The LOFAR EoR project: LC0_019 + LC1_039

Ger de Bruyn ++

++ EoR project team

Kapteyn Institute, Groningen &
ASTRON, Dwingeloo

Data transfer, storage, initial processing,..

Observations: LC1_039 (since 15 Nov 2013)

LC0_019 results (see www.astron.nl/gerfeest)

Data transfer issues (see Hanno Holties talk)

General data transport and processing procedure until mid-Dec 2013:

1) CEP2 → TARGET (F area)
2) TARGET F → EoR cluster
- RFI mitigation: on 64ch/2s
- Averaging: 64ch/2s → 15ch/2s, 3ch/2s and 1ch/10s
3) 15ch/2s EoR cluster → TARGET E (→ tape)

All our LC0_019 15ch/2s data on TARGET E have been inaccessible for some time .

From mid-Dec 2013 onwards

1) CEP2 → EoR cluster (10 Gb/s)
2) EoR → SARA still not working…
……
3) EoR cluster 15ch/2s data → SARA

Thanks to heroic 'vacation time' efforts of Yan Grange, Mike Sipior, Pandey, Maaijke Mevius, Adriaan Renting,…

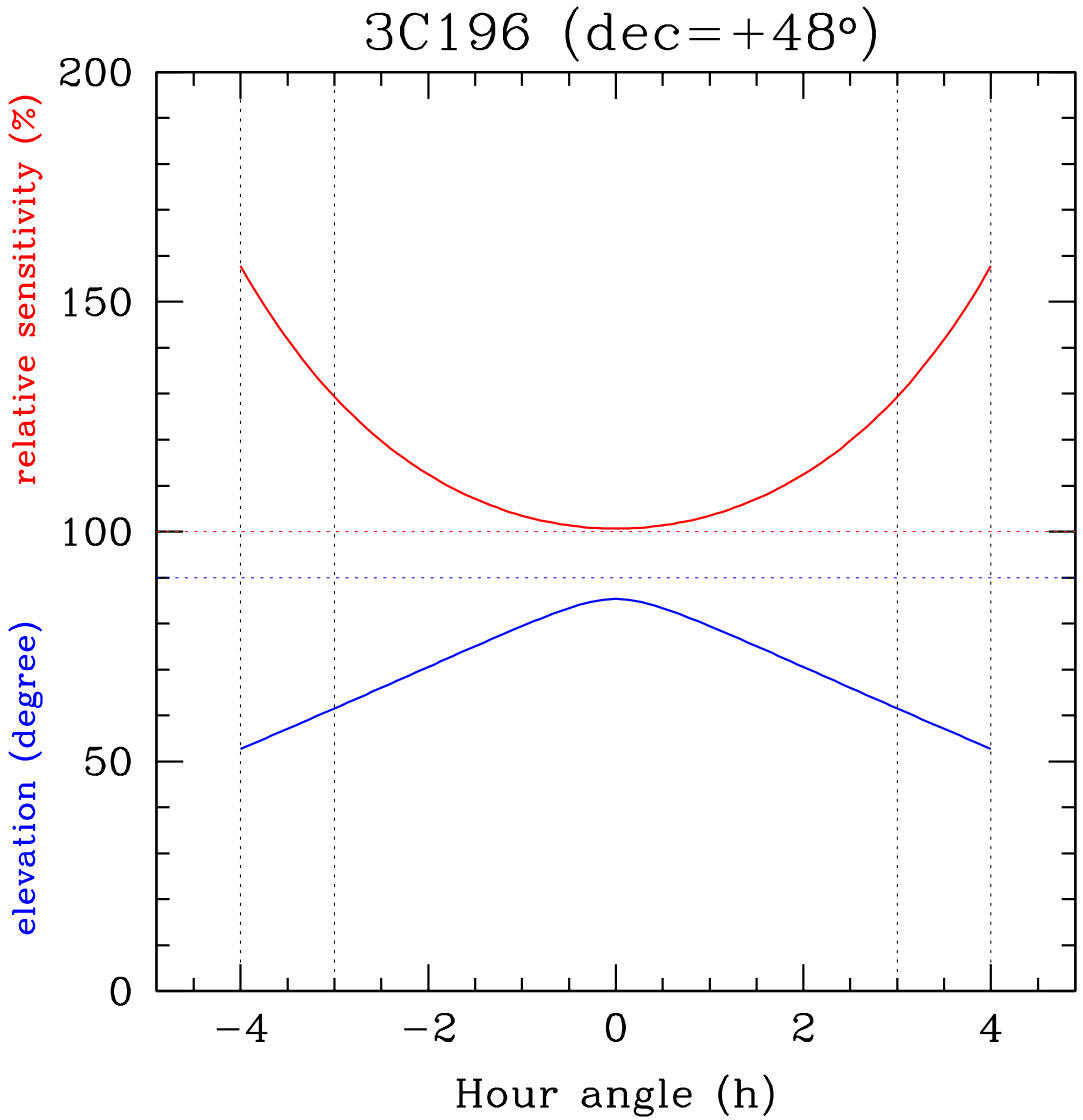
Planned LC1_039 observing program

- 300h on NCP (~ 20 nights)
- 200h on 3C196 (~ 33 'nights')

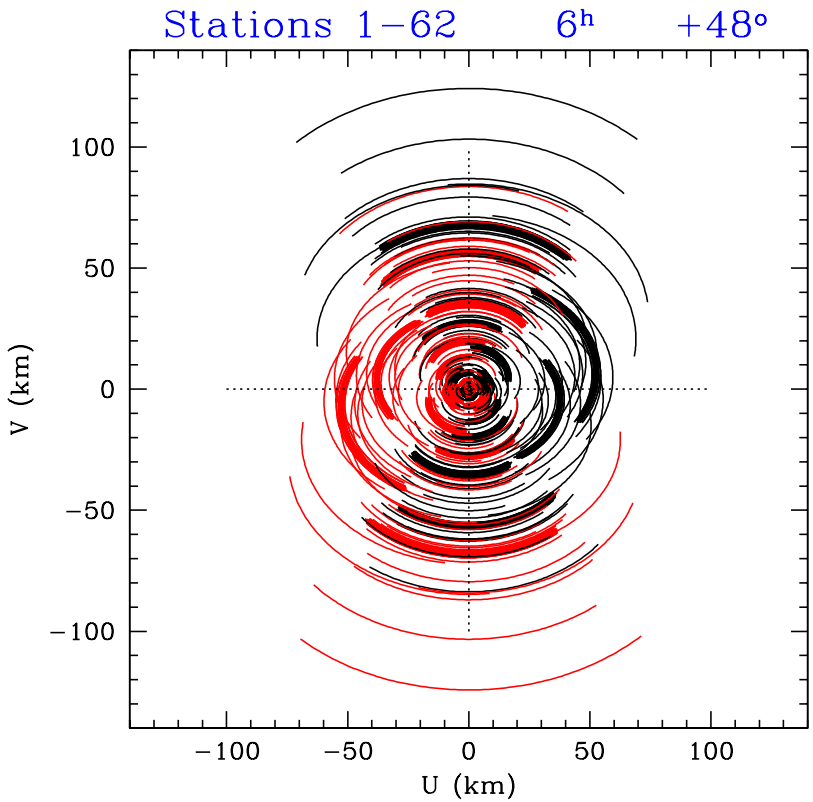
Some changes compared to LC0_019

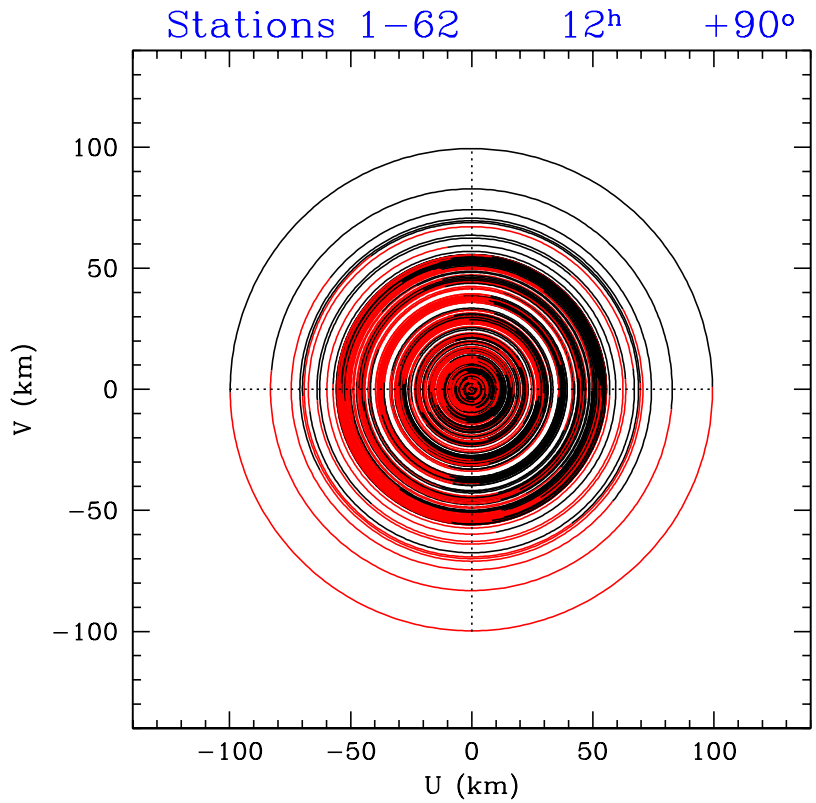
- 8h 3C196 syntheses → 6h syntheses (elevation/beam and sensitivity issues)
- 120 km baselines (RS210) → more smearing → 5ch/subband data product as well

Due to element beam + station projection issues



uv-coverages including RS210





Description of ionosphere is based on amplitude scintillation on 100m baselines:
4 categories: Quiet, Average, Bad & Very Bad (m > 20%)

LC1_039 Observing log **blue → on EoR cluster** **red → bad data: no TX**

	3C196	#h	NCP	#h	Comments
15/16 Nov 2013					
16/17					
17/18					
18/19			189293	14.6	
19/20					
20/21					
21/22					
22/23					
23/24					
24/25	189376	6			
25/26					
26/27	191030	6			
27/28					
28/29					
29/30					
30/1 Dec					
1/2					
2/3					
3/4	192360	6			average ionosphere, CS011 out
4/5			192362	15.3	
5/6					
6/7					
7/8					
8/9					
10/11	192833	6			2h scintillation, RS210 out
11/12	194338	6			bad ionosphere, first 4h
12/13					
13/14					
14/15					
15/16	192832	6			quiet ionosphere !
16/17					
17/18					
18/19			195297	15.5	
19/20					
20/21					
21/22					
22/23					
23/24			196427	15.5	
24/25	196438	6			bad ionosphere, CS006 out
25/26			196424	15.5	only 1% data written
26/27	196437	6			bad ionosphere, CS006 out
27/28			196421	15.5	
28/29	196436	6			quiet ionosphere
29/30	196863	6			bad ionosphere, all night
30/31	196435	6			very bad ionosphere, first 3h
31/1 Jan	196867	6			quiet ionosphere, CS201HBA0 ?
1/2	196434	6			quiet ionosphere
2/3	196866	6			very bad ionosphere, first 4h
3/4					
4/5	196869	6			quiet ionosphere

LC1_039 overview till 8 Jan 2014

3C196 16x6 = 96h
NCP 5x15.5 = 77h

3C196 data shows that 30-40% is seriously affected by ionospheric scintillation !

Comparison between winter 2012/2013 and winter 2013/2014

Raw amplitude stability on 3x5 HBA0 superterp baselines

Project LC0_019 3C196 (8h-syntheses)

L78444 30/1 Dec 2012
L80897 21/22 Dec 2012
L80892 11/12 Jan 2013

Project LC1_039 3C196 (6h syntheses)

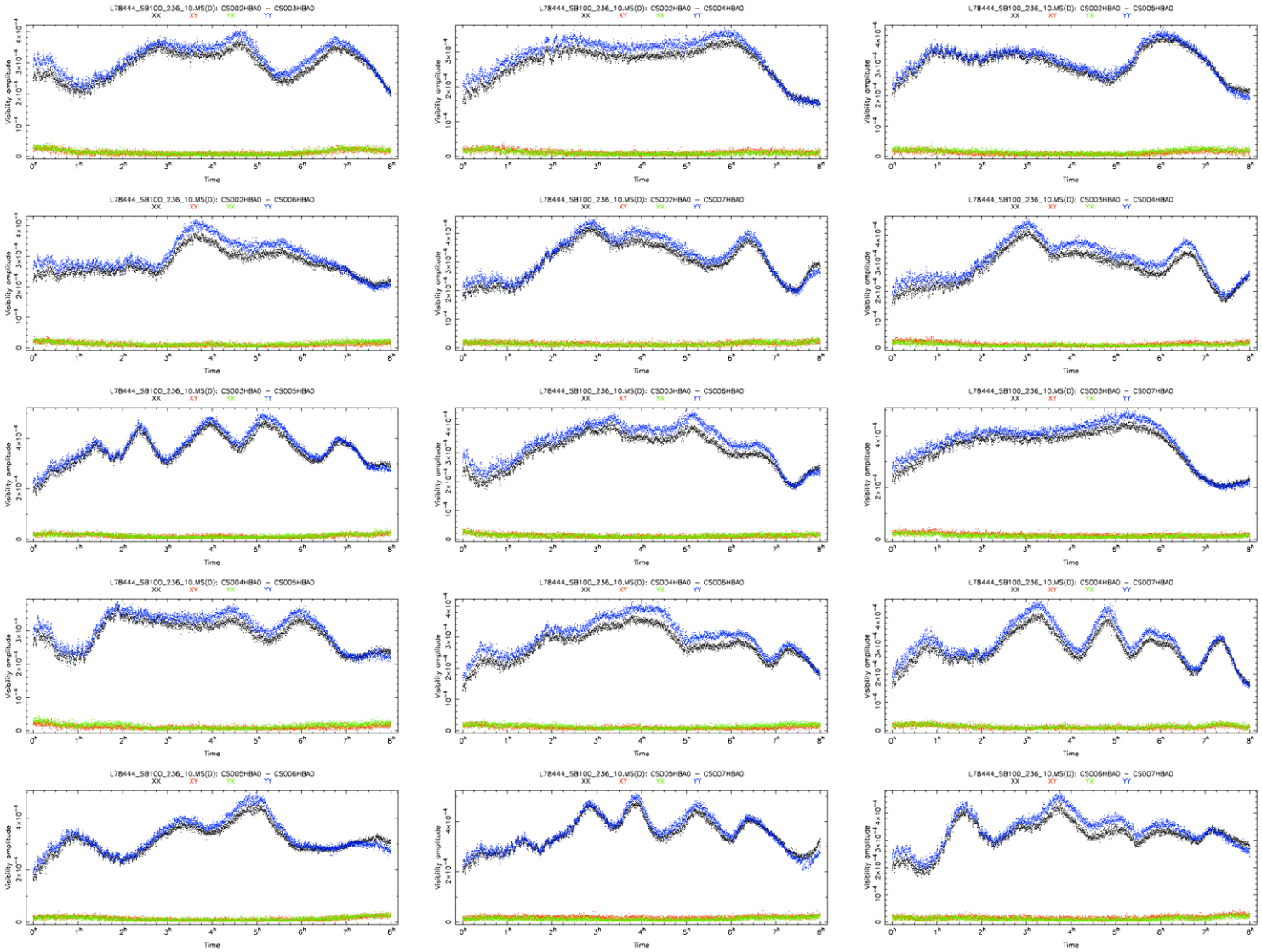
L189376 24 nov 2013
L194338 11 dec 2013

L78444

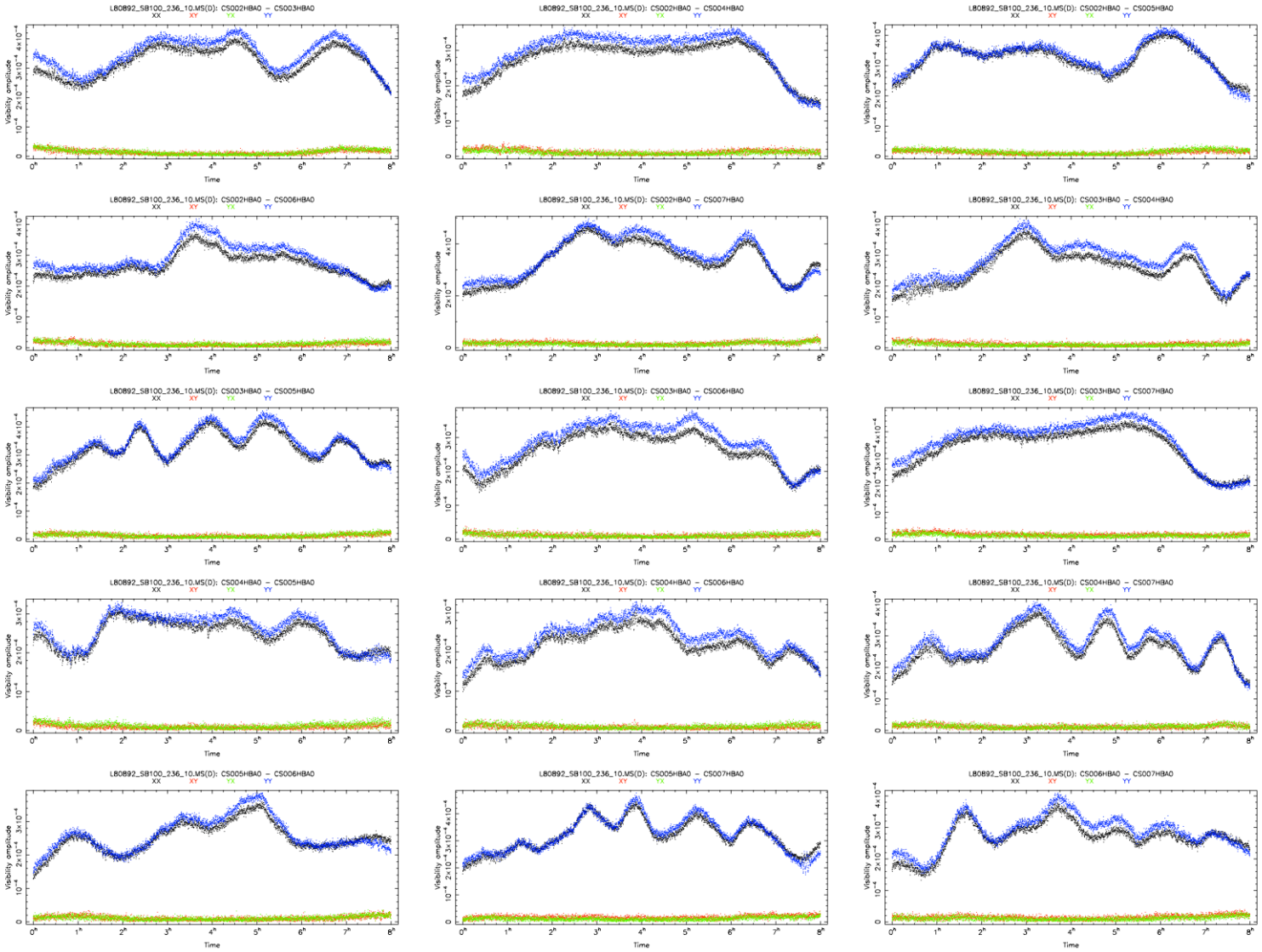
3x5 ST Sb100

8h

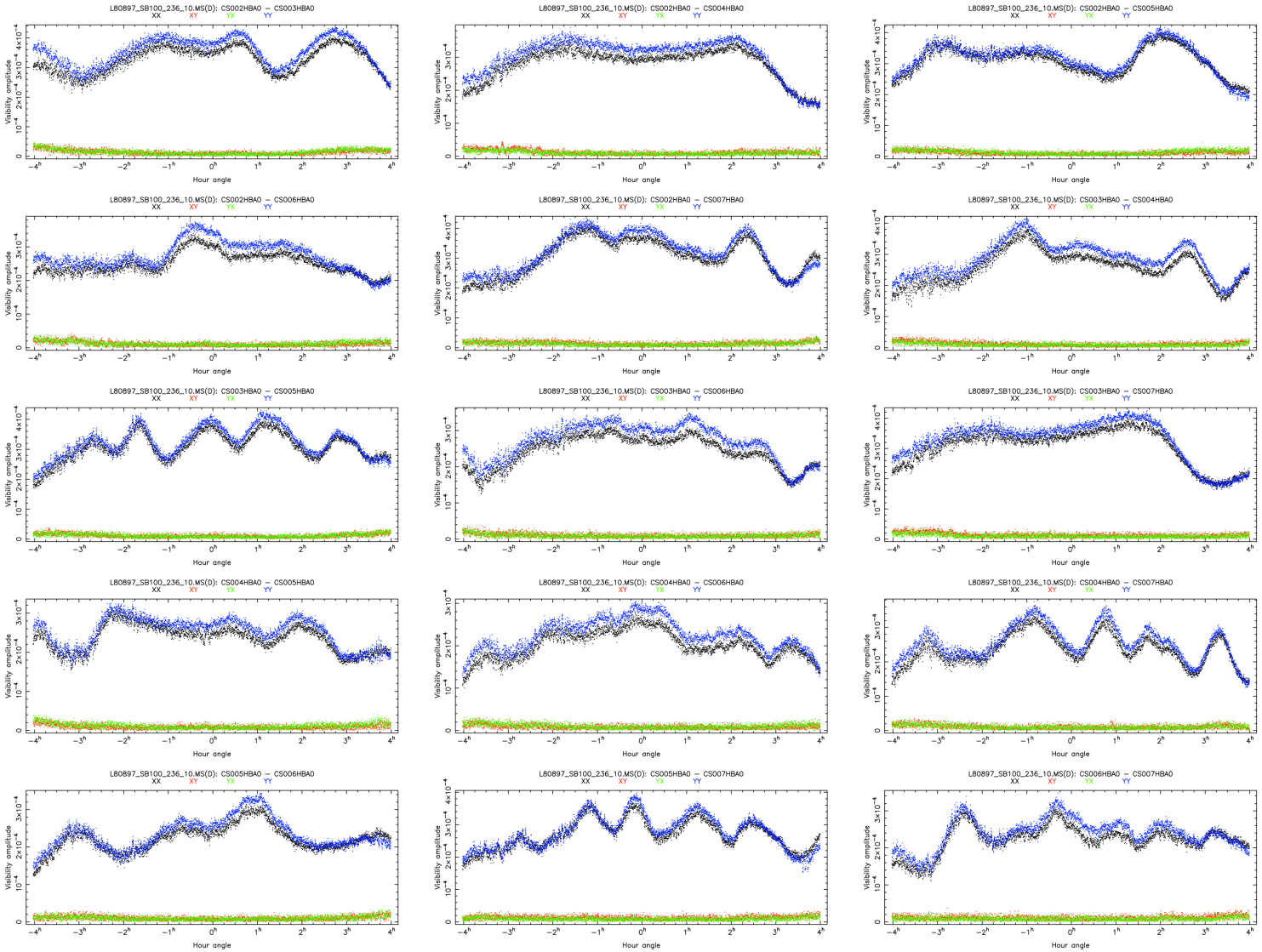
3C196



L80892


L80892_SB100_236_10.MS(D): CS002HBA0 – CS003HBA0
L80892_SB100_236_10.MS(D): CS002HBA0 – CS004HBA0
L80892_SB100_236_10.MS(D): CS002HBA0 – CS005HBA0
L80892_SB100_236_10.MS(D): CS002HBA0 – CS006HBA0
L80892_SB100_236_10.MS(D): CS002HBA0 – CS007HBA0
L80892_SB100_236_10.MS(D): CS003HBA0 – CS004HBA0
L80892_SB100_236_10.MS(D): CS003HBA0 – CS005HBA0
L80892_SB100_236_10.MS(D): CS003HBA0 – CS006HBA0
L80892_SB100_236_10.MS(D): CS003HBA0 – CS007HBA0
L80892_SB100_236_10.MS(D): CS004HBA0 – CS005HBA0
L80892_SB100_236_10.MS(D): CS004HBA0 – CS006HBA0
L80892_SB100_236_10.MS(D): CS004HBA0 – CS007HBA0
L80892_SB100_236_10.MS(D): CS005HBA0 – CS006HBA0
L80892_SB100_236_10.MS(D): CS005HBA0 – CS007HBA0
L80892_SB100_236_10.MS(D): CS006HBA0 – CS007HBA0
XX XY YX YY
Visibility amplitude
Time

L80897

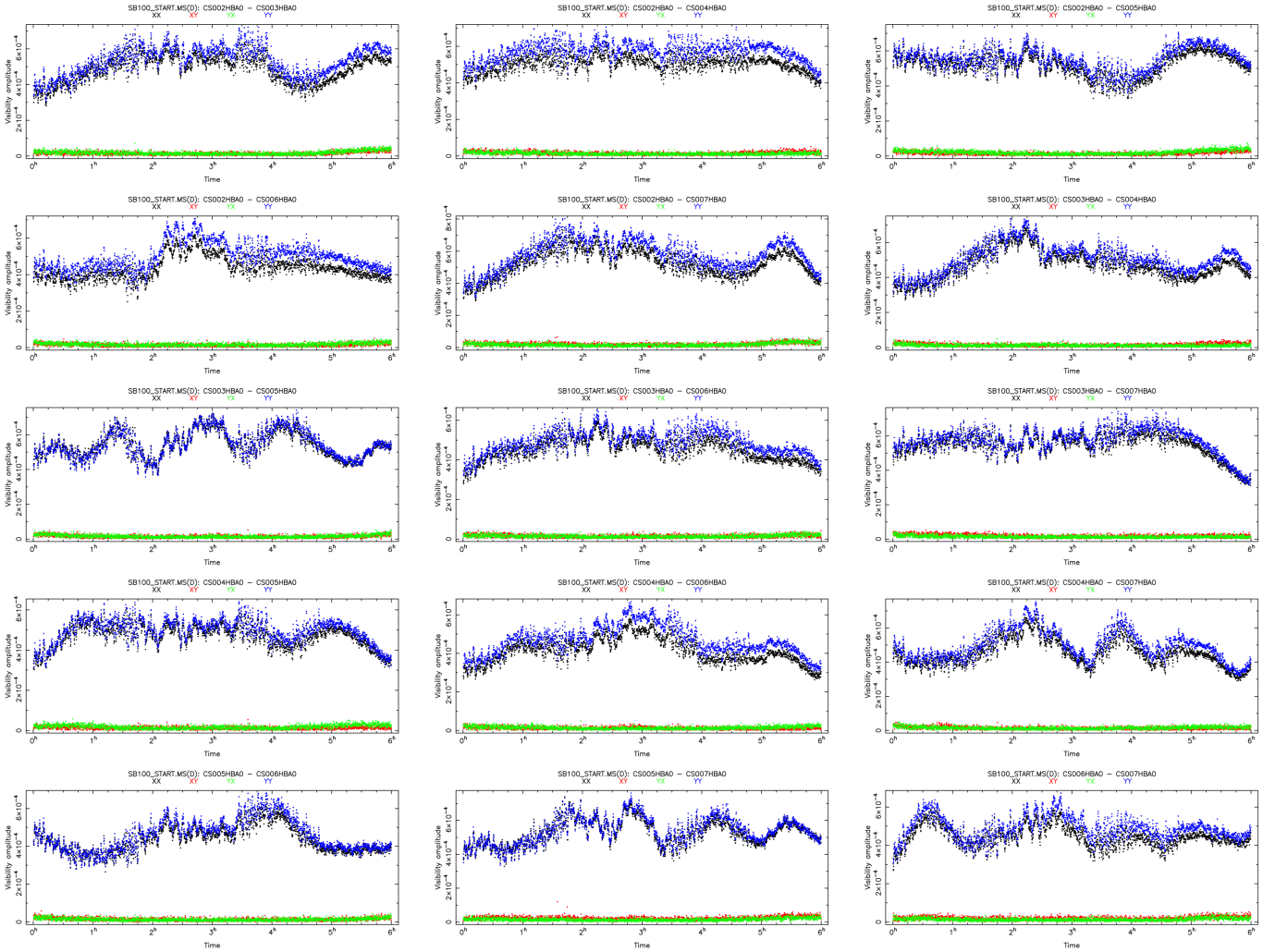

L80897_SB100_236_10.MS(D): CS002HBA0 — CS003HBA0
L80897_SB100_236_10.MS(D): CS002HBA0 — CS004HBA0
L80897_SB100_236_10.MS(D): CS002HBA0 — CS005HBA0
L80897_SB100_236_10.MS(D): CS002HBA0 — CS006HBA0
L80897_SB100_236_10.MS(D): CS002HBA0 — CS007HBA0
L80897_SB100_236_10.MS(D): CS003HBA0 — CS004HBA0
L80897_SB100_236_10.MS(D): CS003HBA0 — CS005HBA0
L80897_SB100_236_10.MS(D): CS003HBA0 — CS006HBA0
L80897_SB100_236_10.MS(D): CS003HBA0 — CS007HBA0
L80897_SB100_236_10.MS(D): CS004HBA0 — CS005HBA0
L80897_SB100_236_10.MS(D): CS004HBA0 — CS006HBA0
L80897_SB100_236_10.MS(D): CS004HBA0 — CS007HBA0
L80897_SB100_236_10.MS(D): CS005HBA0 — CS006HBA0
L80897_SB100_236_10.MS(D): CS005HBA0 — CS007HBA0
L80897_SB100_236_10.MS(D): CS006HBA0 — CS007HBA0
XX XY YX YY
Visibility amplitude
Hour angle

L189376

sb100

24 Nov 2013

6h run

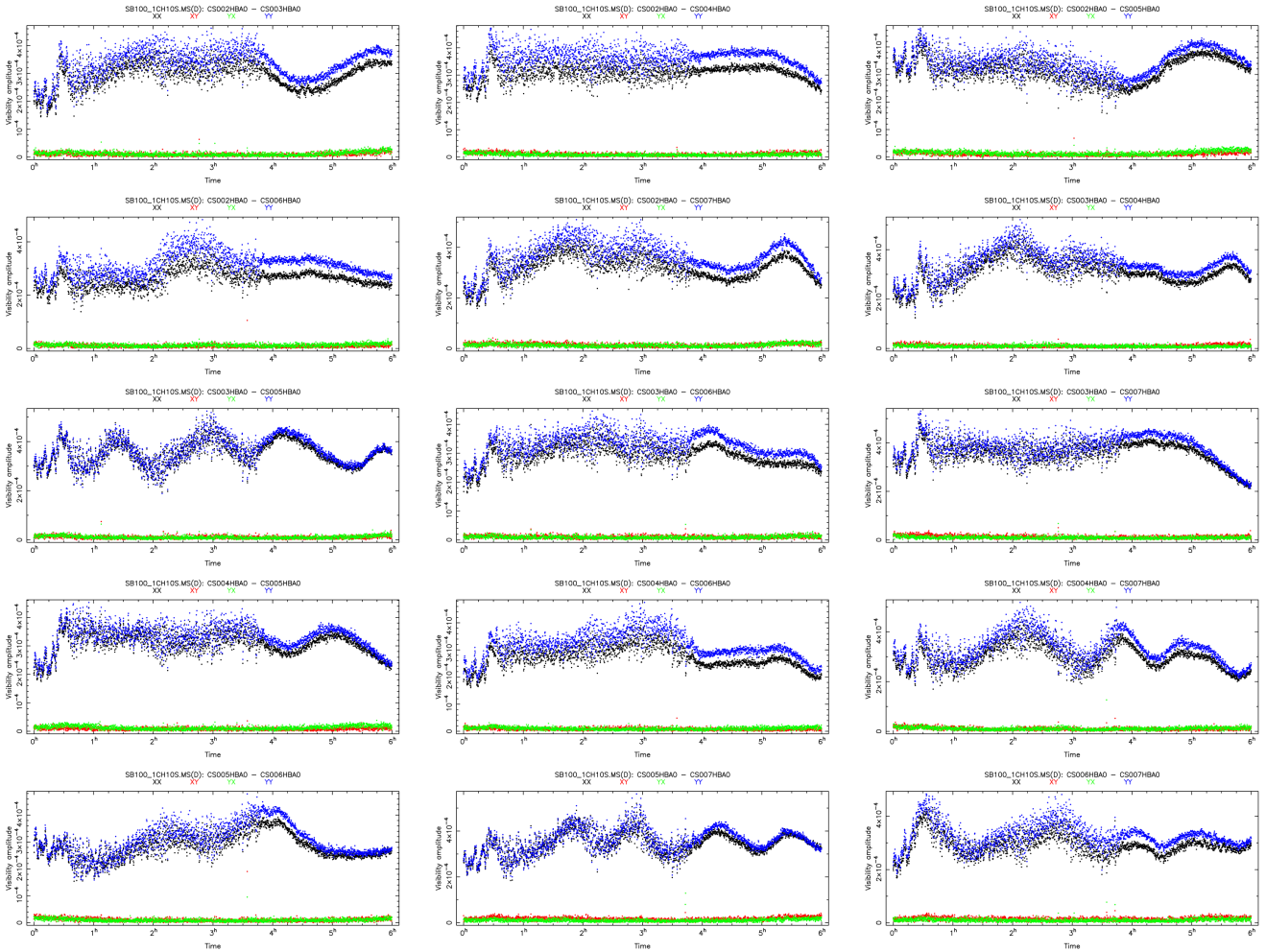


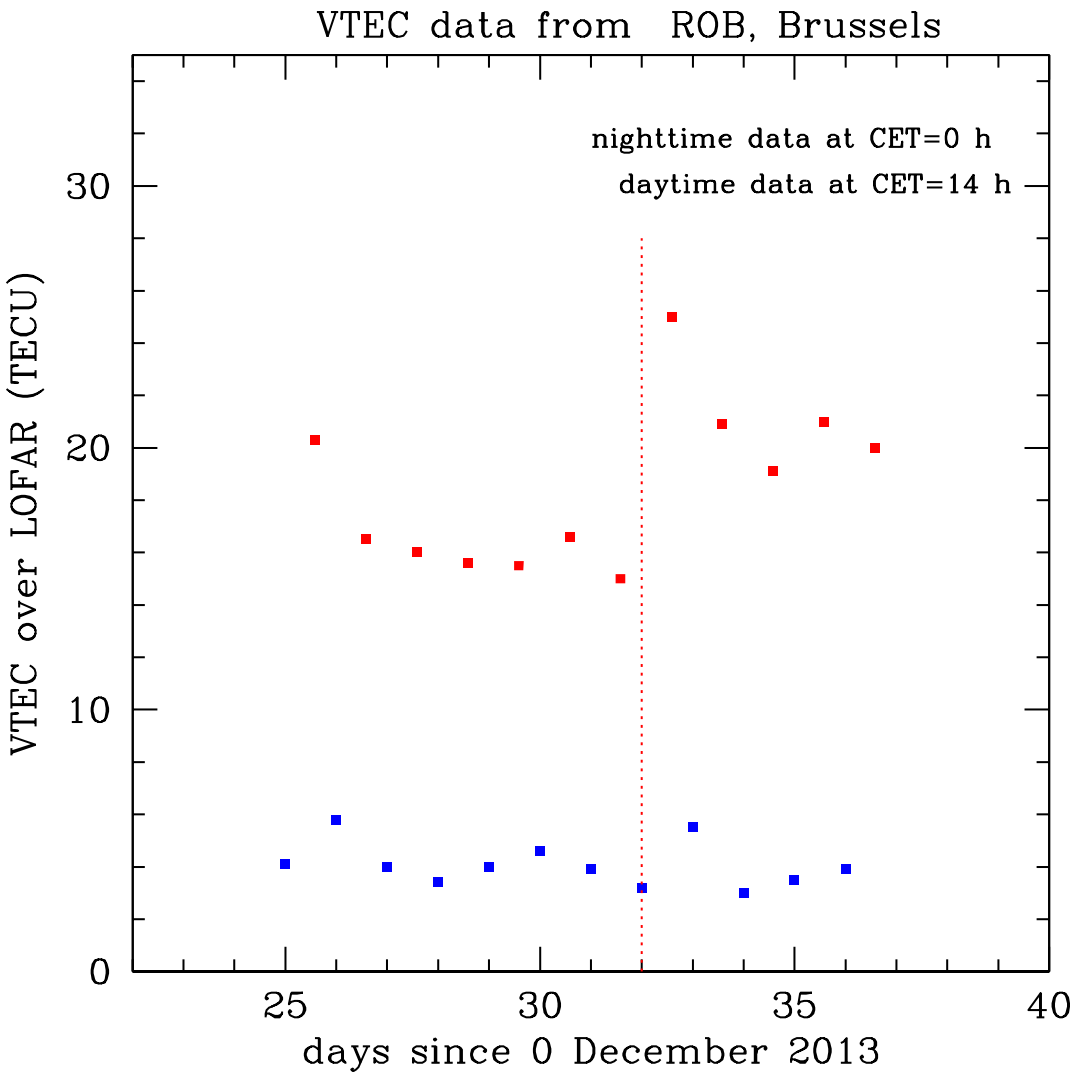
L194338

sb100

11 Dec 2013

6h run




VTEC data from ROB, Brussels
nighttime data at CET=0 h
daytime data at CET=14 h
VTEC over LOFAR (TECU)
0
10
20
30
25
30
35
40
days since 0 December 2013

Wide field imaging and bandwidth/time smearing: → limits on integration time and spectral resolution

To image a field of about 5 degrees (HBA) with a 100 km baseline (RS210-RS509 is 120 km → 4" PSF at 150 MHz) we need to limit the smearing due to time +frequency averaging

Within the EoR project we have been using/saving the following dataproducts:

64ch / 2s → 15ch / 2s (1 subband =183 kHz)

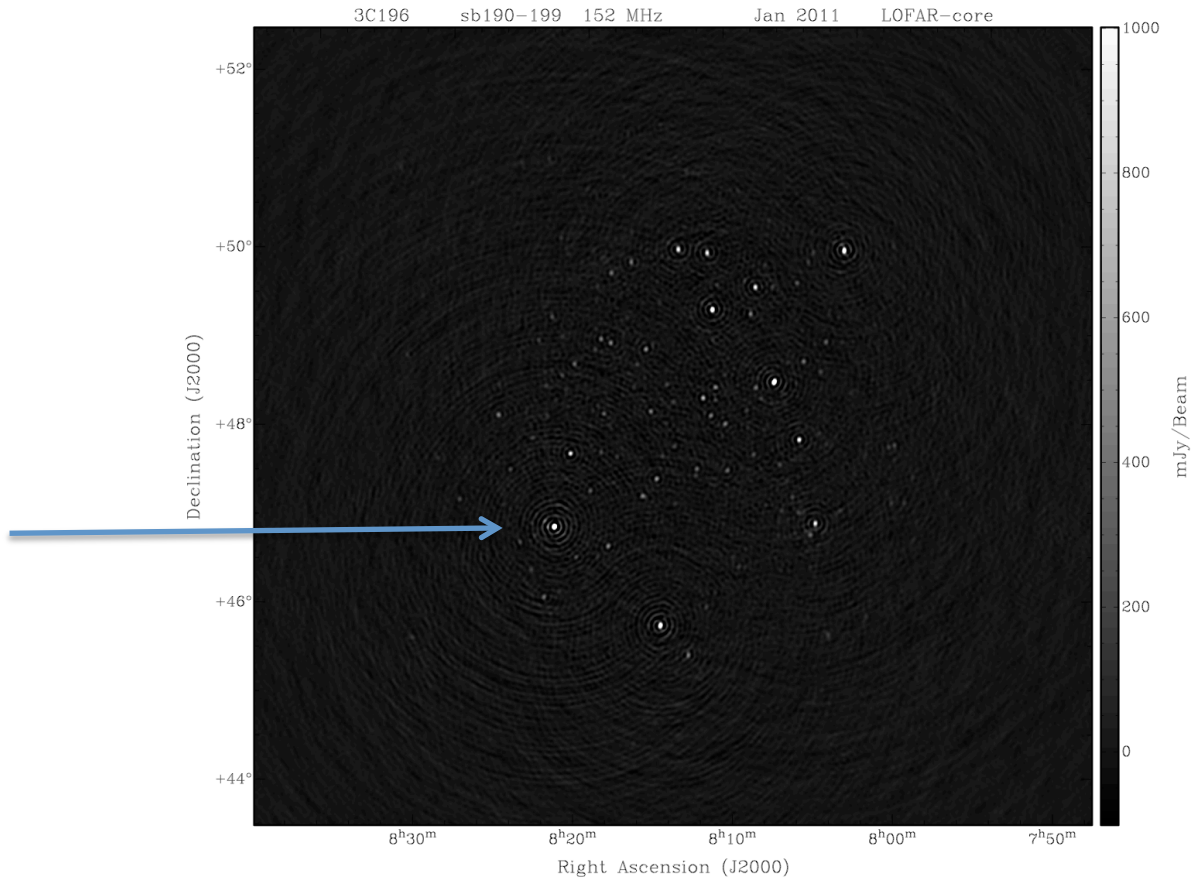
From this dataset we make several other products:
15ch /2 s → 1ch / 10s initial processing
15ch /2 s → 3ch / 6 s imaging with MFS

But to limit smearing to 2" at 2 degree radius (=1/3600) we will now switch to

15ch / 2s → 5ch / 4 s

A 9°x9° LOFAR image of the 3C196 field (3C196 subtracted)

Source
6.5 Jy double



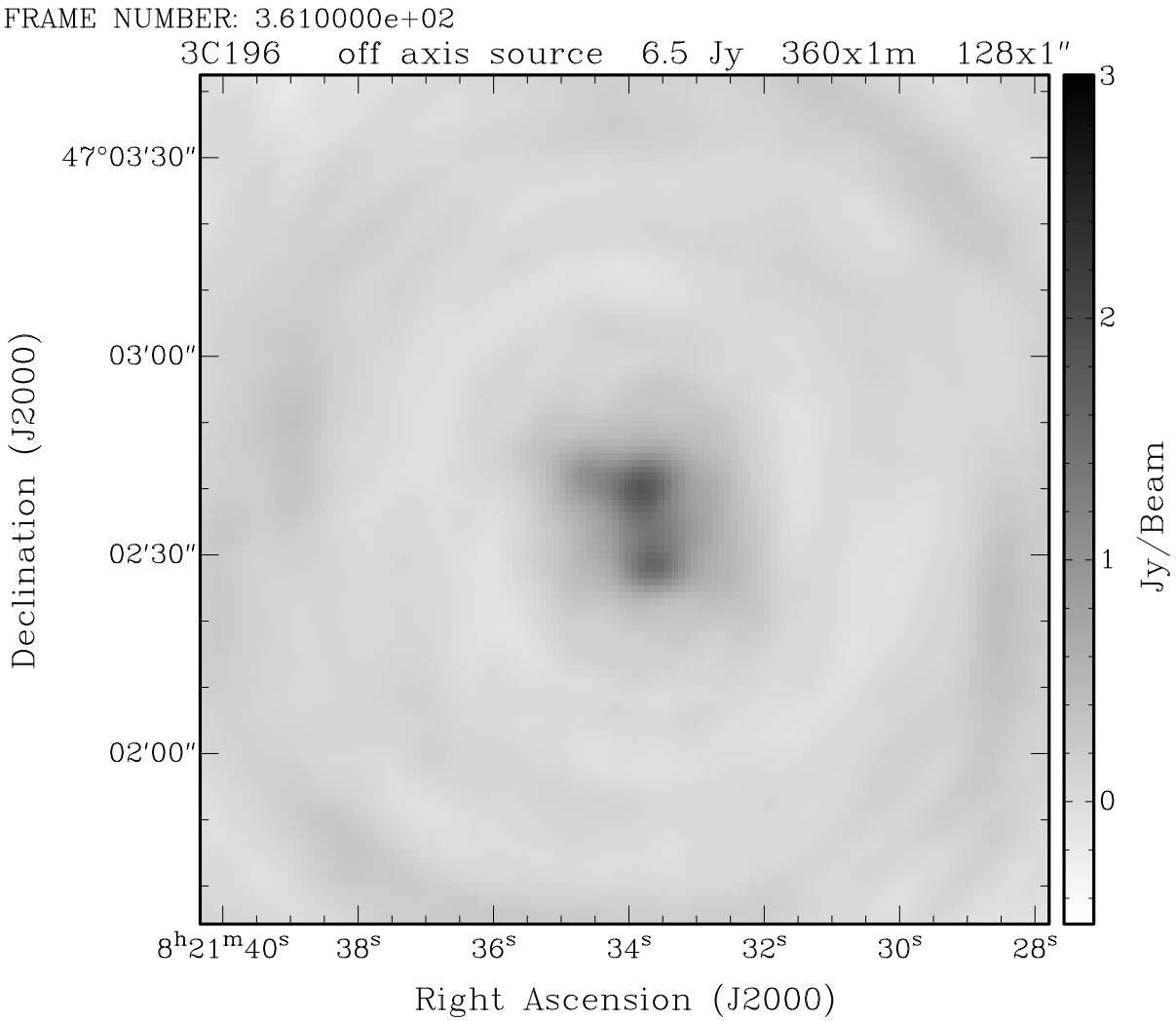
3C196

15/16 dec 2013
6h synthesis
1 subband 135 MHz

Average image after BBS

4x6” PSF

12” double



Ionospheric scintillation

Relevant linear/angular scales

- Source angular size (3C196 6" ~ 100m at 300 km height) → pointlike for ionophere
- $R_{Fresnel} = (2 \lambda H)^{0.5}$ ~ 1 km at 300 km
- R_{diff} = linear scale over which screen phase fluctuation ~ 1 radian

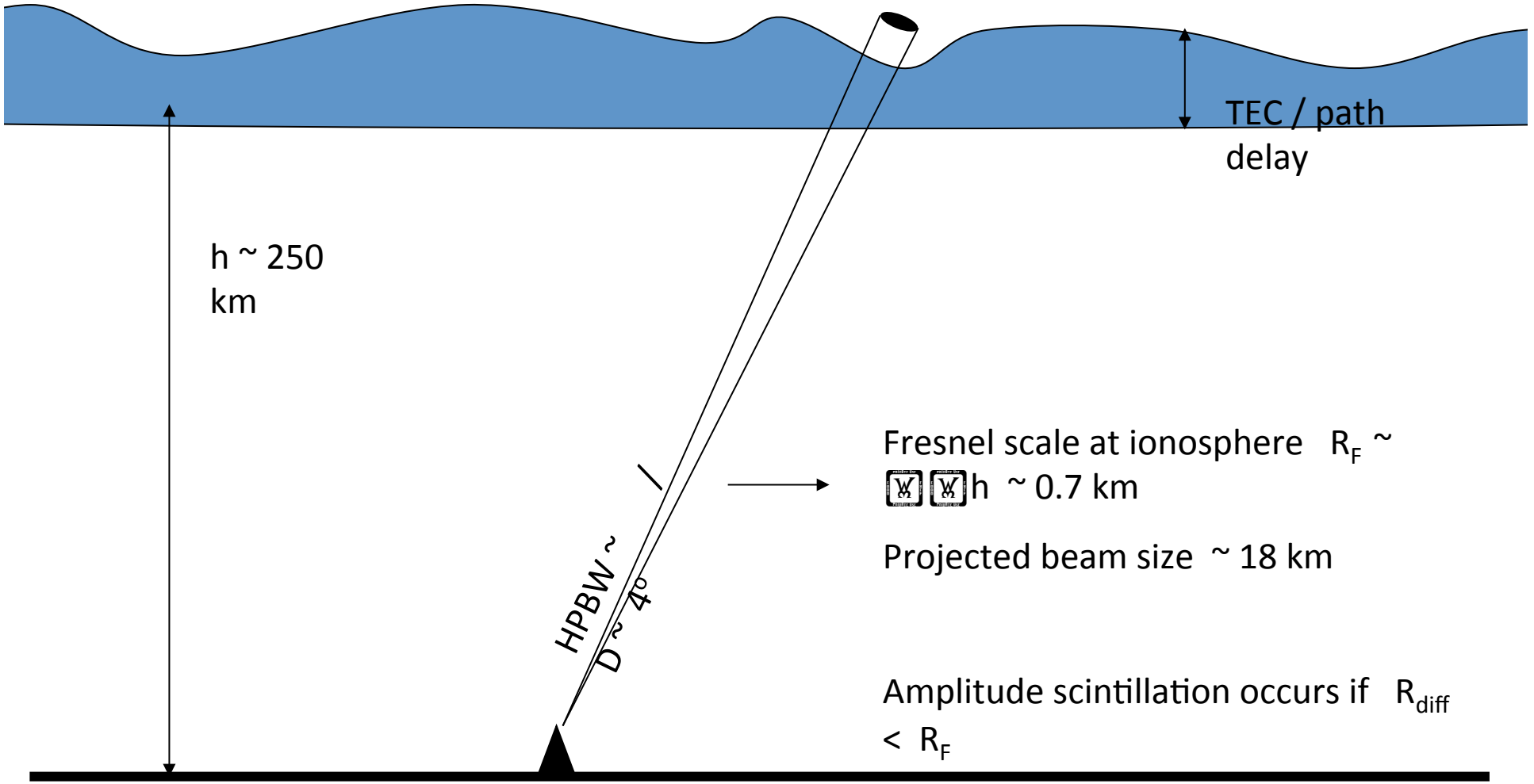
If $R_{diff} < R_{Fresnel}$ → diffractive scintillation (interference between components of the sources within the Fresnel zone

Hence scintillation with m=10-20% requires < 1km turbulence scales

Since 1km at 300km = 10' → very small 'isoplanatic' angle
No imaging possible (see next cartoon)

High DR calibration/imaging under scintillation conditions. Forget it !!

150 MHz, 2m



Fresnel scale at ionosphere $R_F \sim \sqrt{\lambda h} \sim 0.7$ km

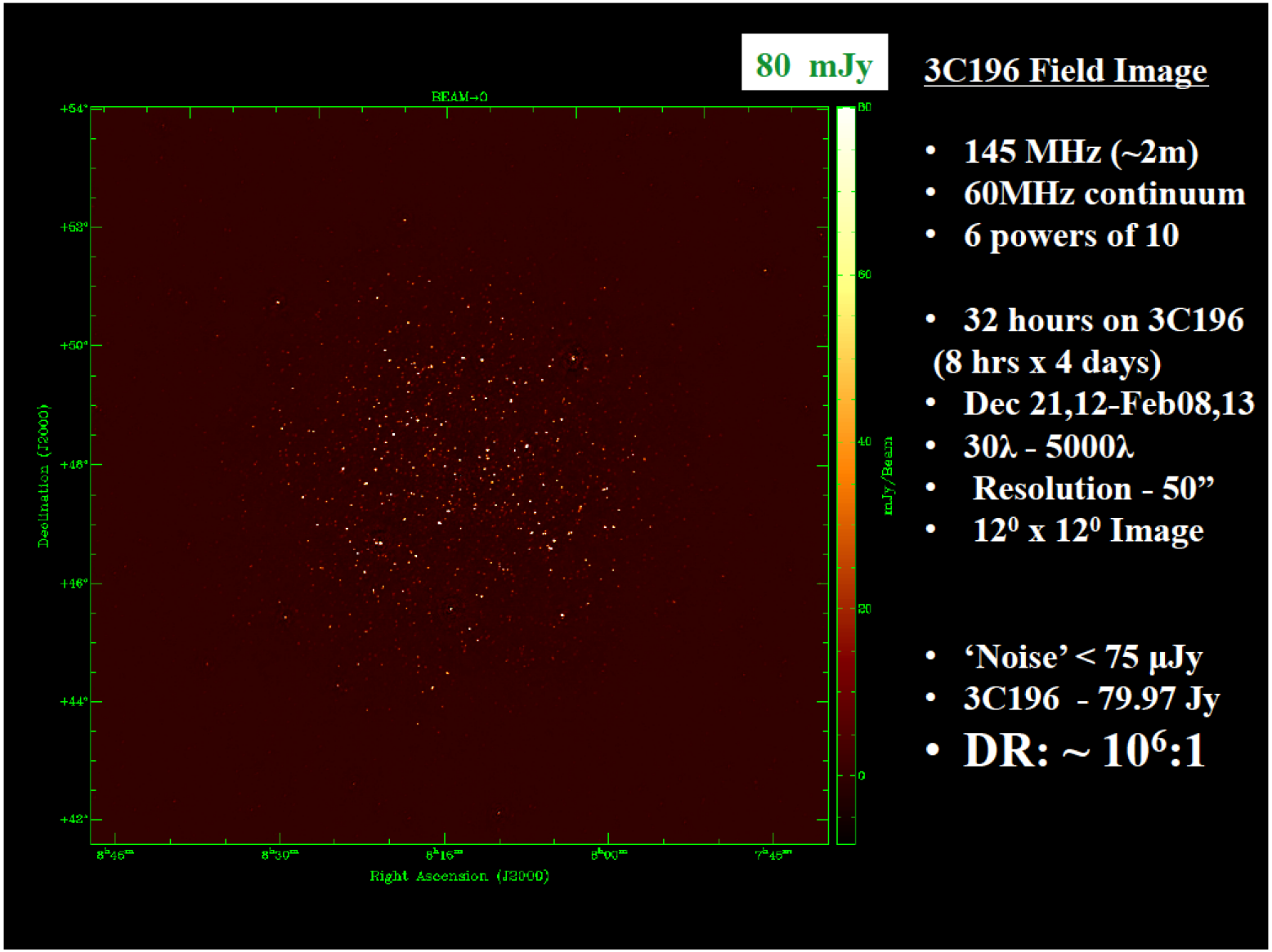
Projected beam size ~ 18 km

Amplitude scintillation occurs if $R_{diff} < R_F$

with timescale $\sim R_{diff} / V < 5$ s

Under these conditions there will be

Pandey et al , ‘Gerfeest’ presentation

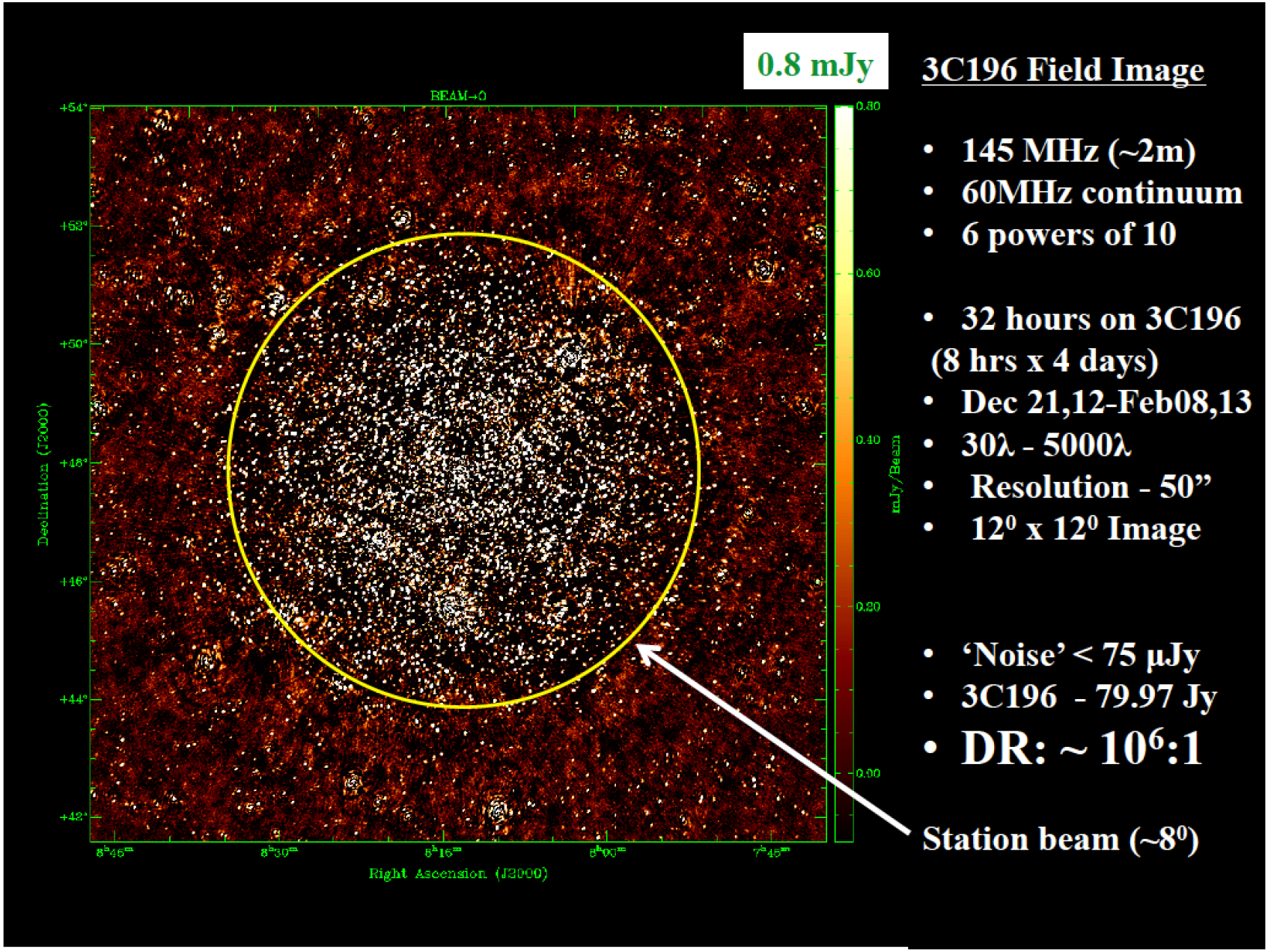


3C196 Field Image

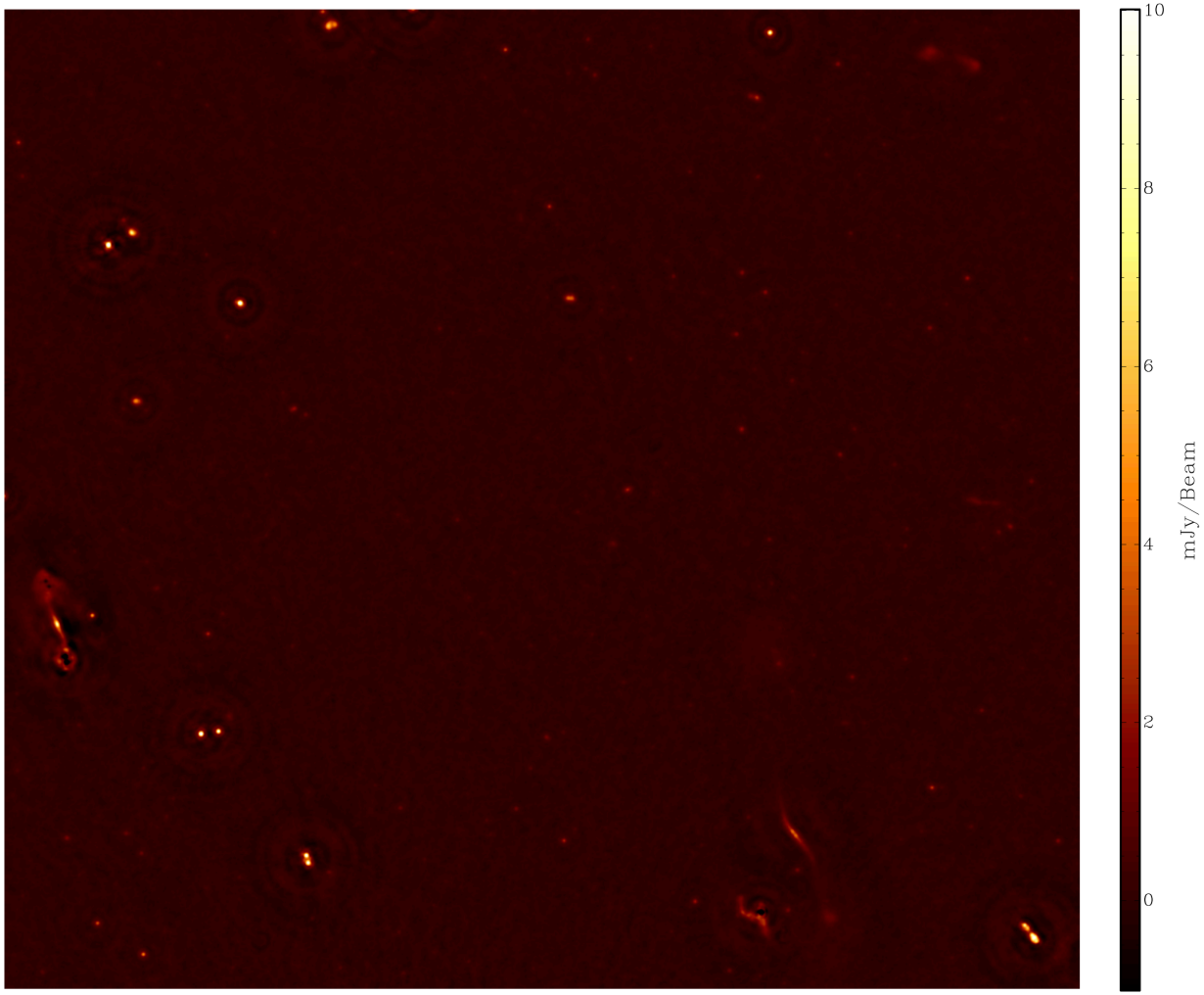
- 145 MHz (~2m)
- 60MHz continuum
- 6 powers of 10

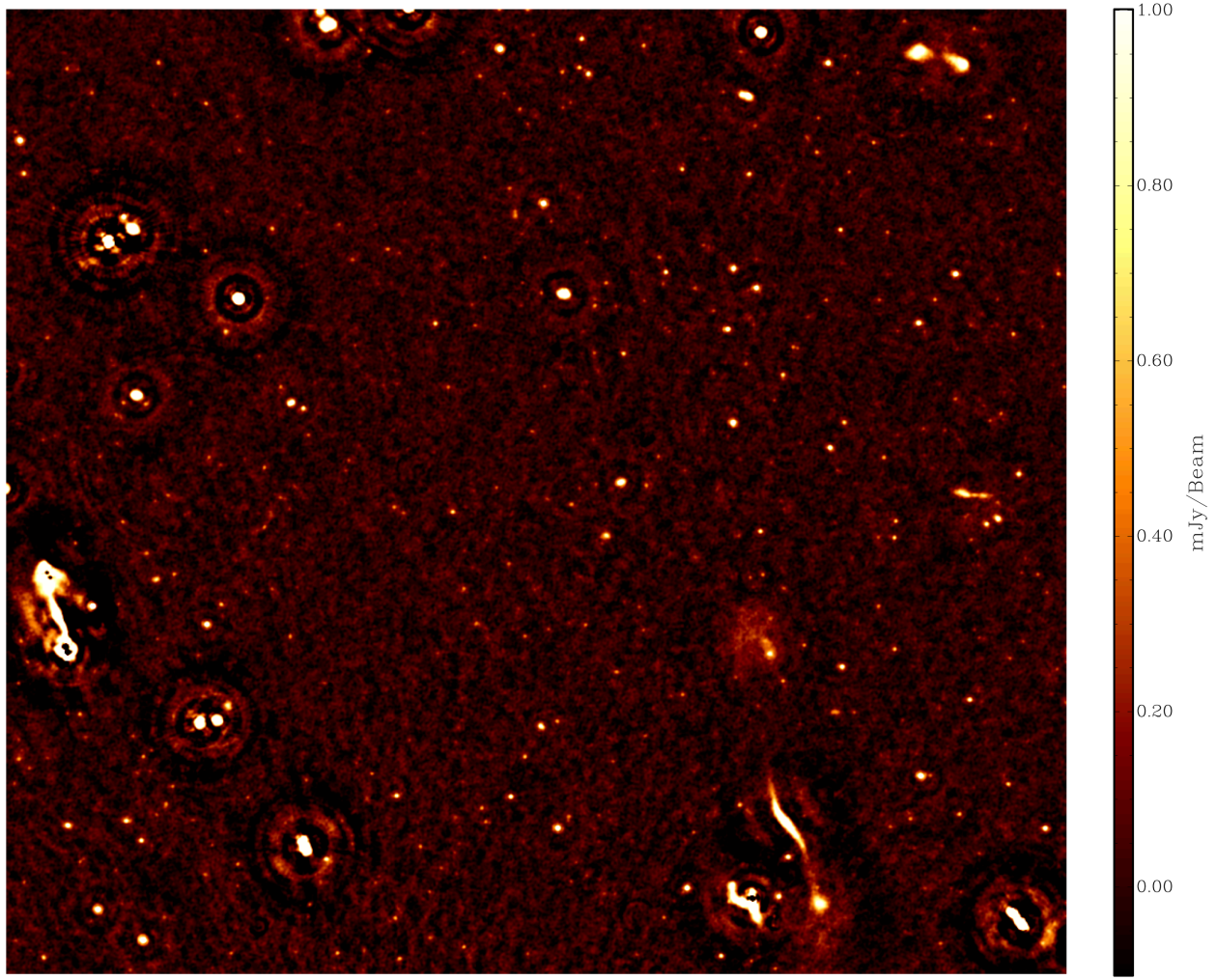
- 32 hours on 3C196 (8 hrs x 4 days)
- Dec 21,12-Feb08,13
- 30λ - 5000λ
- Resolution - 50”
- 12^0 x 12^0 Image

- ‘Noise’ < 75 µJy
- 3C196 - 79.97 Jy
- DR: ~ 10^6:1


0.8 mJy
3C196 Field Image
BEAM-0
Declination (J2000)
Right Ascension (J2000)
mJy/Beam
+54°
+52°
+50°
+48°
+46°
+44°
+42°
8h46m
8h30m
8h16m
8h00m
7h45m
0.80
0.60
0.40
0.20
0.00
• 145 MHz (~2m)
• 60MHz continuum
• 6 powers of 10
• 32 hours on 3C196 (8 hrs x 4 days)
• Dec 21,12-Feb08,13
• 30λ - 5000λ
• Resolution - 50”
• 12⁰ x 12⁰ Image
• ‘Noise’ < 75 µJy
• 3C196 - 79.97 Jy
• DR: ~ 10⁶:1
Station beam (~8⁰)

Sarod Yatawatta et al , NCP, 114h




1.00
0.80
0.60
0.40
0.20
0.00
mJy/Beam