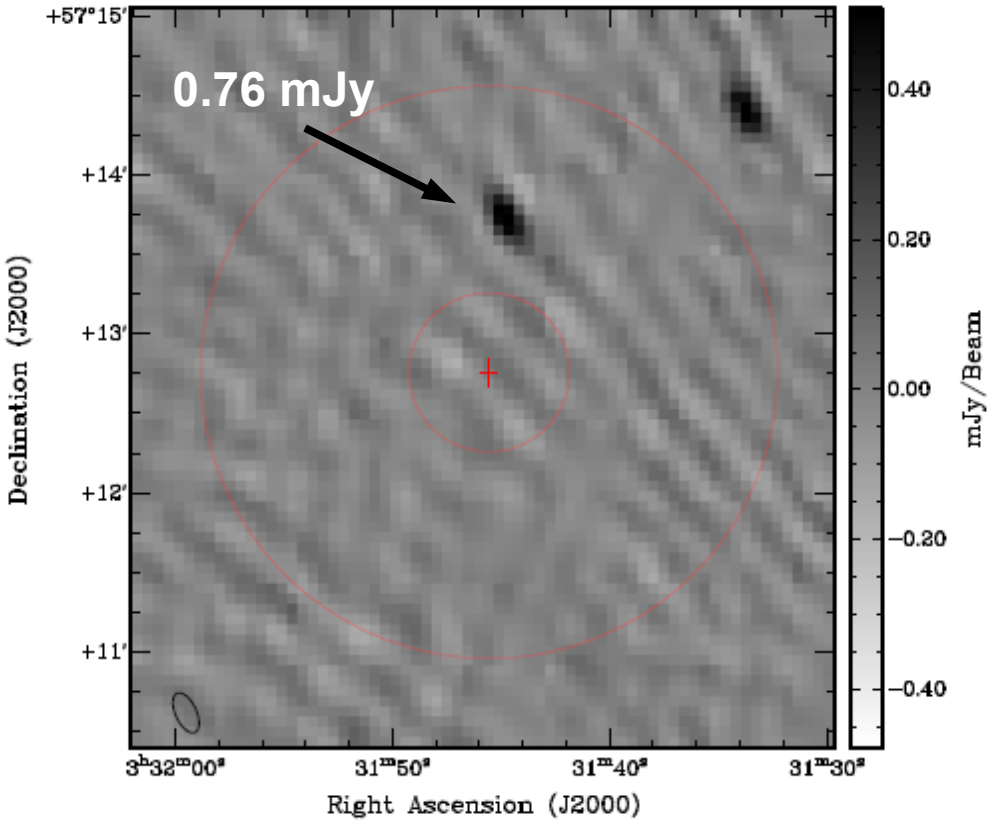
Optical and Radio Follow-up.

Courtesy D. Bersier

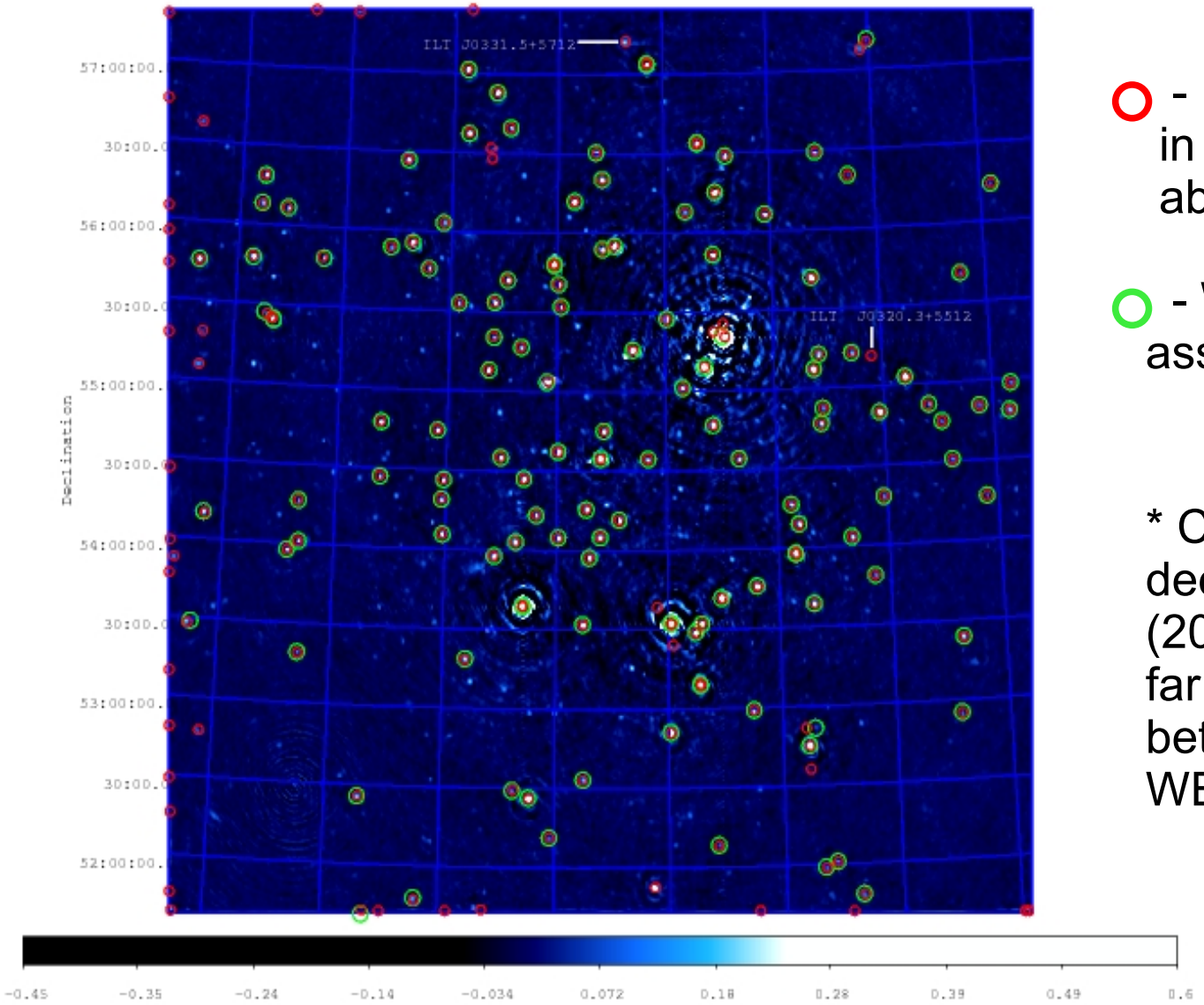


Liverpool telescope (*r* band).

Courtesy V. Tudose



WSRT 1.4 GHz

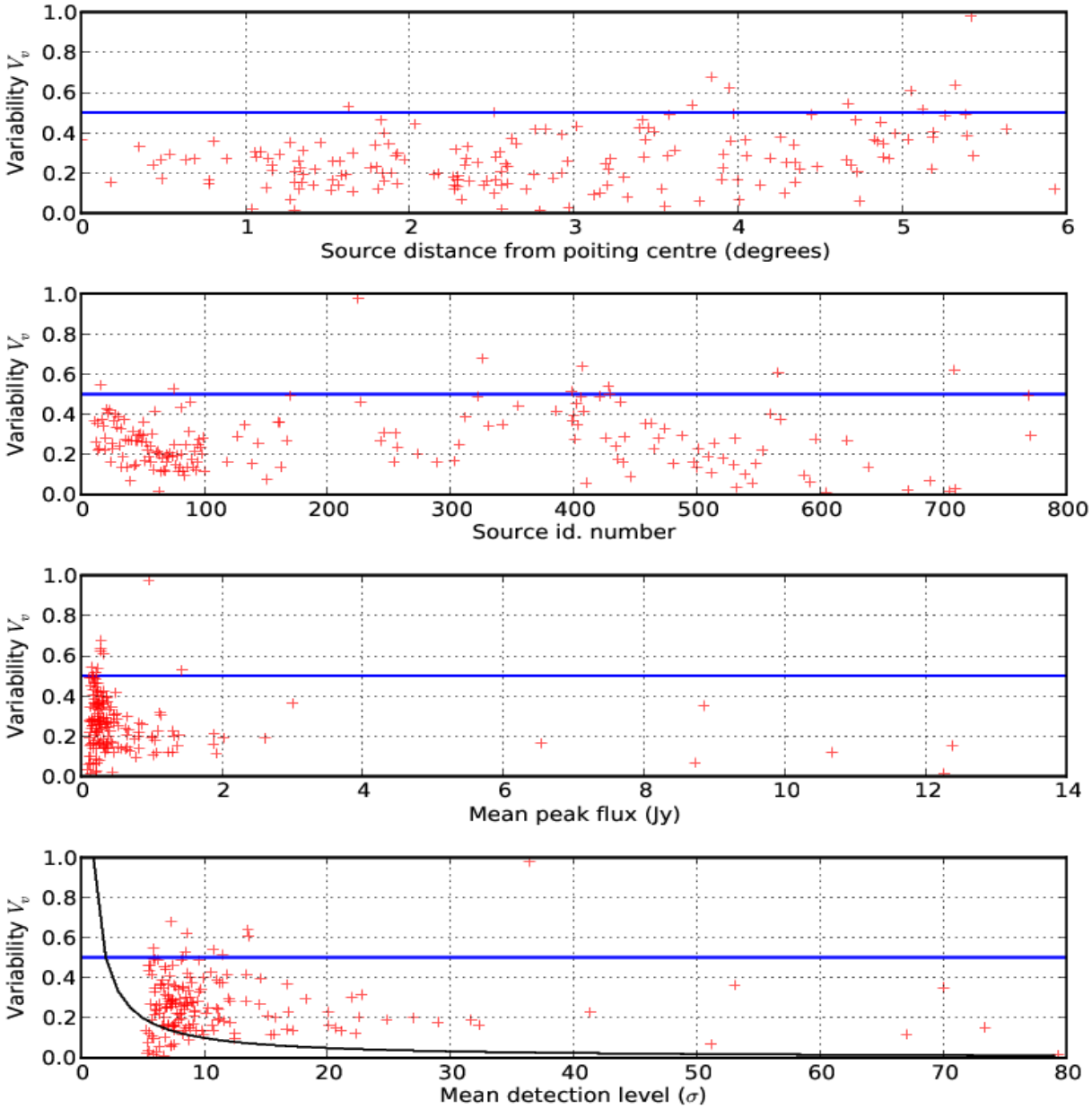


- LOFAR sources detected in **more** than one epoch above 10 sigma

- WENSS catalogue associations

* Circles are overlaid on the deepest image of this field (2010 Dec) that we have so far. Also good agreement between this map and WENSS.

V = std dev / mean



cimager vs casapy

L2010_21641 (December)

240 SBs

cimager

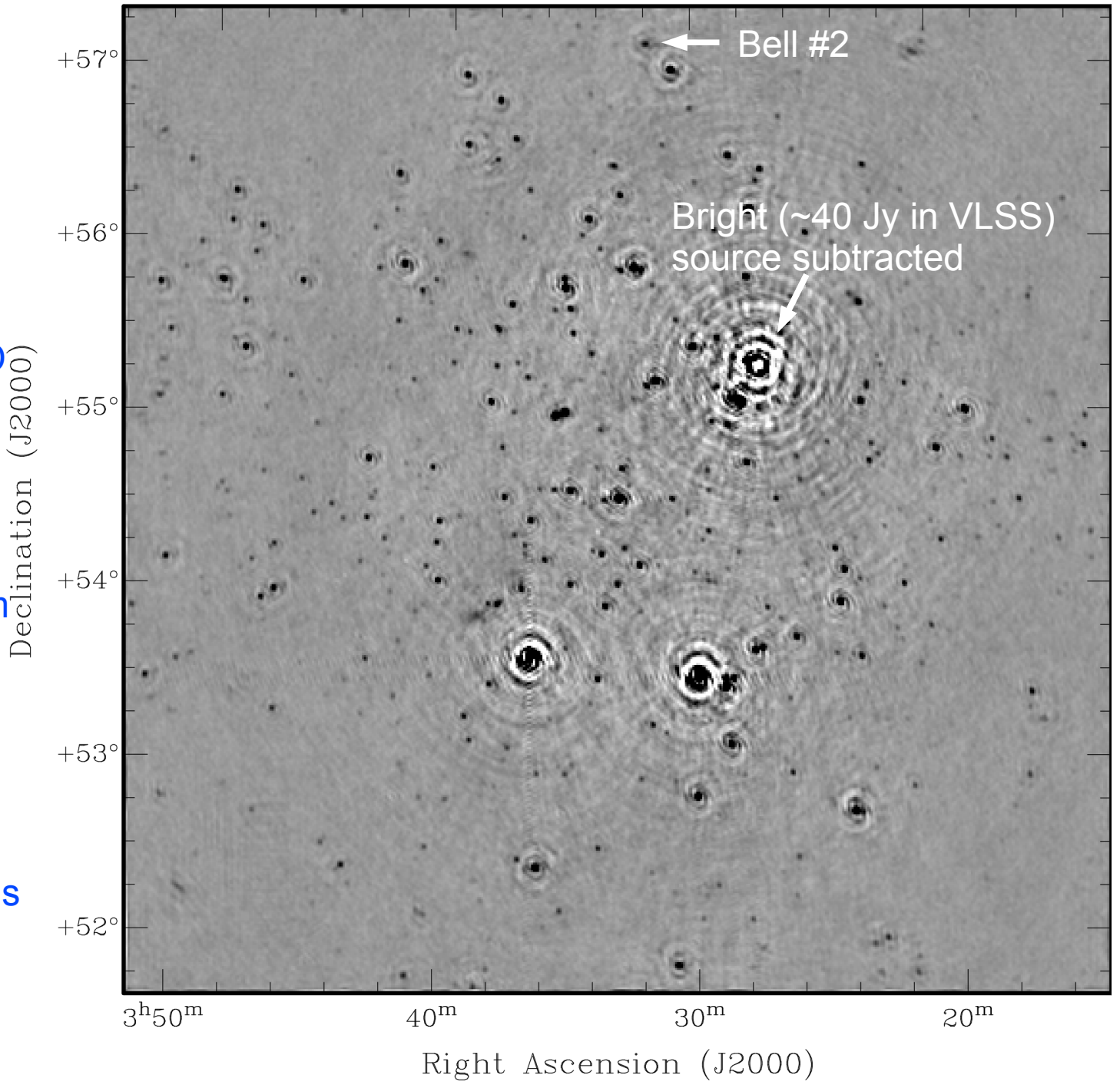
SUBTRACTED DATA column

robust=0 weighting

~2.9 mJy/beam rms

resolution 100 arcsec x 90 arcsec

40 arcsec pixels



cimager vs casapy

L2010_21641 (December)

240 SBs

casapy imager (gridmode 'widefield')

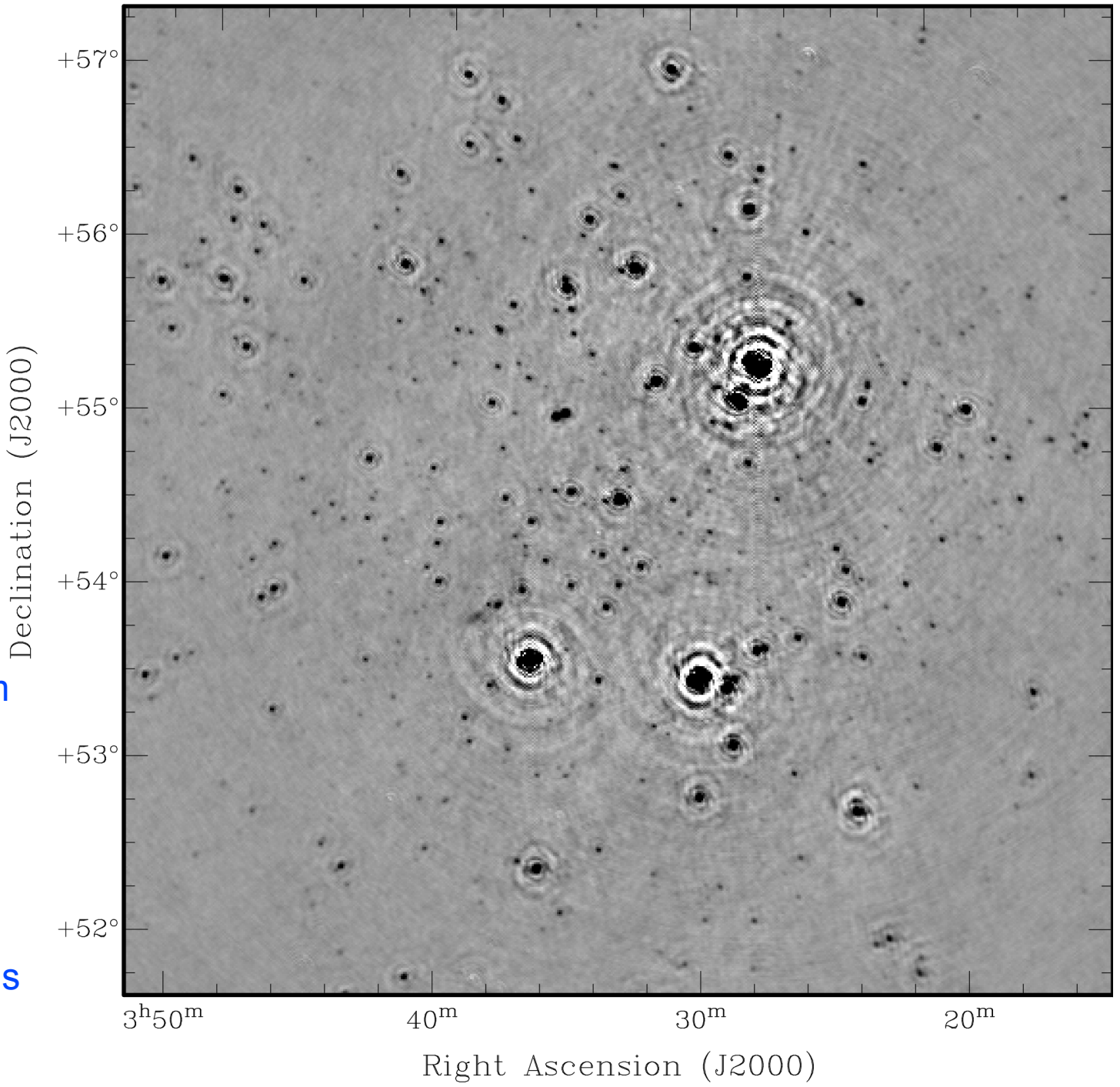
CORRECTED DATA column

robust=0 weighting

~2.5 mJy/beam rms

resolution 120 arcsec x 120 arcsec

40 arcsec pixels



Newer HBA data – different phase centre (close to Bell #2)

L2011_24933 (April 3, 10:05-16:05 UT)

240 SBs, 139-186 MHz

17 core stations (HBA_DUAL) and 5 Dutch remote stations

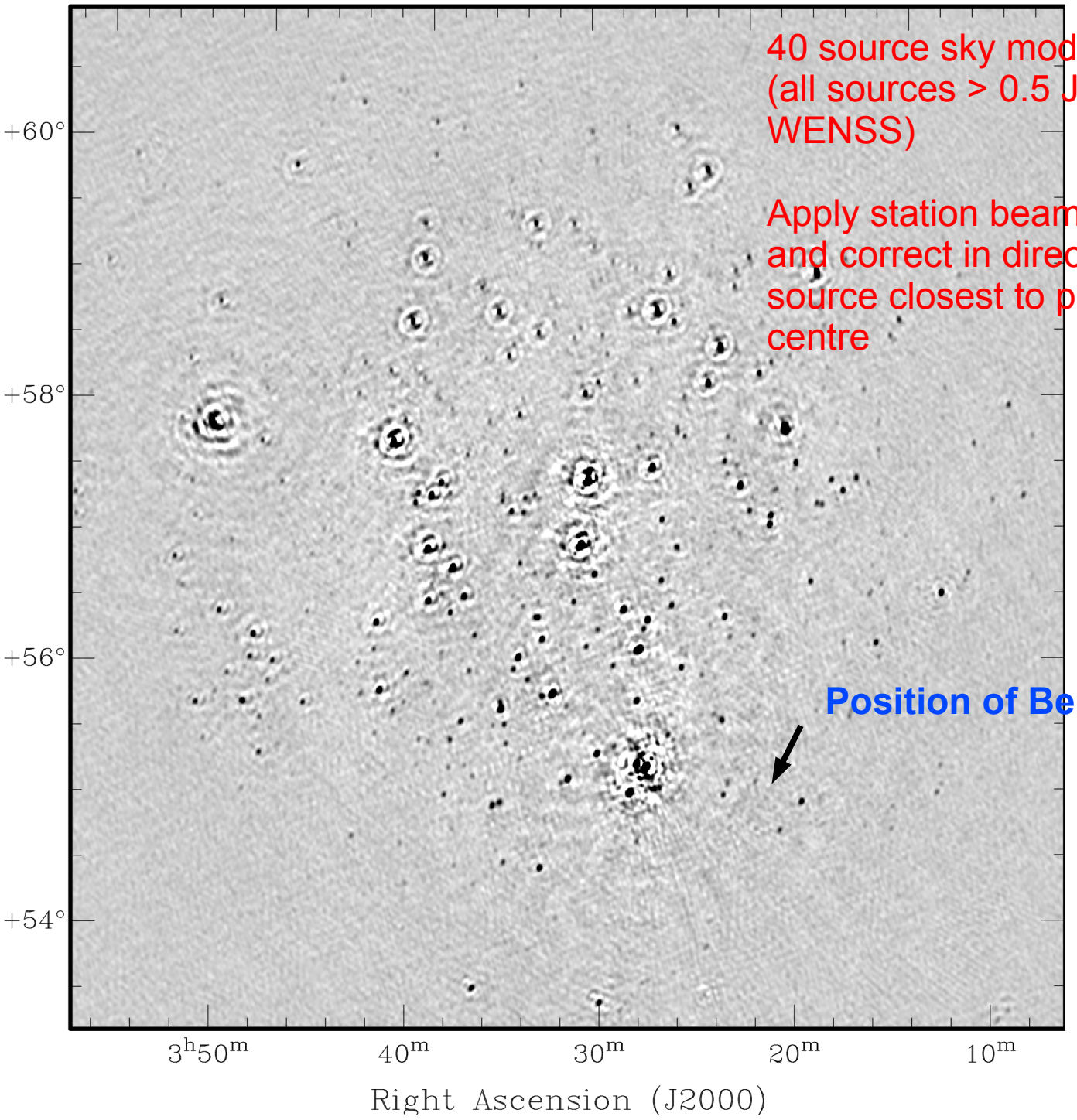
casapy imager (widefield gridmode)

uniform weighting, core stations only (max uvdist 3.75 km)

~2.5 mJy/beam rms

resolution 140 arcsec x 100 arcsec

20 arcsec pixels

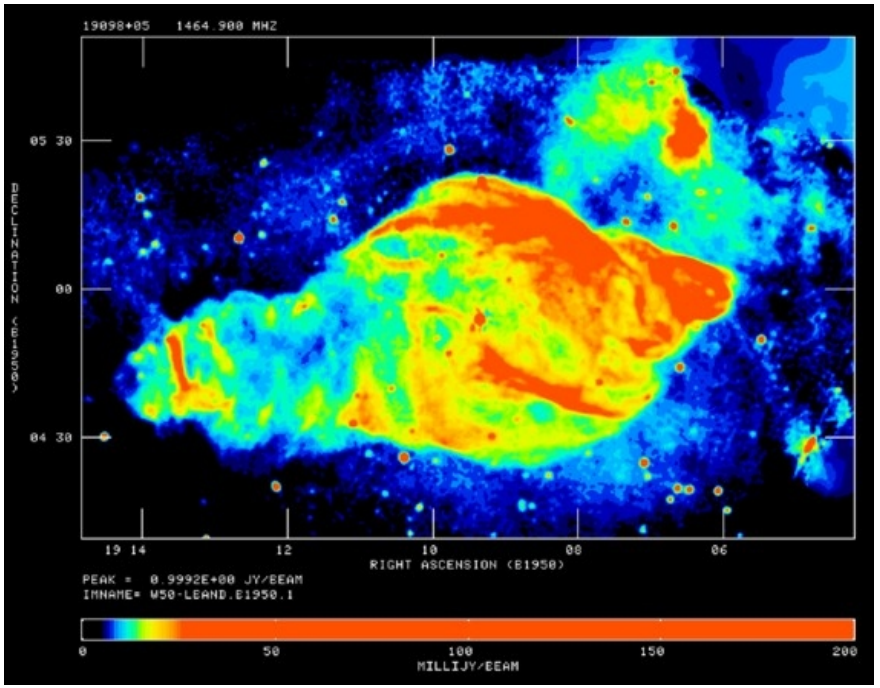


Summary and future work – B0329+54 zenith field

- Image quality reasonably good despite the current calibration/imaging limitations and sky models derived using ~arcmin resolution catalogues. Can already do basic studies of variable and transient sources (keeping in mind the various caveats).
- Two candidate transients, but is Bell #2 a real source or some sort of artefact?
- Need to reduce at least some of the datasets again with updated calibration parsets and better sky models.
- Several new HBA datasets to be looked at in the near future.
- Expand FOV using 7 beam hexagonal pattern.

SS433 / W50

- Famous Galactic microquasar
- RA 19 11 49.57, Dec +04 58 57.9
- D = 5.5 kpc (18 kly)
- Supernova remnant W50 ~10 000 years old. Size ~ 100 pc x 50 pc.
- Mildly-relativistic (v = 0.27c), precessing jets (precession period 162.5 days) from SS433 inflate ‘ear-like’ structures in W50.

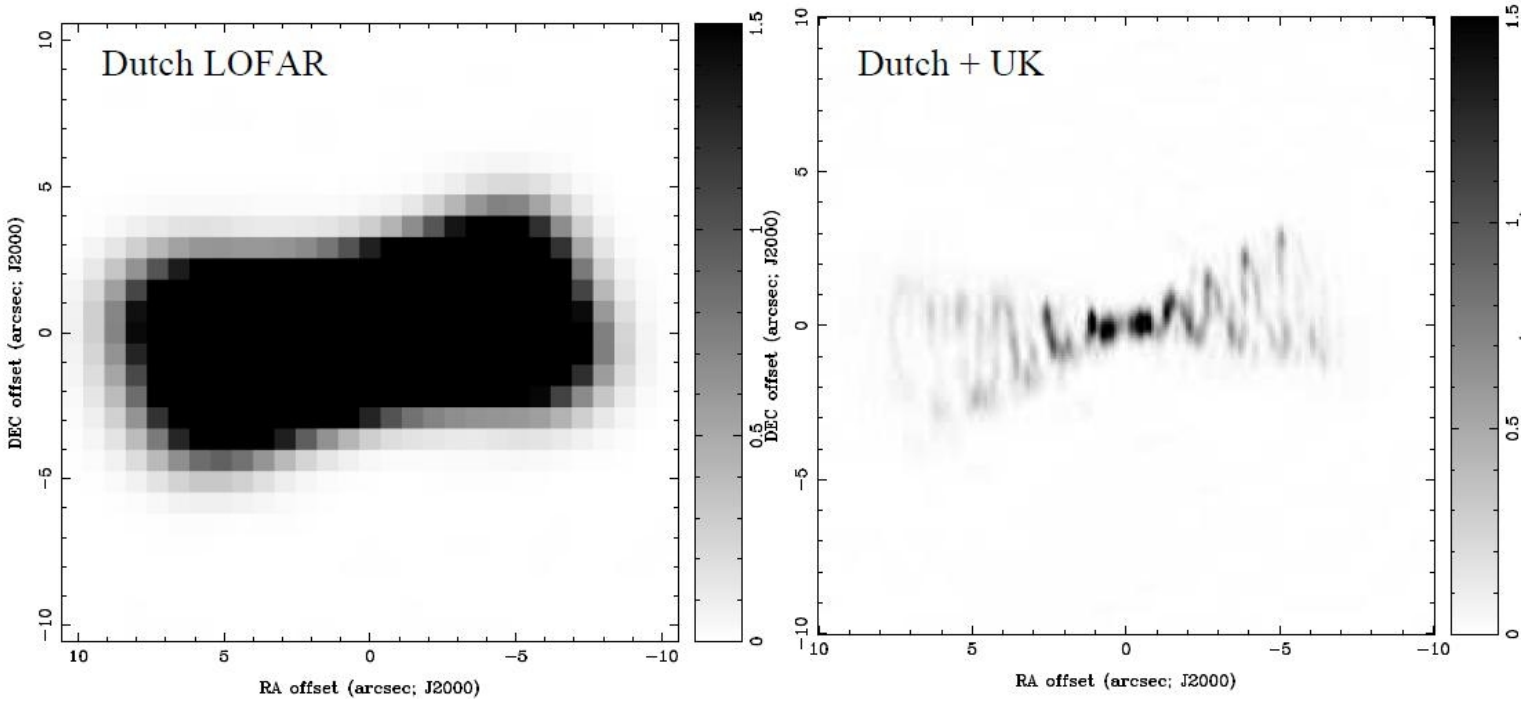


- VLA 1465 MHz map (Dubner et al., 1998, AJ, 116, 1842).

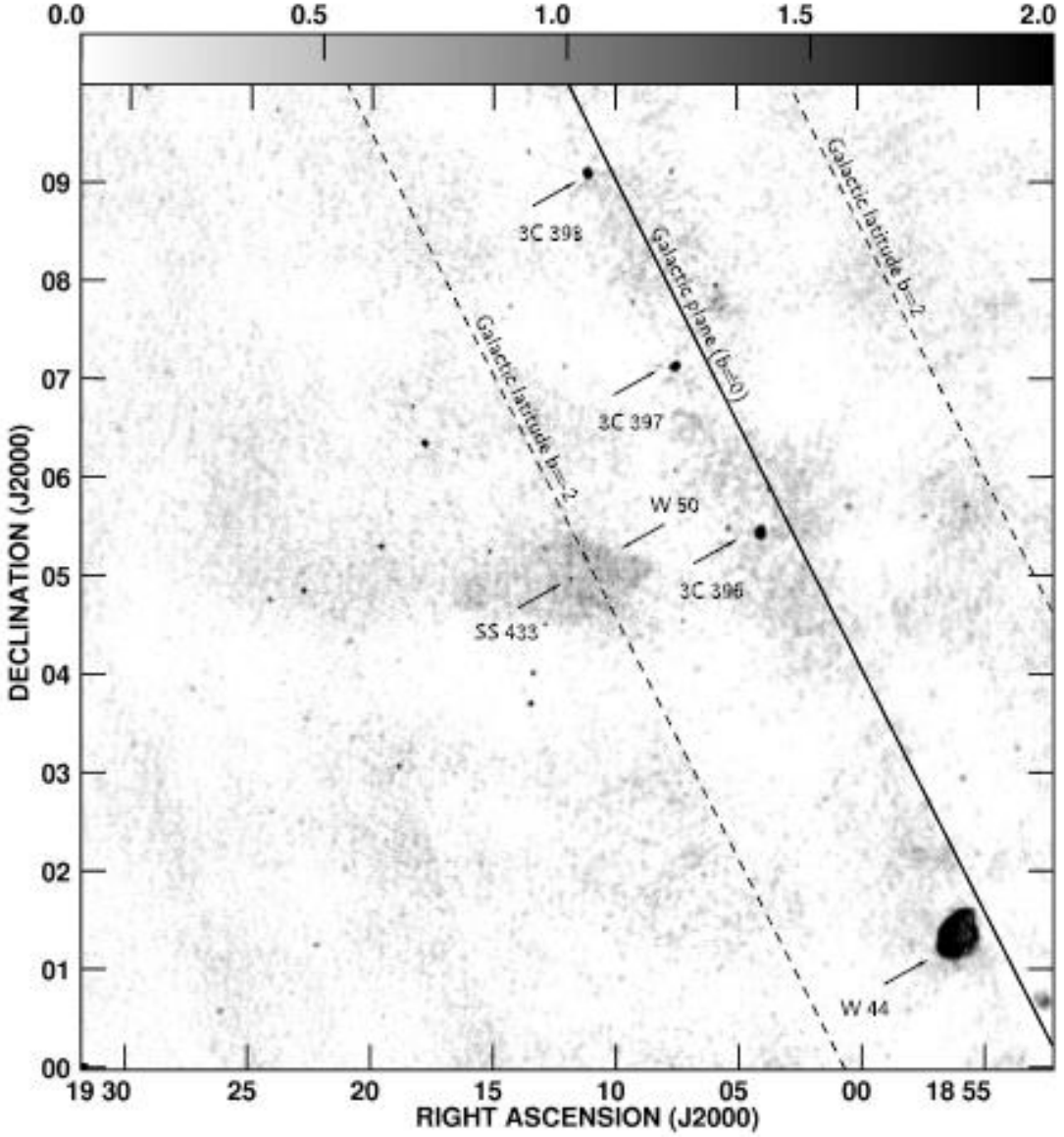
  Resolution 56 arcsec x 54 arcsec, rms 0.5 mJy/beam.

SS433 / W50

- Famous Galactic microquasar
- RA 19 11 49.57, Dec +04 58 57.9
- D = 5.5 kpc (18 kly)
- Supernova remnant W50 ~10 000 years old. Size ~ 100 pc x 50 pc.
- Mildly-relativistic (v = 0.27c), precessing jets (precession period 162.5 days) from SS433 inflate ‘ear-like’ structures in W50.



LOFAR simulations of central region (Cashman, Hill & Fender; LOFAR workshop 2007 April).



- VLA 74 MHz map [Miller-Jones et al., 2007, PoS(Dynamic2007)011]. Resolution 108 arcsec x 93 arcsec, rms 192 mJy/beam.

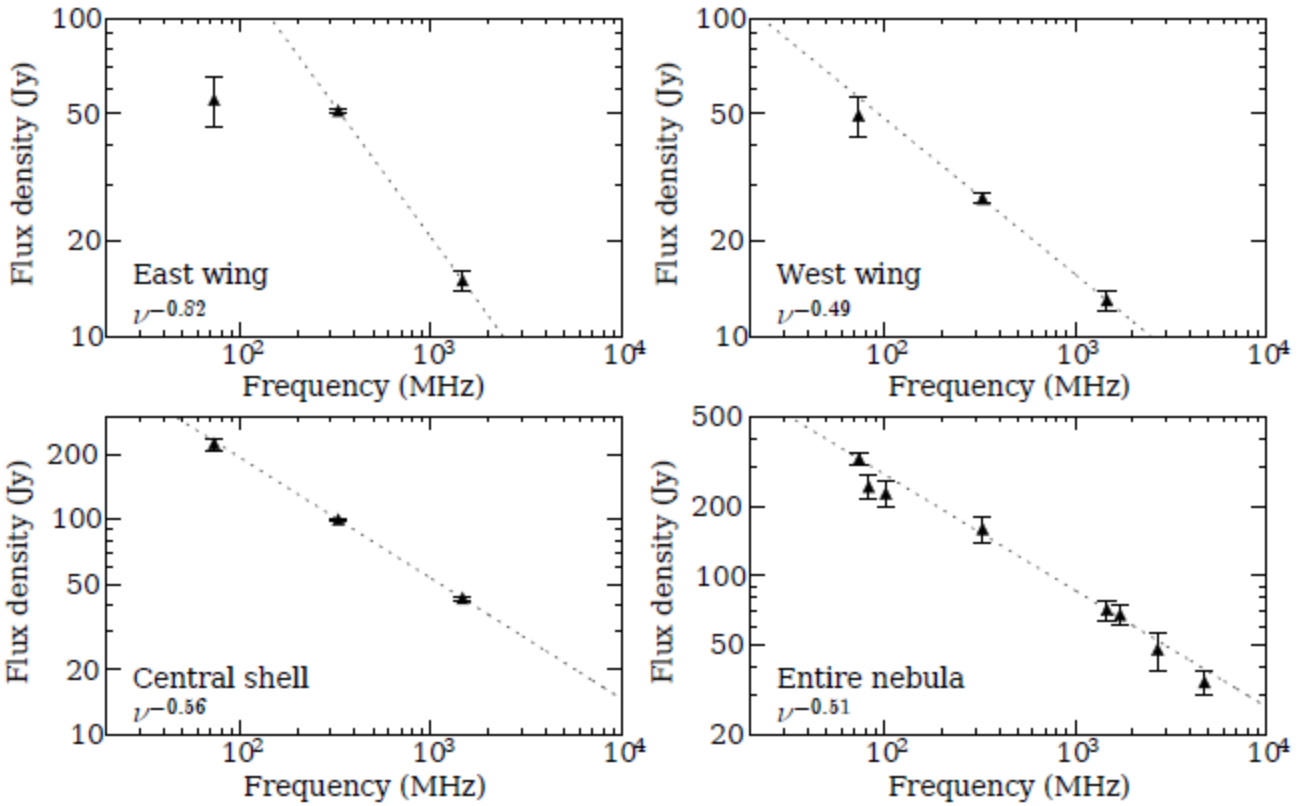
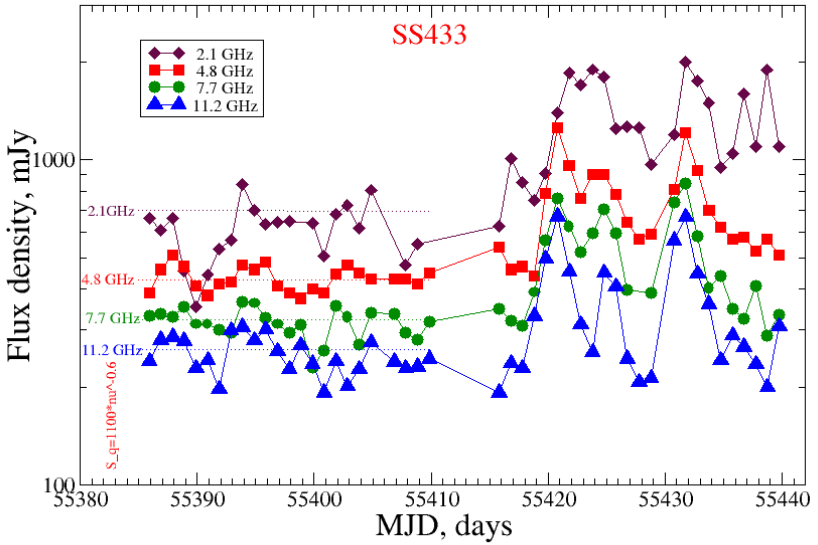


Figure 5: Spectra of the different components of the W 50 nebula. *Top left:* Eastern wing. *Top right:* Western wing. *Bottom left:* Central shell. *Bottom right:* Entire nebula, including previous measurements [4, 8, 3]. Dashed lines show the spectral indices between 1465 and 327.5 MHz previously derived [4] for the components of the nebula, and in the bottom right plot, our derived spectrum of $\alpha = -0.51 \pm 0.02$.

- Miller-Jones et al., 2007, PoS(Dynamic2007)011

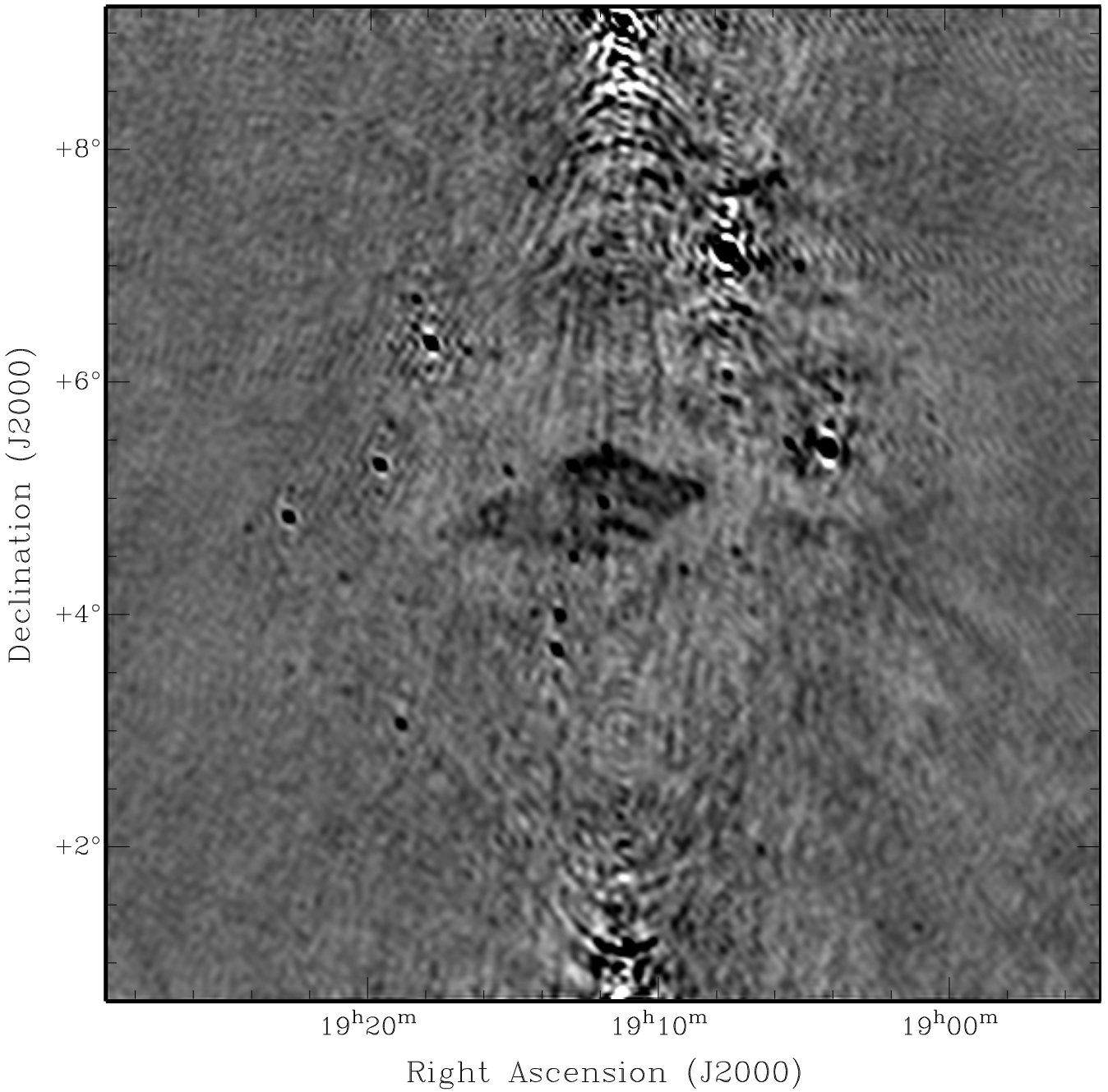
A LOFAR image of SS433 / W50

- 2 x 4 hr runs (2010 August 25 & 26).
- UT range 18:23 – 22:23 in both cases.
- 15 core stations (HBA_DUAL) + 4 Dutch remote stations; 561 baselines, max baseline ~25 km
- Frequency range 115-163 MHz; 248 subbands; 256 channels per subband.
- Processed data compressed in time and frequency; integration time per data point 5 s and 1 channel per subband (channel width 183.1 kHz).



'A very bright radio flare of SS433' - ATel #2812 (Trushkin and Nizhelskij; SAO RAS)

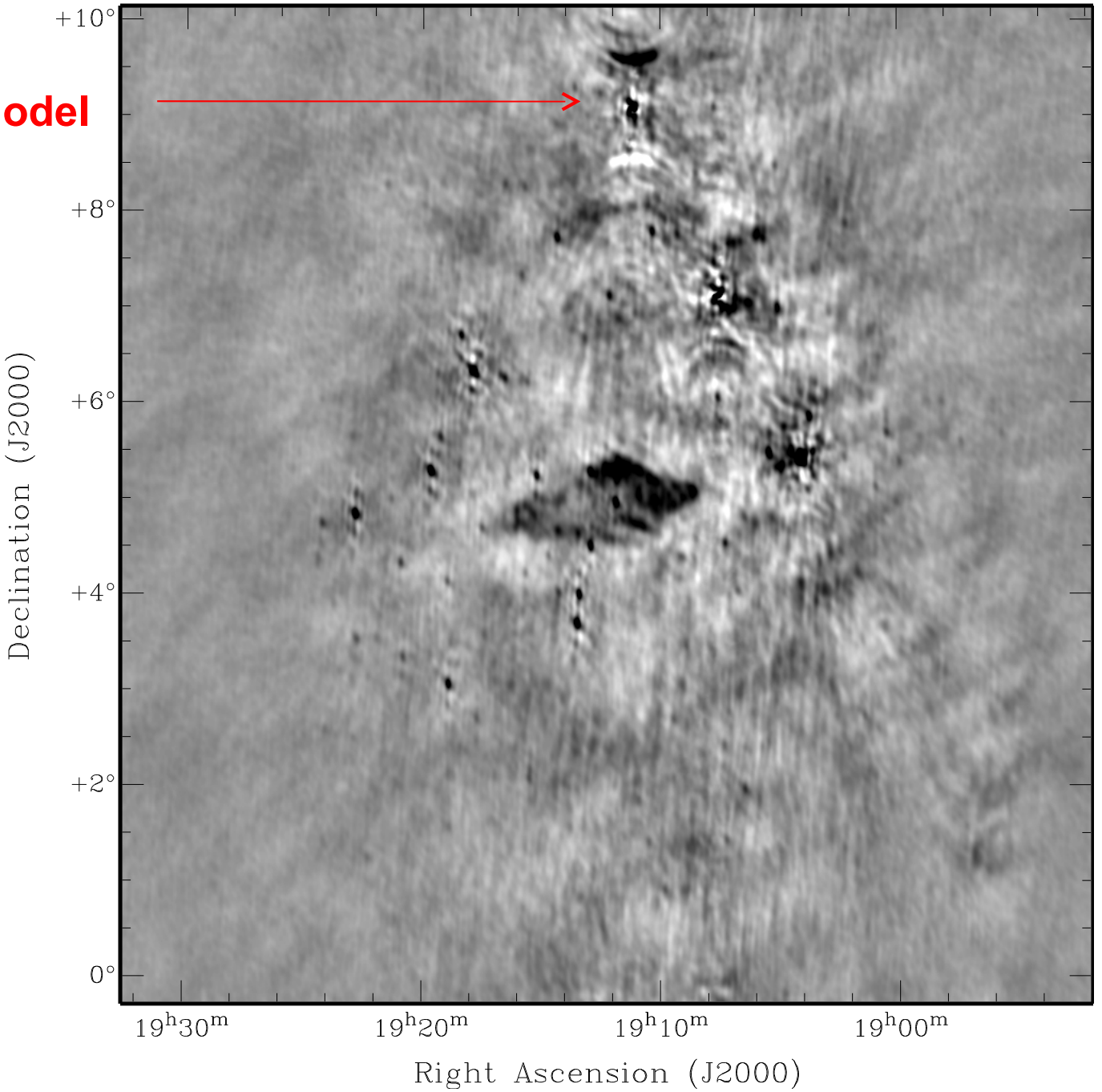
Sky model derived using VLSS and NVSS



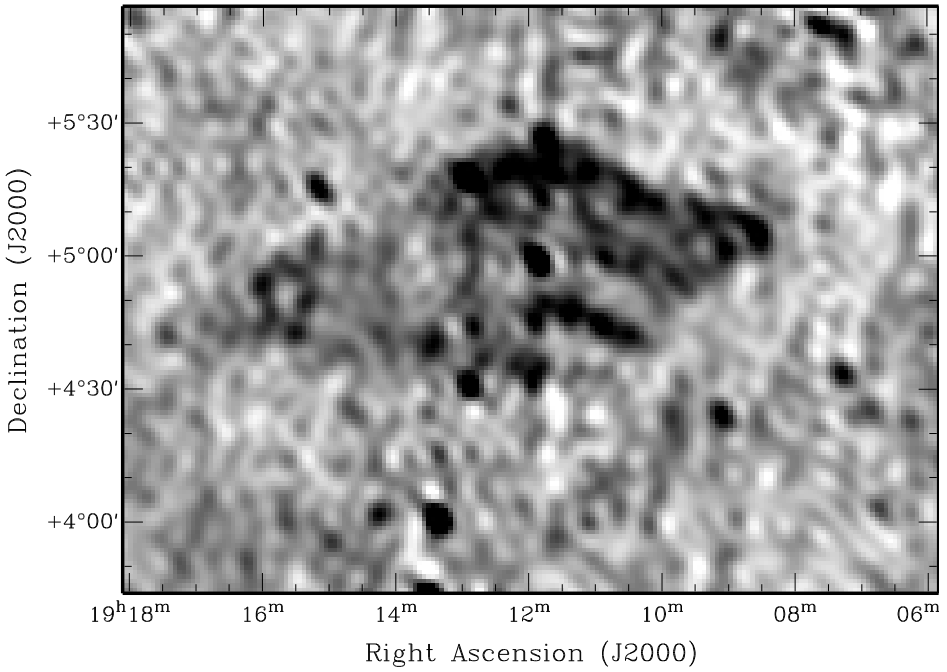
SS433 flux about 1.4 Jy

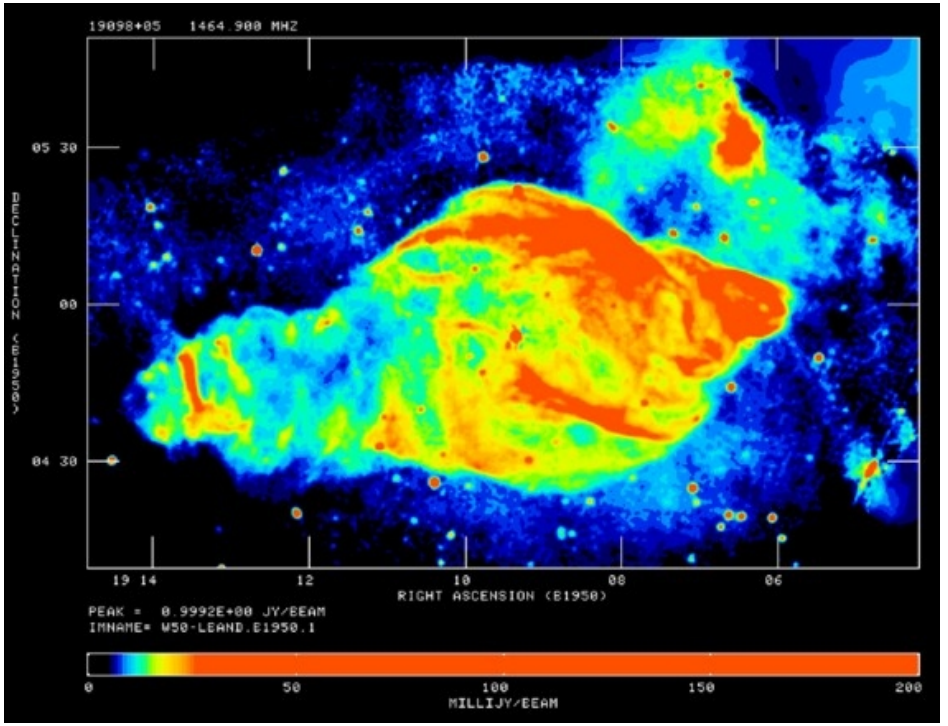
- 2010 Aug. 25 data - averaged image from 246 sub-bands. Pixel size 60 arcsec, image 512 x 512 pixels. Robust weighting (r=0). Rms ~ 60 mJy/beam.

Better model



- 2010 Aug. 25 data - averaged image from 243 sub-bands. Pixel size 40 arcsec, image 1024 x 1024 pixels. Robust weighting (r=1). Rms ~ 40 mJy/beam.


Declination (J2000)
+5°30′
+5°00′
+4°30′
+4°00′
19h18m
16m
14m
12m
10m
08m
06m
Right Ascension (J2000)


19098+05 1464.900 MHZ
05 30
00
04 30
DECLINATION (B1950)
19 14
12
10
08
06
RIGHT ASCENSION (B1950)
PEAK = 0.9992E+00 JY/BEAM
IMNAME= W50-LEAND.B1950.1
0
50
100
150
200
MILLIJY/BEAM

Newer SS433 data

- 2 x 2 hr HBA observations (2011 April 10 and 11)
- 1 x 6 hr HBA 2011 Jun 25/26
- 1 x 6 hr HBA 2011 Aug 16

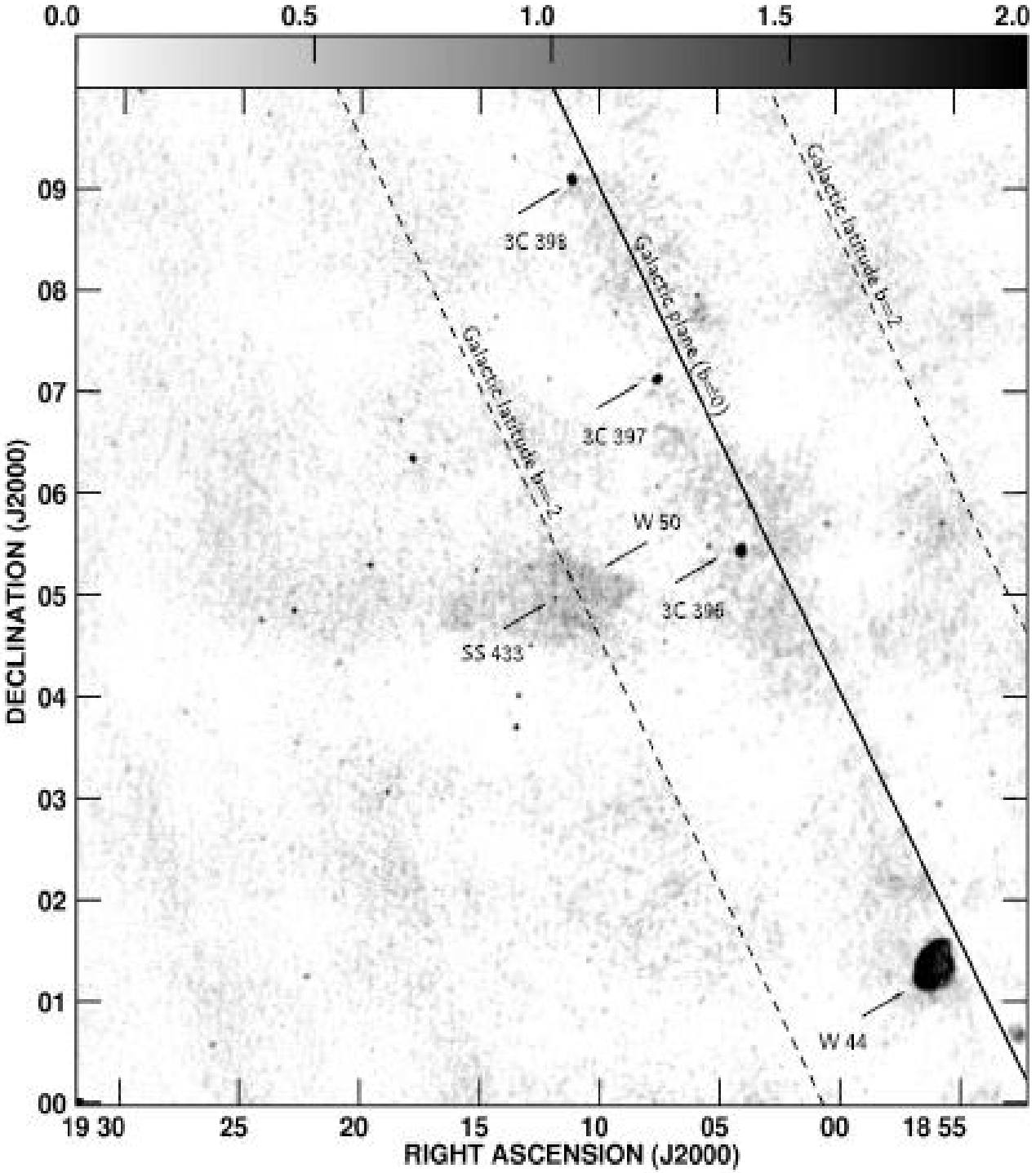
- LBA dataset obtained in May; data reduction still at relatively early stage only (testing demixing on a few subbands).

- Sky model constructed using VLSS and a 74 MHz VLA map courtesy of James Miller-Jones. Station beam model applied.

- 2 x 2
- 1 x 6
- 1 x 6

- LBA d
  (testir

- Sky m
  Jame



2011 April 11 HBA

April 11, 04:00-06:00 UT

SBs 0-121 (119-143 MHz)

El. 39-42 deg (transit)

20 core stations (HBA_DUAL) and 7 Dutch remote stations

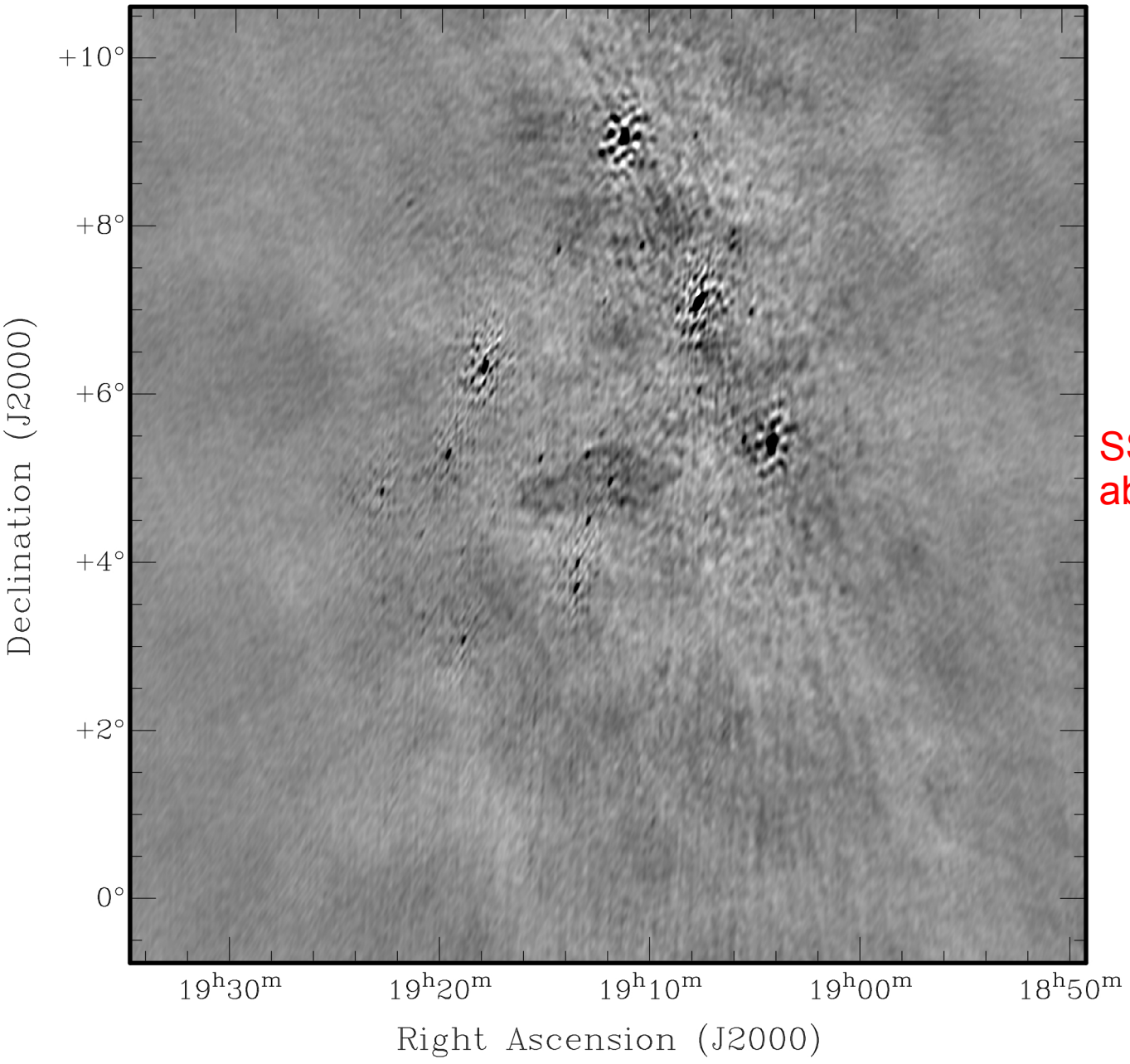
casapy imager (widefield gridmode)

uniform weighting; core stations only

~30 mJy/beam rms

resolution 350 arcsec x 135 arcsec

20 arcsec pixels



SS433 flux about 1 Jy

2011 June 25/26 HBA

June 25/26, 21:30-03:30 UT

31 SBs roughly evenly spread across freq. range (115-163 MHz)

El. 30-42 deg

19 core stations (HBA_DUAL) and 7 Dutch remote stations

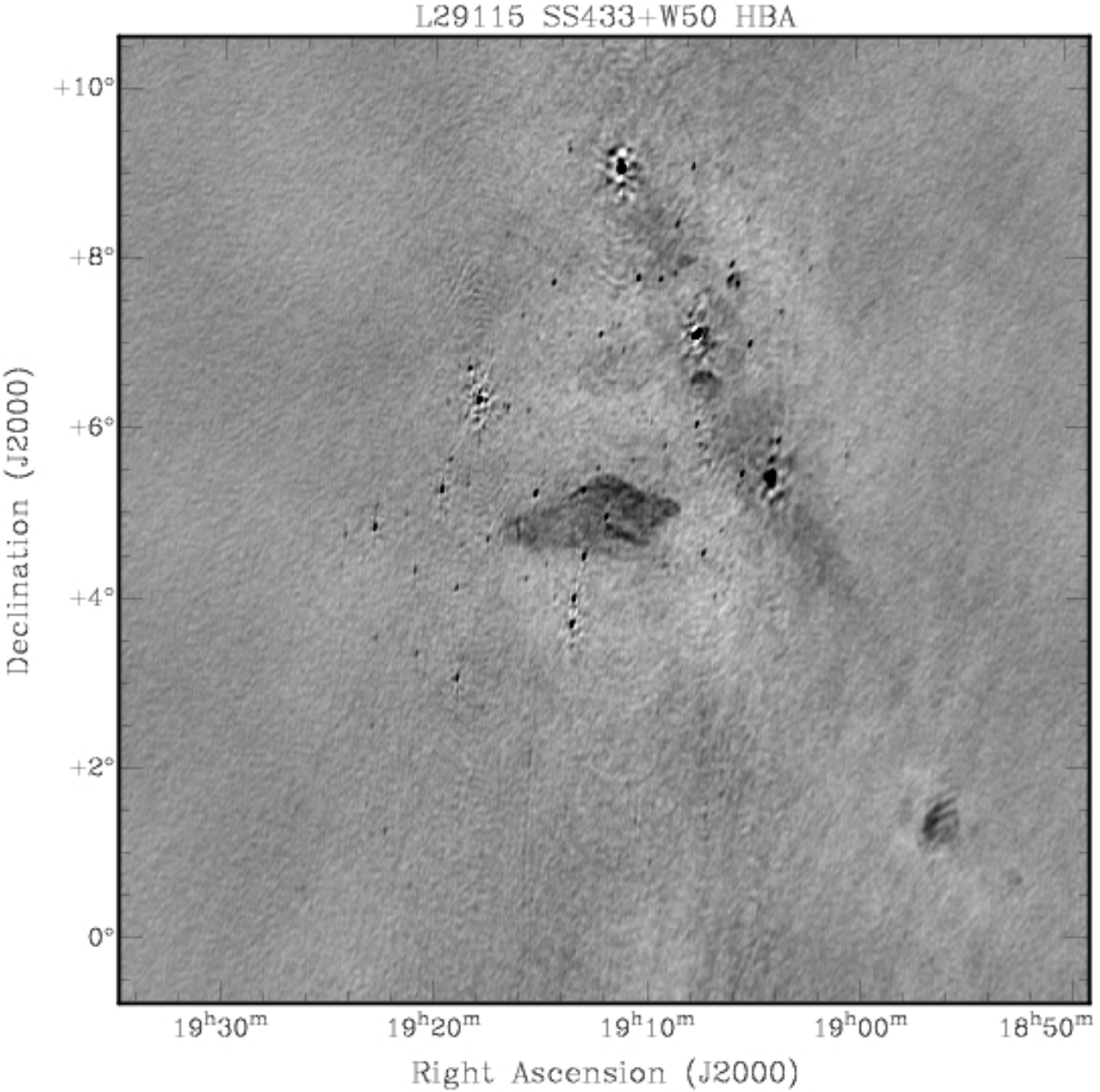
casapy imager (widefield gridmode)

Robust=0 weighting; core Stations only

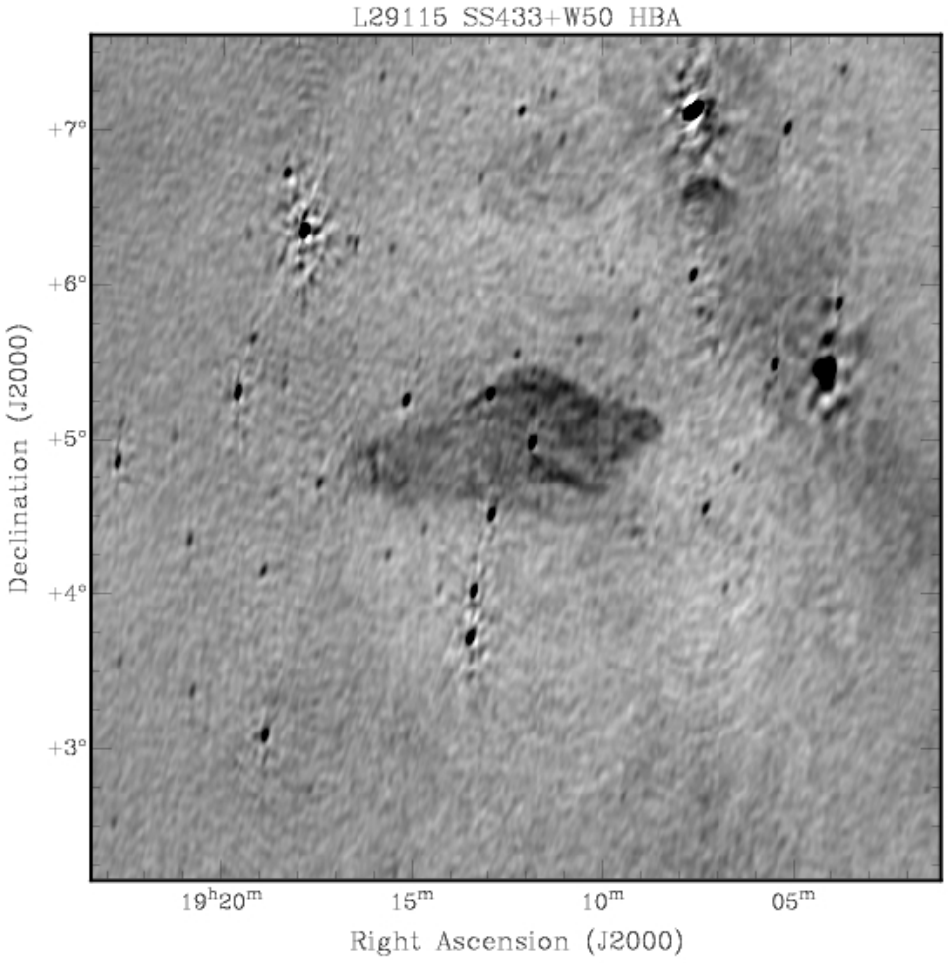
~20 mJy/beam rms

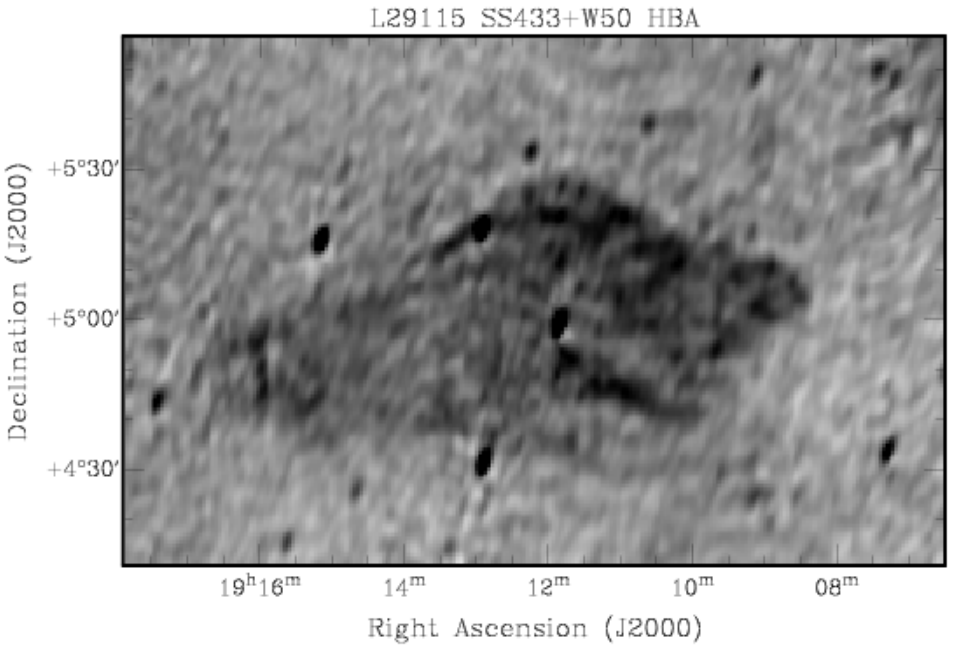
resolution ~180 arcsec x 120 arcsec

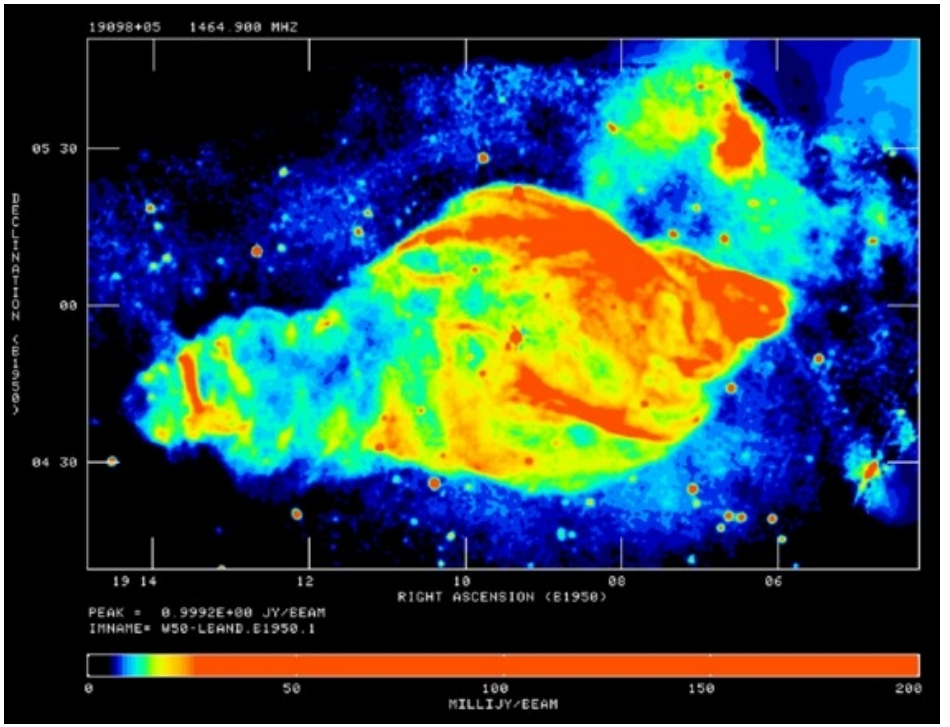
40 arcsec pixels

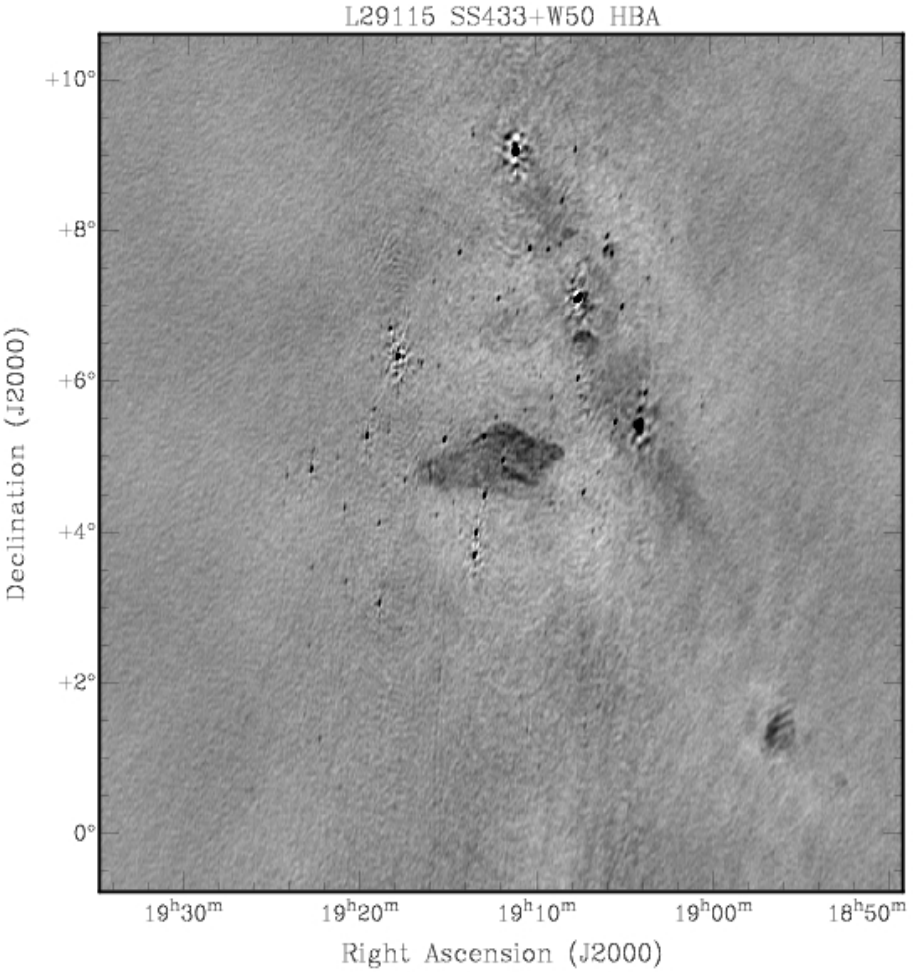


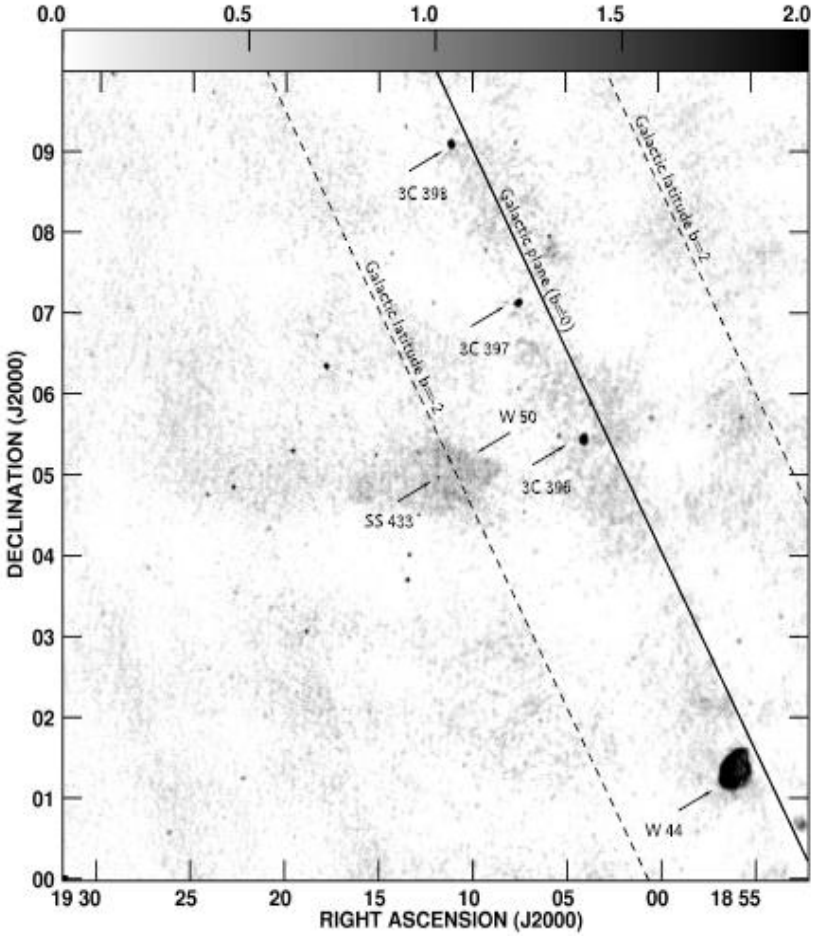
SS433 flux about 1.2 Jy

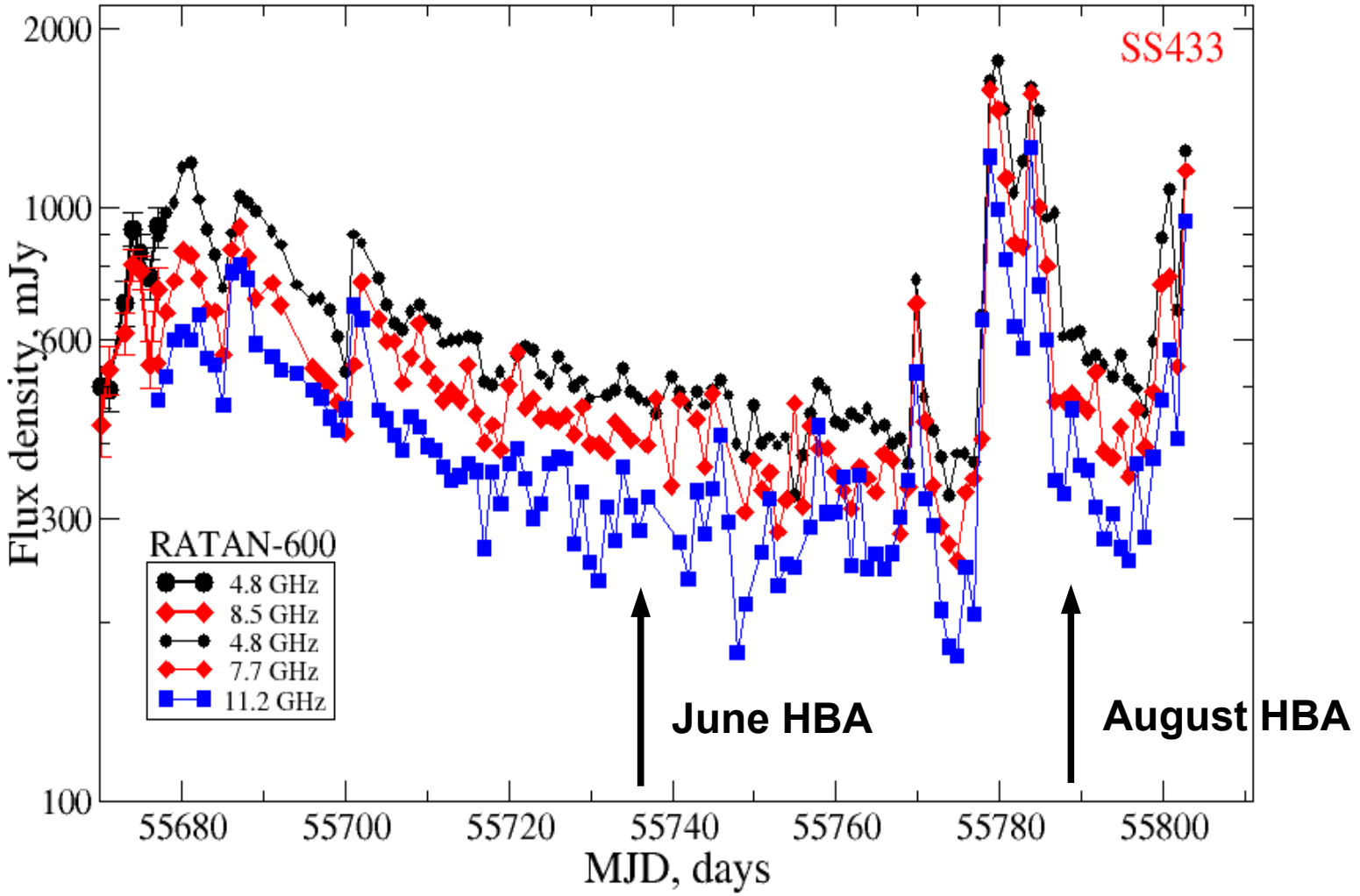

L29115 SS433+W50 HBA
Declination (J2000)
+7°
+6°
+5°
+4°
+3°
19h20m
15m
10m
05m
Right Ascension (J2000)


L29115 SS433+W50 HBA
Declination (J2000)
+5°30′
+5°00′
+4°30′
19h16m
14m
12m
10m
08m
Right Ascension (J2000)


19098+05 1464.900 MHZ
05 30
00
04 30
DECLINATION (B1950)
19 14
12
10
08
06
RIGHT ASCENSION (B1950)
PEAK = 0.9992E+00 JY/BEAM
IMNAME= W50-LEAND.B1950.1
0
50
100
150
200
MILLIJY/BEAM


L29115 SS433+W50 HBA
+10°
+8°
+6°
+4°
+2°
0°
Declination (J2000)
19h30m
19h20m
19h10m
19h00m
18h50m
Right Ascension (J2000)


0.0
0.5
1.0
1.5
2.0
3C 398
Galactic latitude b=2
Galactic plane (b=0)
Galactic latitude b=-2
3C 397
W 50
3C 396
SS 433
W 44
09
08
07
06
05
04
03
02
01
00
DECLINATION (J2000)
19 30
25
20
15
10
05
00
18 55
RIGHT ASCENSION (J2000)



ATel #3547; S.A. Trushkin, N.A. Nizhelskij, G.V. Zhekanis (SAO RAS)

Summary and future work – SS433+W50

- HBA images look promising but still a lot of things to sort out with the calibration.

- The biggest issue is the sky model for W50. Currently attempting to use PyBDSM on a 327 MHz VLA map, but it can take many hours to run. CLEAN components are an alternative option (but would need tens of thousands of these to model the nebula properly).

- May need to initially restrict the baseline range when BBS is run – testing is currently being carried out.

- Depending on the exact science goals, the simplest option might be to just flag out the shortest baselines.