LOFAR-LBA calibration
the case of Virgo A and the toothbrush cluster

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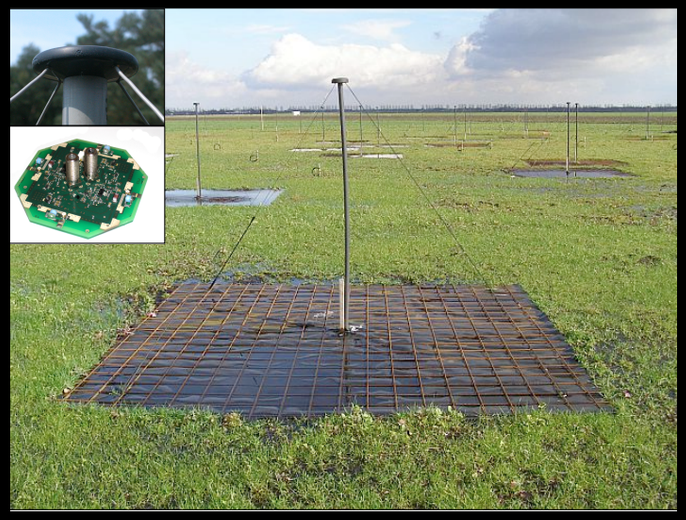
LSM - 4/2/2015

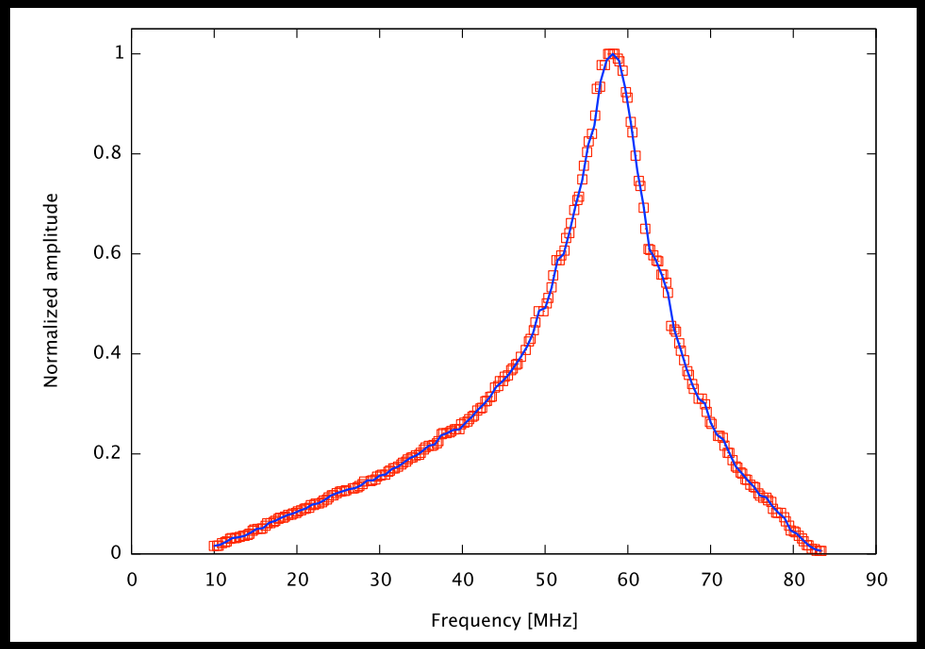
Outline

- LBA vs HBA
- LBA: data reduction strategy
  - strong sources (Virgo A)
  - normal fields (Toothbrush)
- LoSoTo



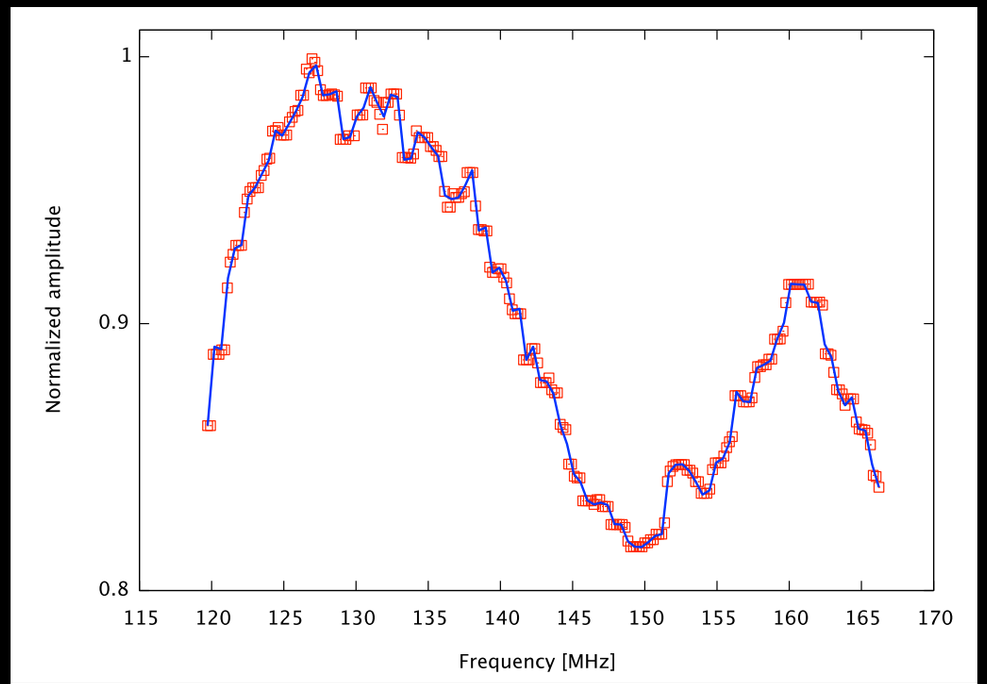
LBA vs HBA

Sensitivity: low, only stronger sources (>1Jy?) can be used for DDE



Bandpass is strongly peaked: strategy is frequency dependent

Sensitivity: good, can correct against 0.1 Jy source for DDE



Bandpass varies by <20%: strategy is frequency independent

LBA vs HBA

Data size: 1035 baselines,
<1GB per SB

Data size: 2850 baselines,
~few GB per SB

Low-res: doesn't need a very accurate model

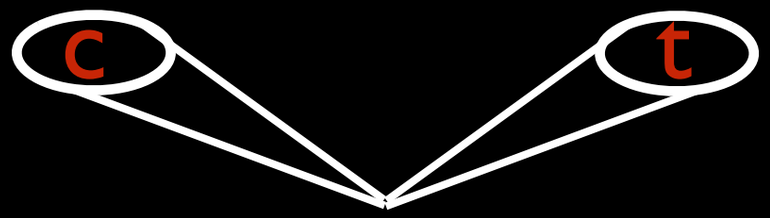
High-res: need a very accurate model

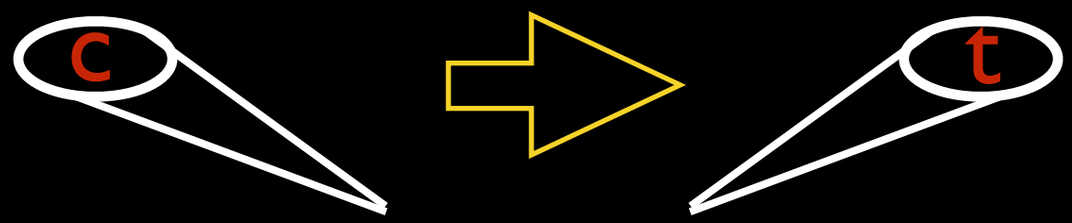
Sparse disposition

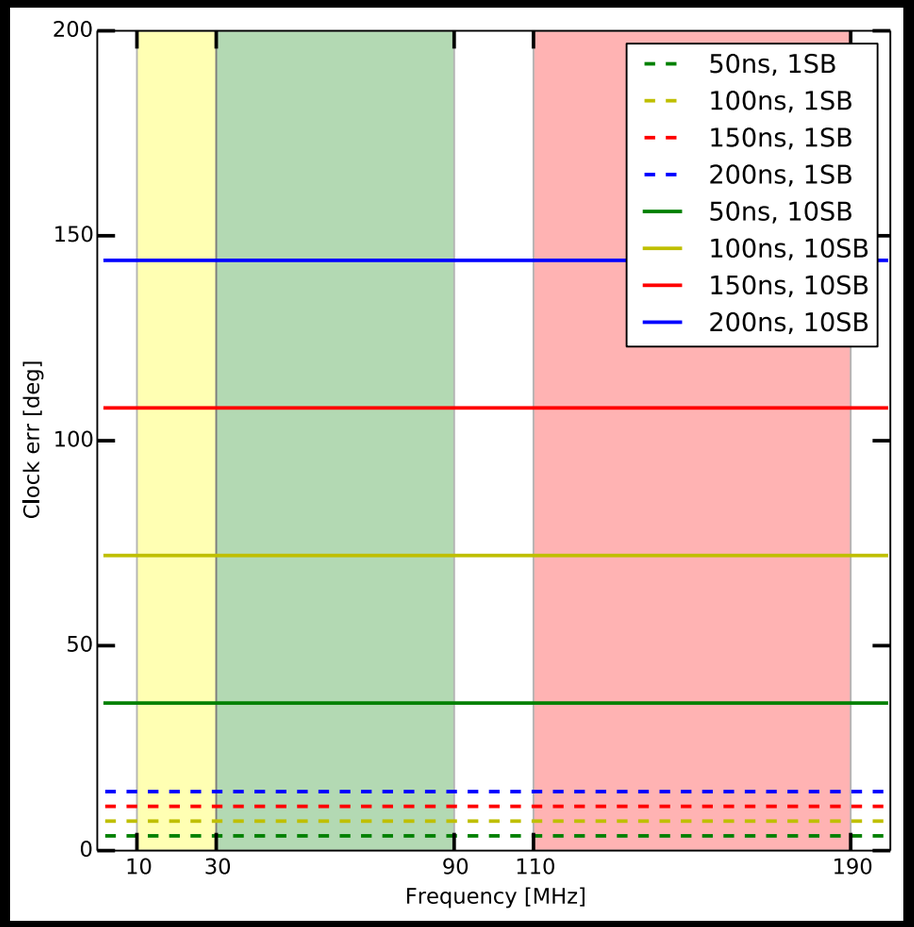
Ordered disposition
("ghost" beam issue)

Dual beam (calibrator+target)
continuously for the entire observation

Beam direction limited
interpolation/extrapolation required







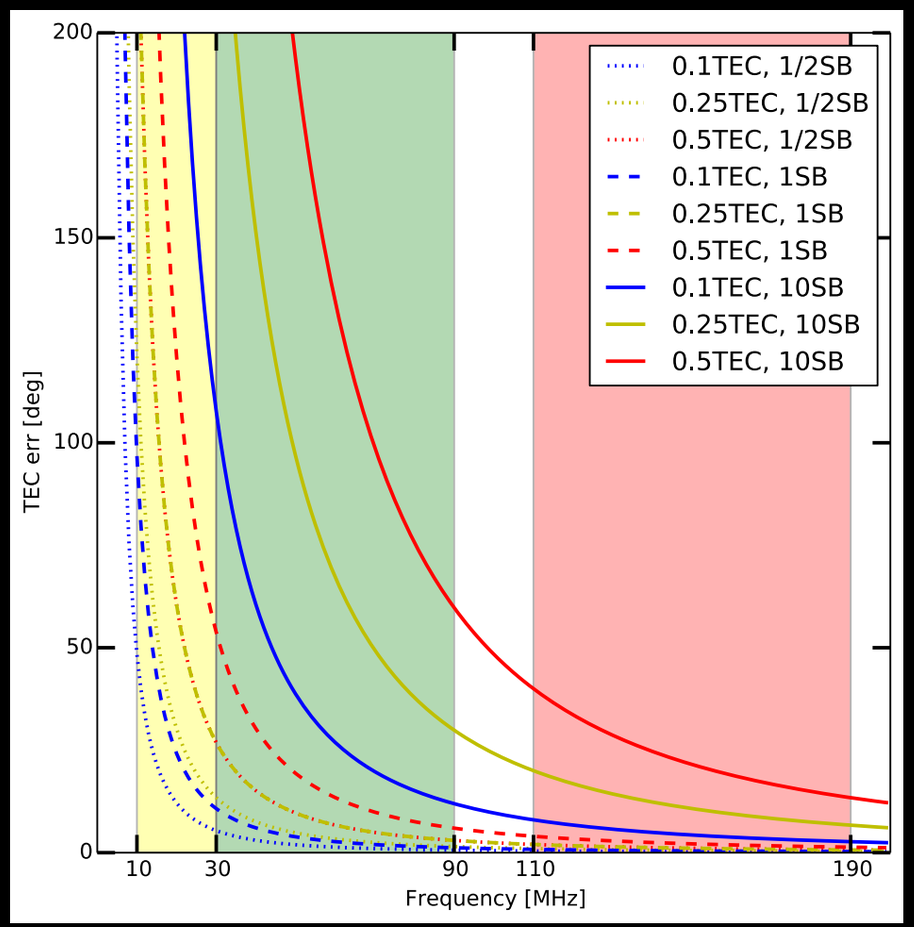
Clock

LBA vs HBA

30-80 MHz

110-190 MHz

Clock is an issue if several SBs are combined

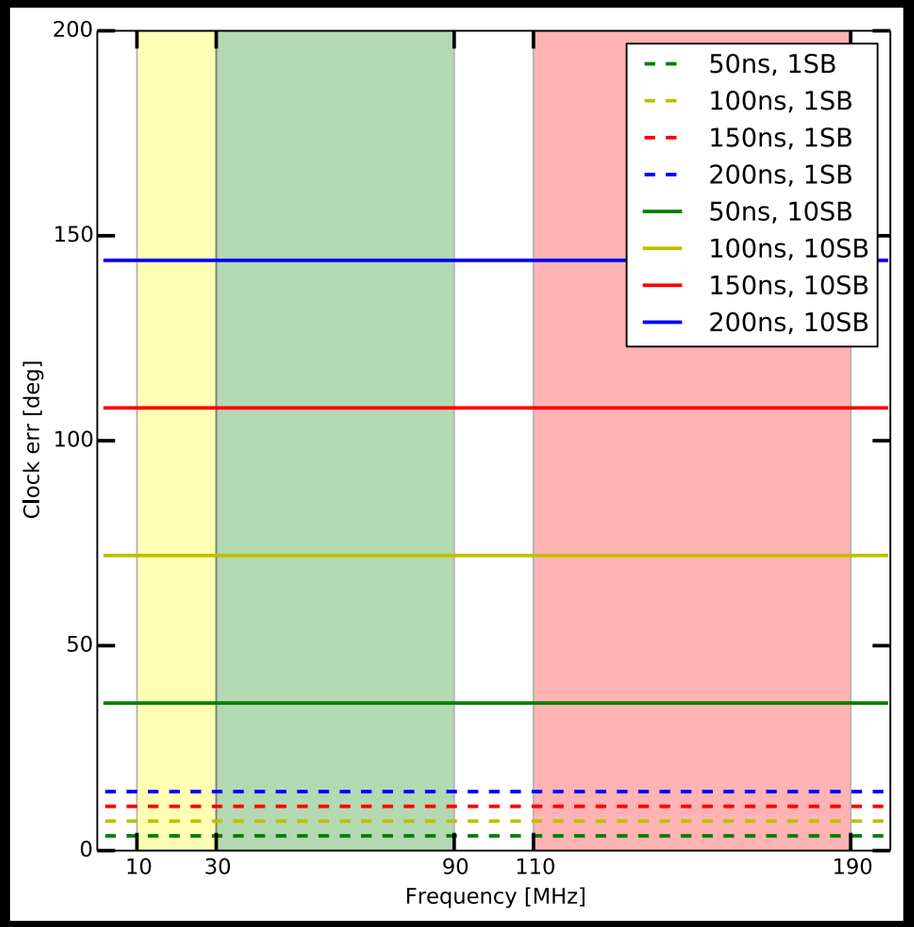


TEC is an issue if several SBs are combined, <40 MHz even in a single SB

TEC is important for bad-ionosphere observations or high-fidelity images

TEC

Clock



LBA vs HBA

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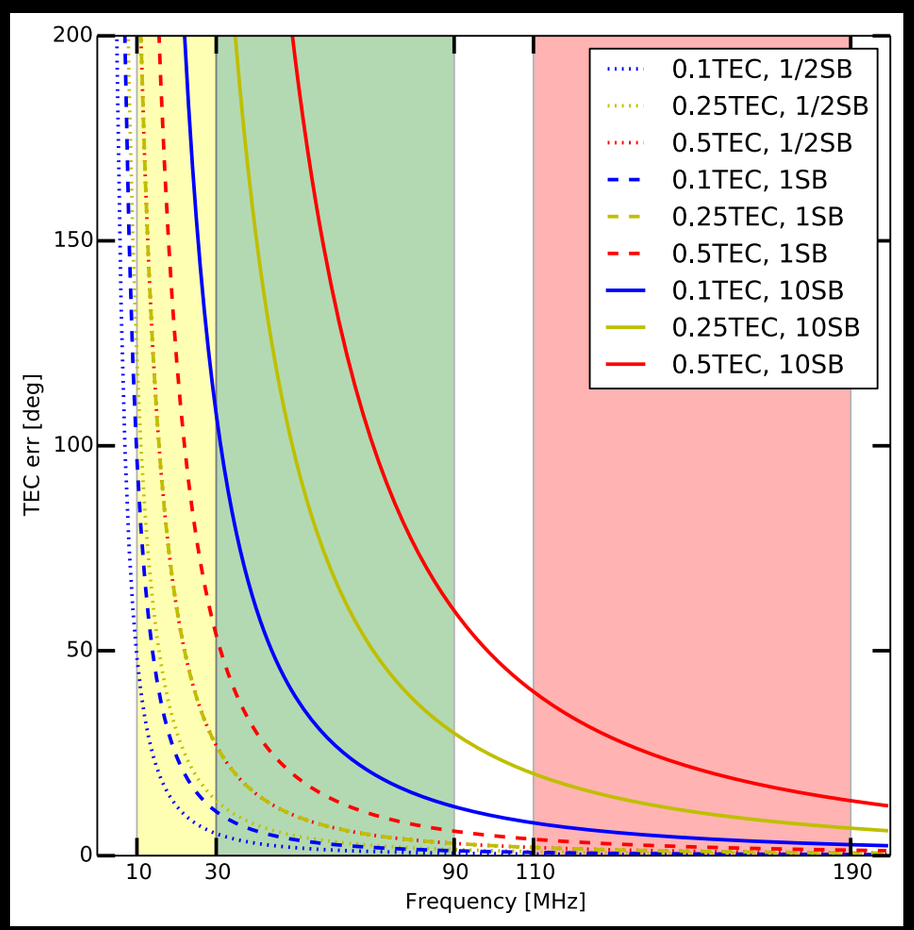
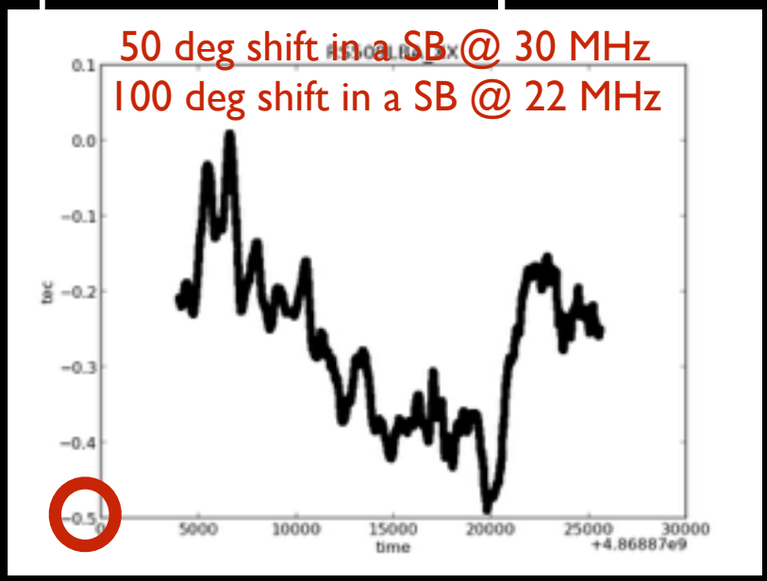


TEC is an issue if several SBs are combined, <40 MHz even in a single SB

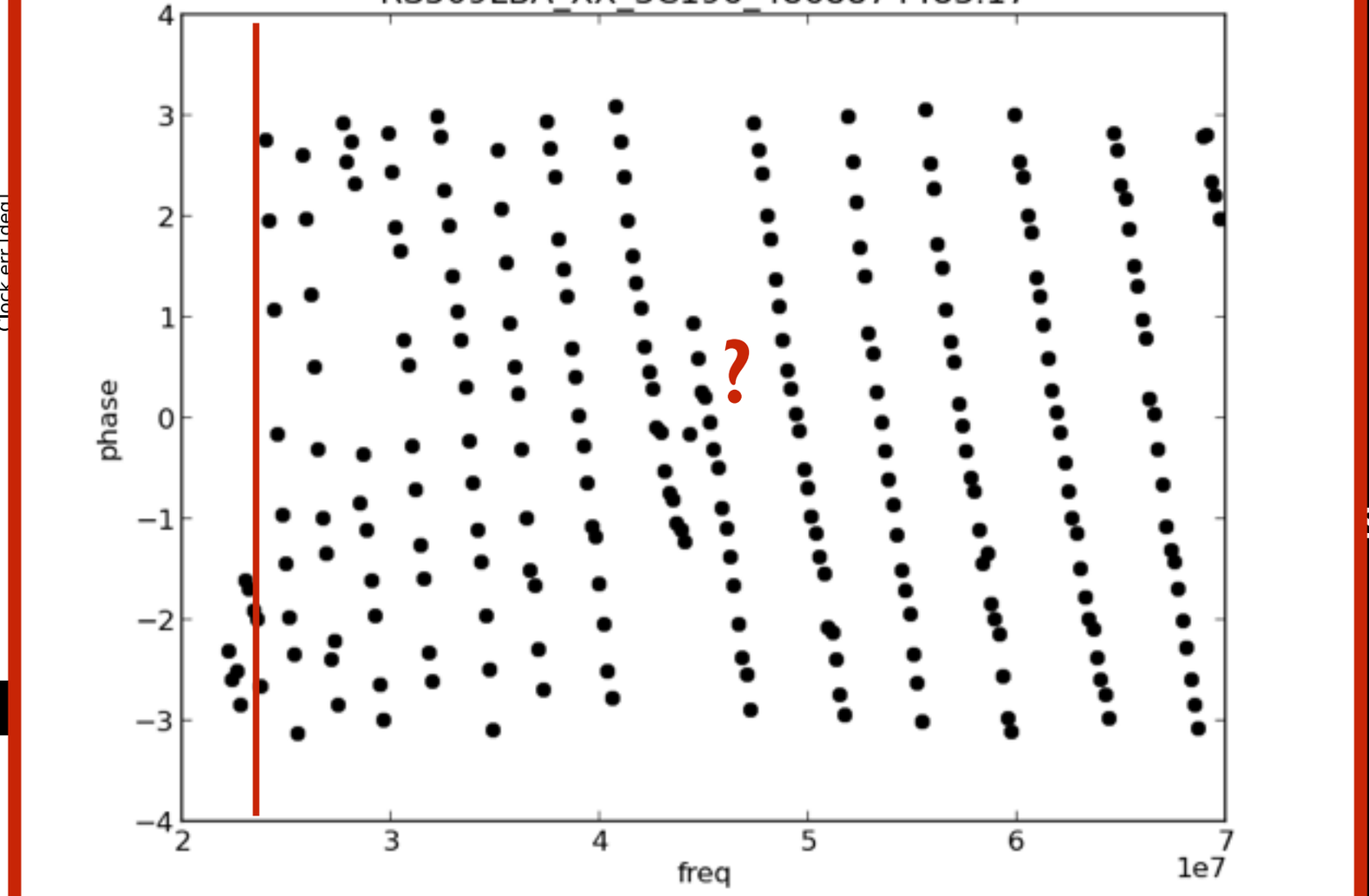
TEC

TEC is important for bad-ionosphere



vs HBA

110-190 MHz



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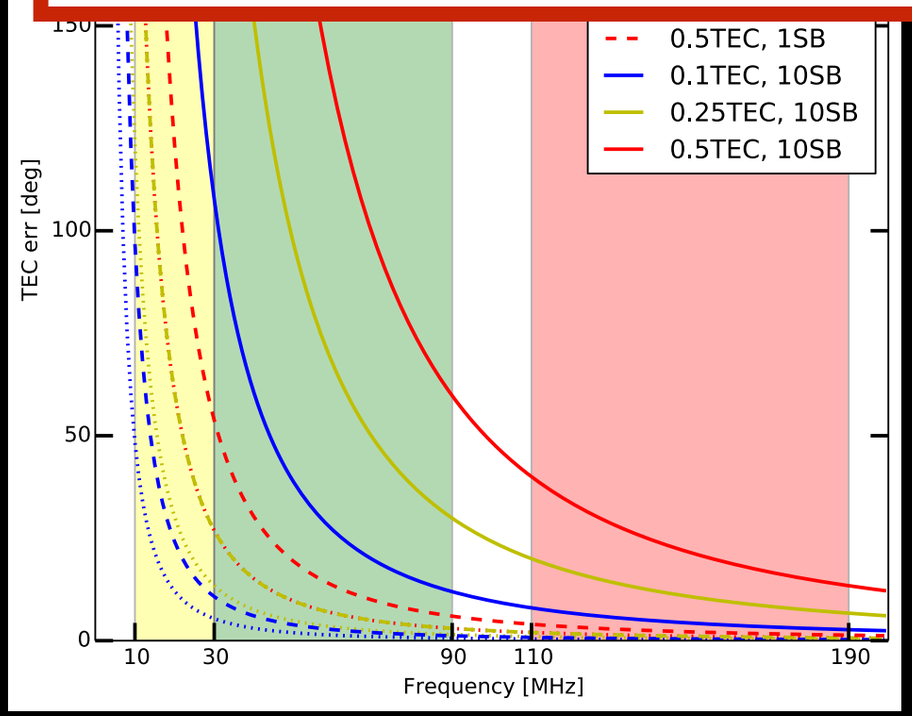
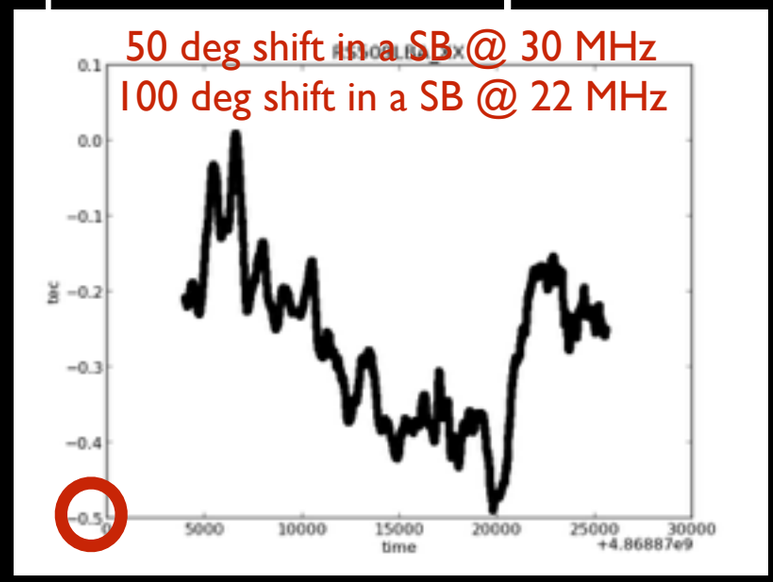
are combined



TEC

TEC is an issue if several SBs are combined, <40 MHz even in a single SB

TEC is important for bad-ionosphere

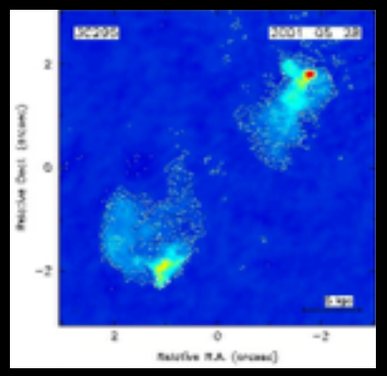


Strategy 1: strong target

Obs strategy: 244 SB on cal, 244 SB on strong target

Pre processing: demix + avg to 4 chan / 1 sec

Freq avg: avoid BW smearing + iono freq dependancy / Time avg: iono time variation



1: calibrator (3C295) - run time: 4 days

BBS on calibrator

Diag(G) + rot ang
<30 MHz: divide SB

LoSoTo

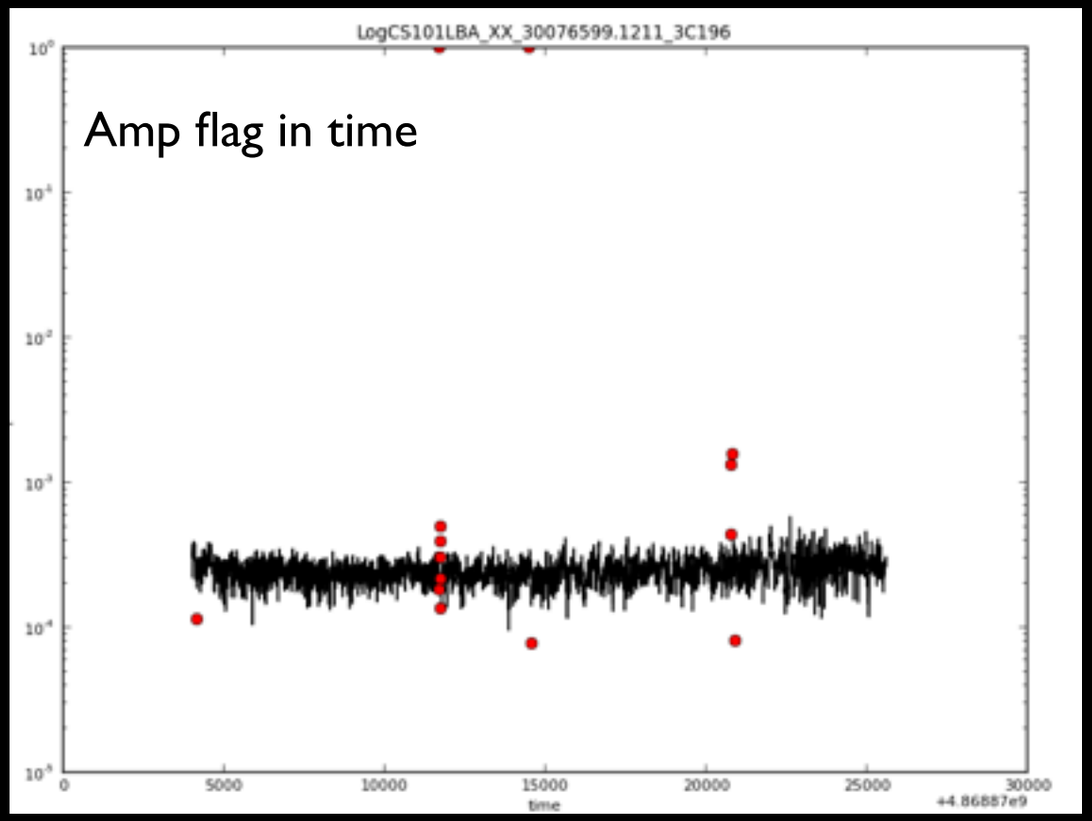
C-T separation (diagnostic) + flag

Cor on target

Transfer A+P (solve clock but dTEC)

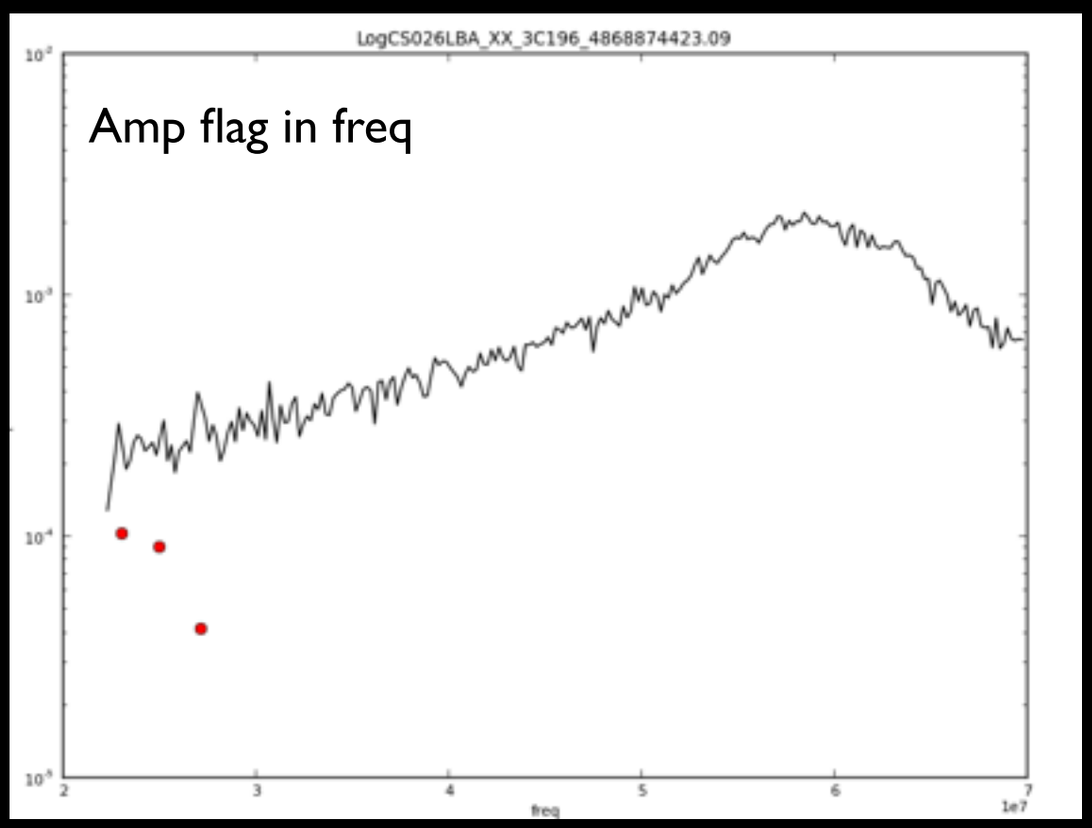
Why rot ang is important?
Faraday rotation can move flux from XX/YY to XY/YX
even if we solve for full G we would have noisier data

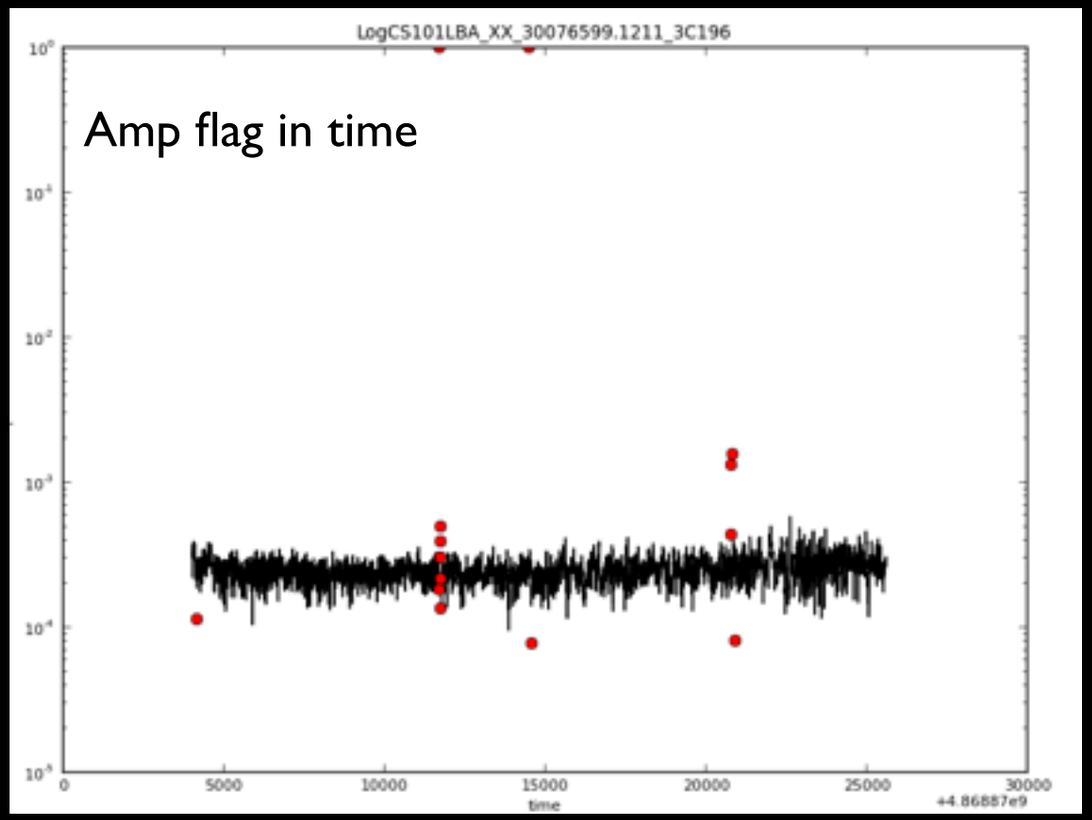
All these steps are done SB per SB, easy to parallelise

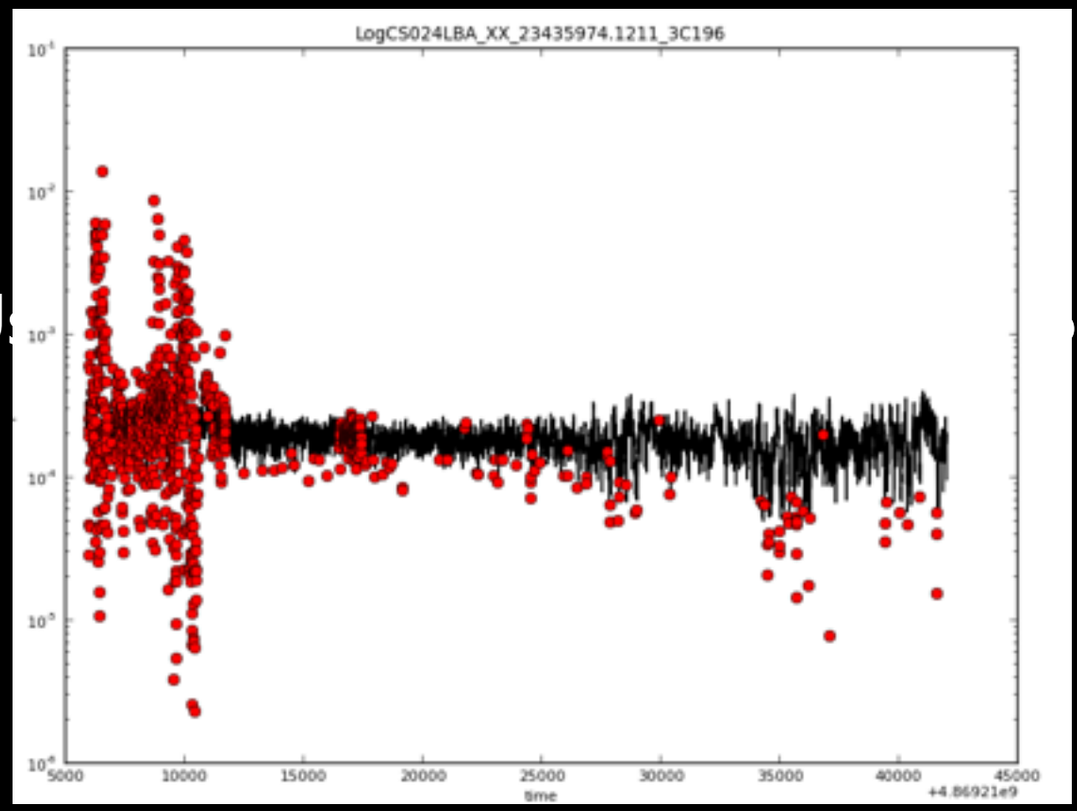


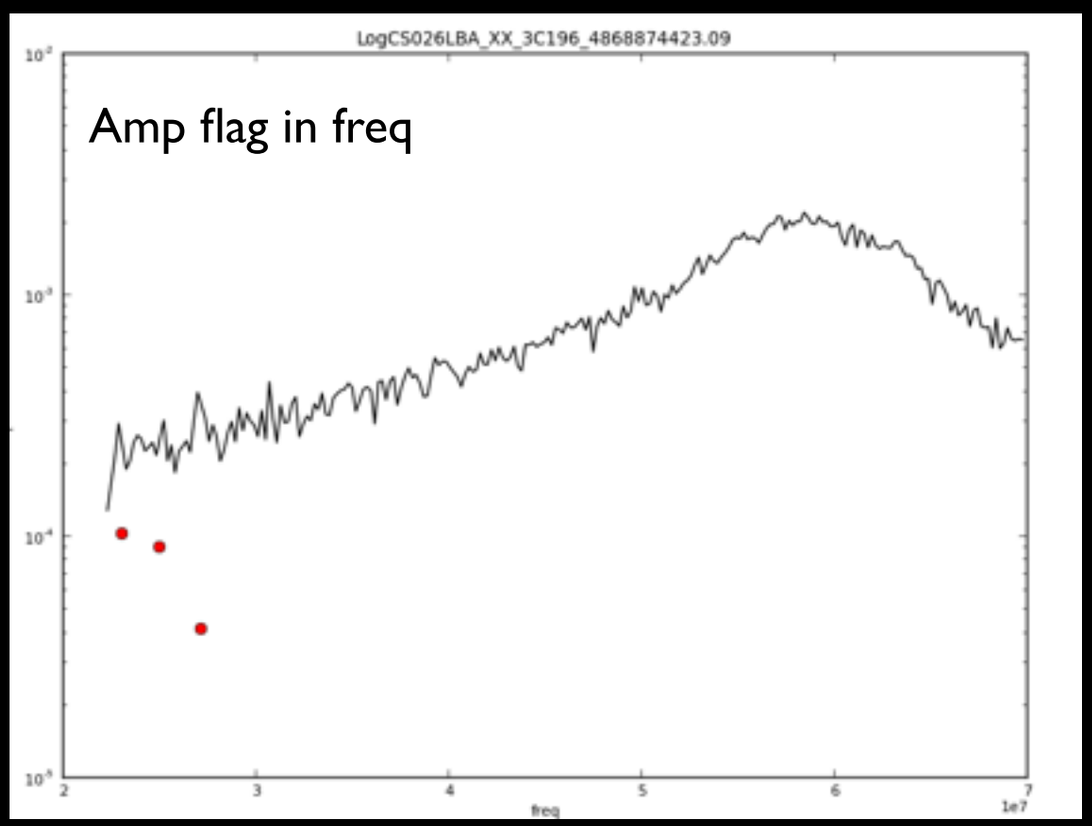
LoSoTo

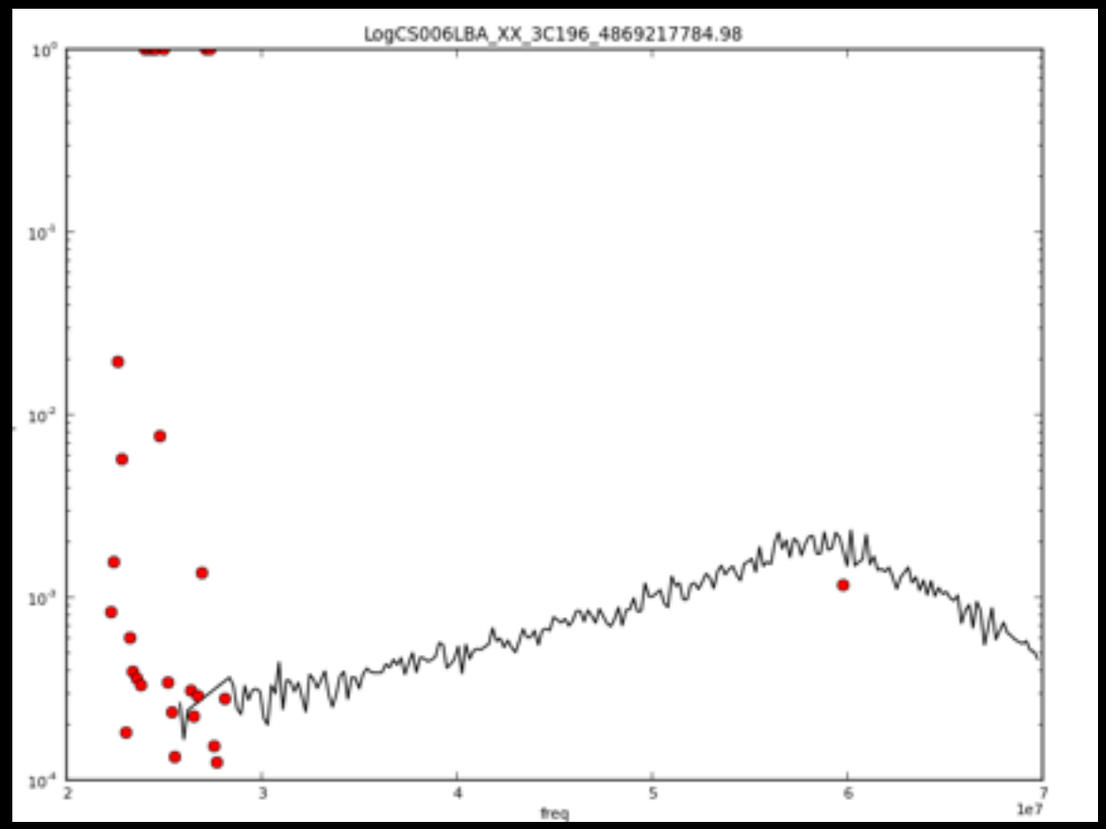
Use for flagging, clock-TEC separation, diagnostic plotting
(more at the end of the talk)




LogCS101LBA_XX_30076599.1211_3C196
Amp flag in time
time
+4.86887e9


LogCS024LBA_XX_23435974.1211_3C196
time
+4.86921e9


LogCS026LBA_XX_3C196_4868874423.09
Amp flag in freq
freq
1e7


LogCS006LBA_XX_3C196_4869217784.98
freq
1e7

On blocks of 10 SBs

II: self-cal loop

run time: 1 day per block

Self-cal on target

Every 3 cycles

Image large field

Subtract large field

Every 3 cycles

Flagging

Imaging

10 times loop

Convert to circular pol

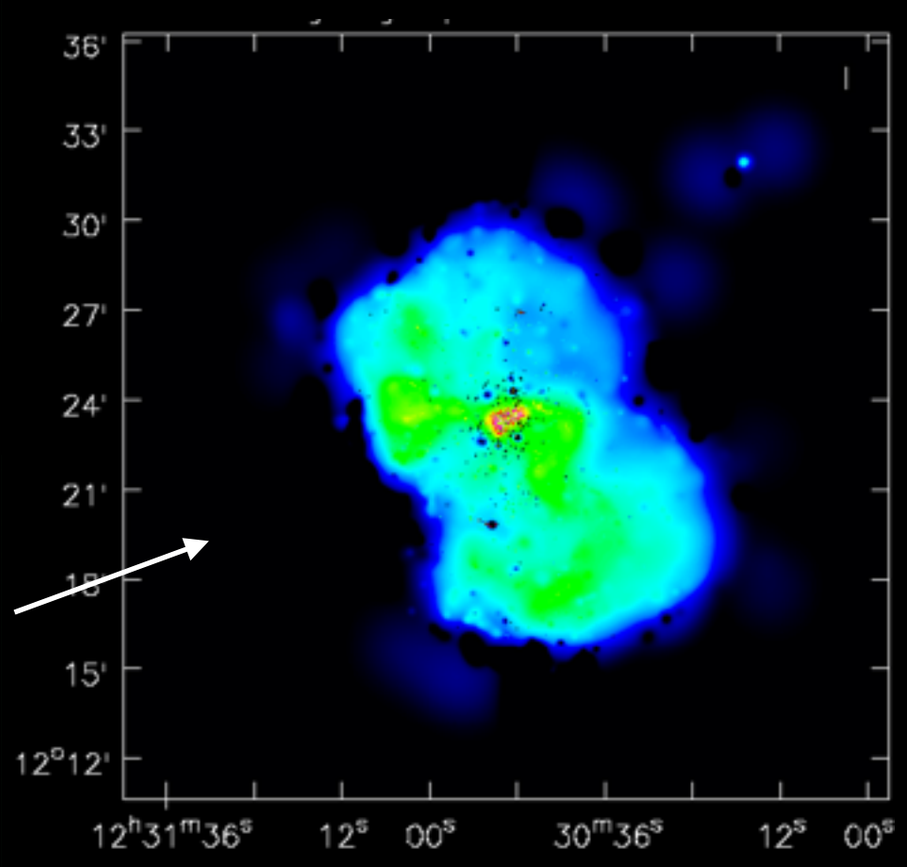
Get rid of Faraday rotation (beam removed!)

Add initial model

Use CC, faster and more precise (no need for the beam)

NDPPP sol+cor

Amp should be normalised to 1 (LoSoTo)



Fast+more stable but no rotation angle (circ pol: not important)

On blocks of 10 SBs

II: self-cal loop

run time: 1 day per block

Self-cal on target

Every 3 cycles

Image large field

Subtract large field

Every 3 cycles

Flagging

Imaging

10 times loop

to linear + concat + corrupt

Concat 10 SB and corrupt for the beam

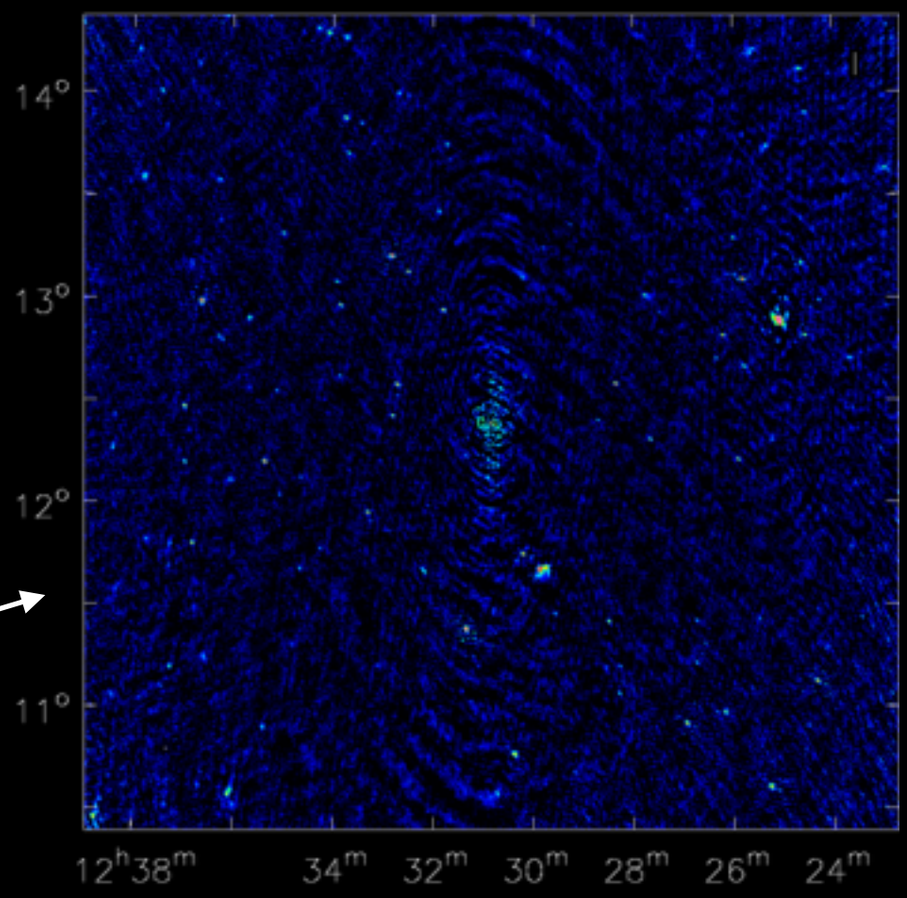
Beam model works only in lin pol
Corruption is needed for beam-dependent prediction of sources

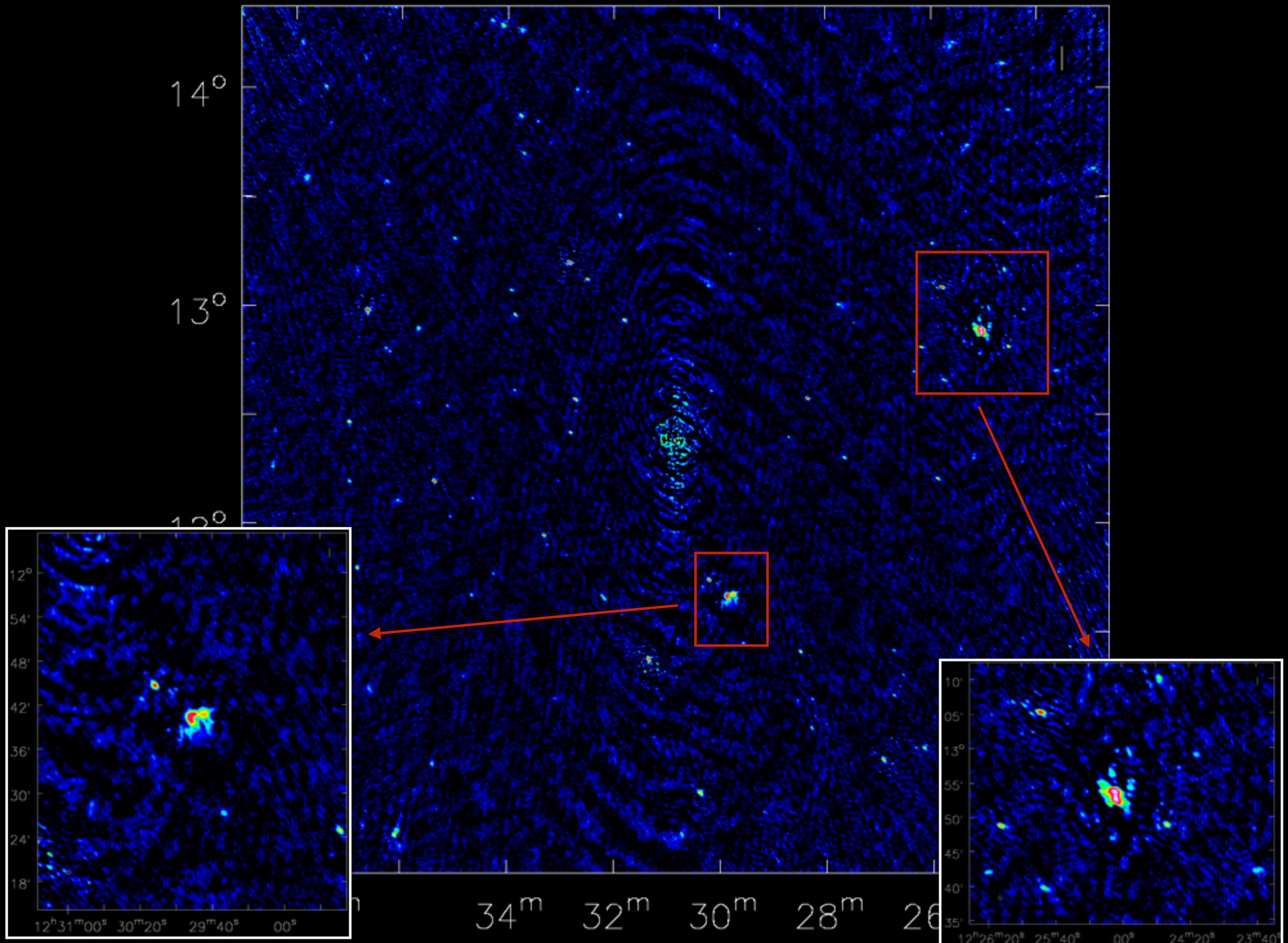
Sub target

Remove best available target model

Wide-field clean

5 x 5 deg, AWimager, automasking
full-freq resolution




14°
13°
12°
34m
32m
30m
28m
12°
54'
48'
42'
36'
30'
24'
18'
12h31m00s
30m20s
29m40s
00s
10'
05'
13°
55'
50'
45'
40'
35'
12h26m20s
25m40s
00s
24m20s
23m40s

On blocks of 10 SBs

II: self-cal loop

run time: 1 day per block

Self-cal on target

Every 3 cycles

Image large field

Subtract large field

Every 3 cycles

Flagging

Imaging

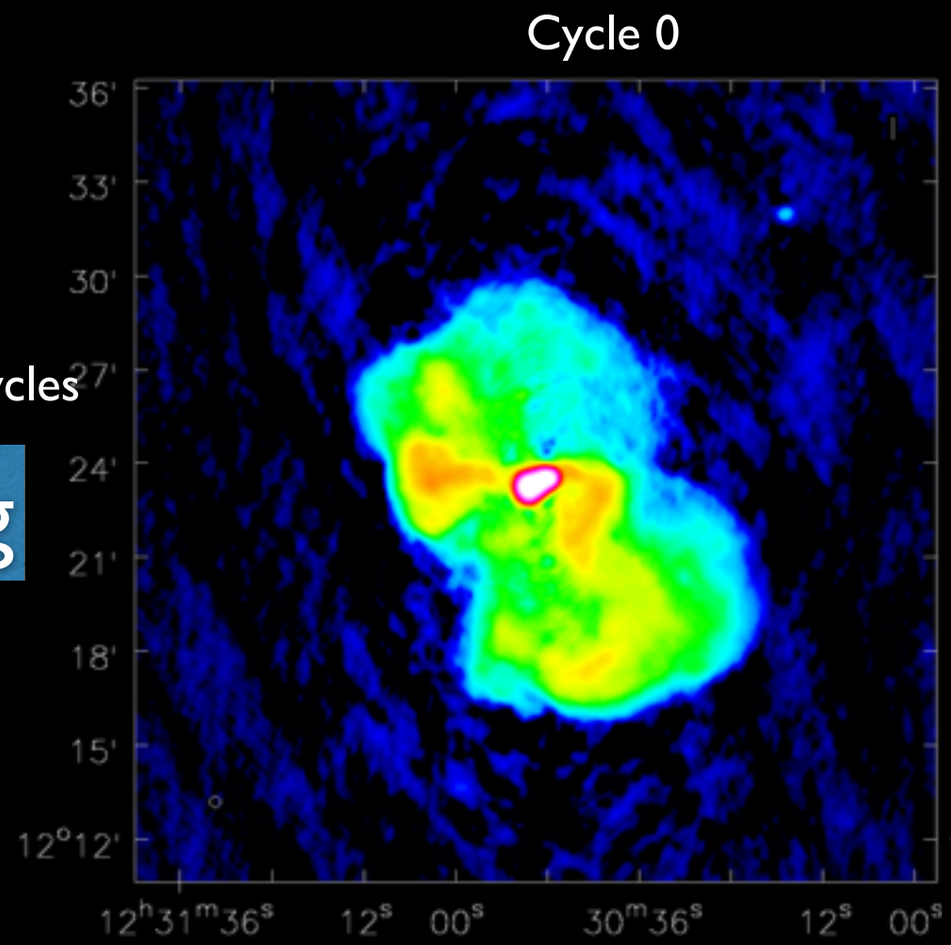
10 times loop

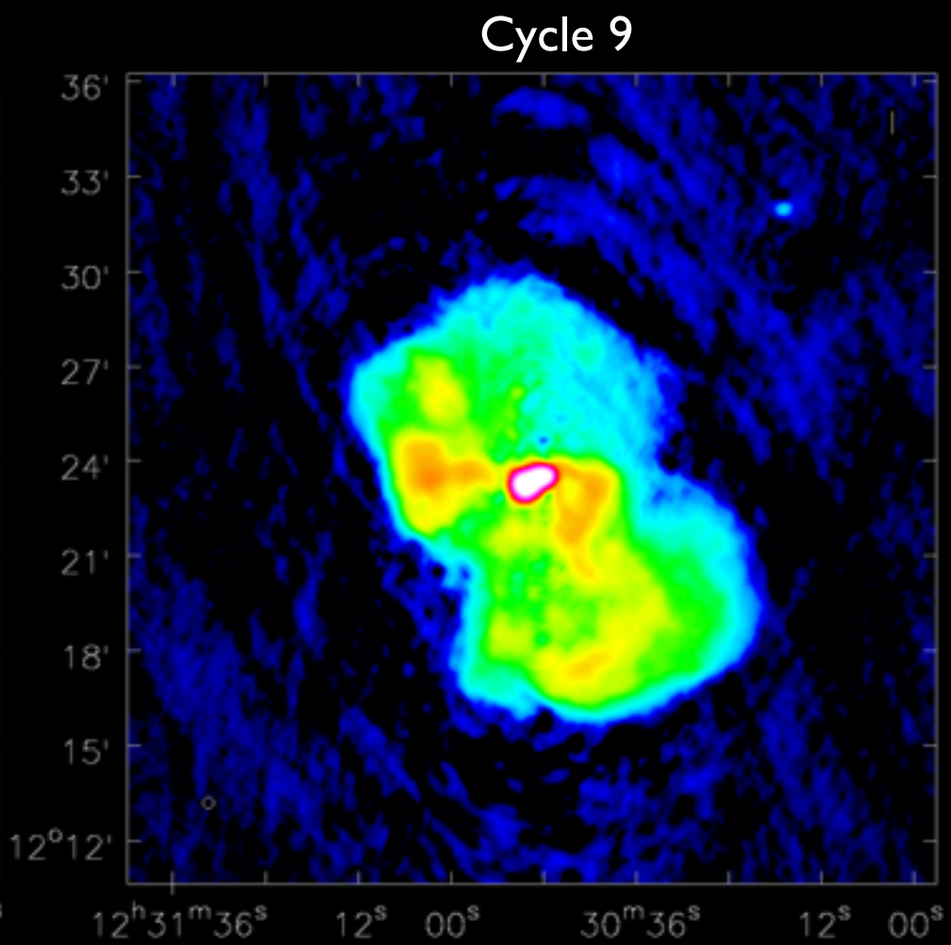
Concat and Clean

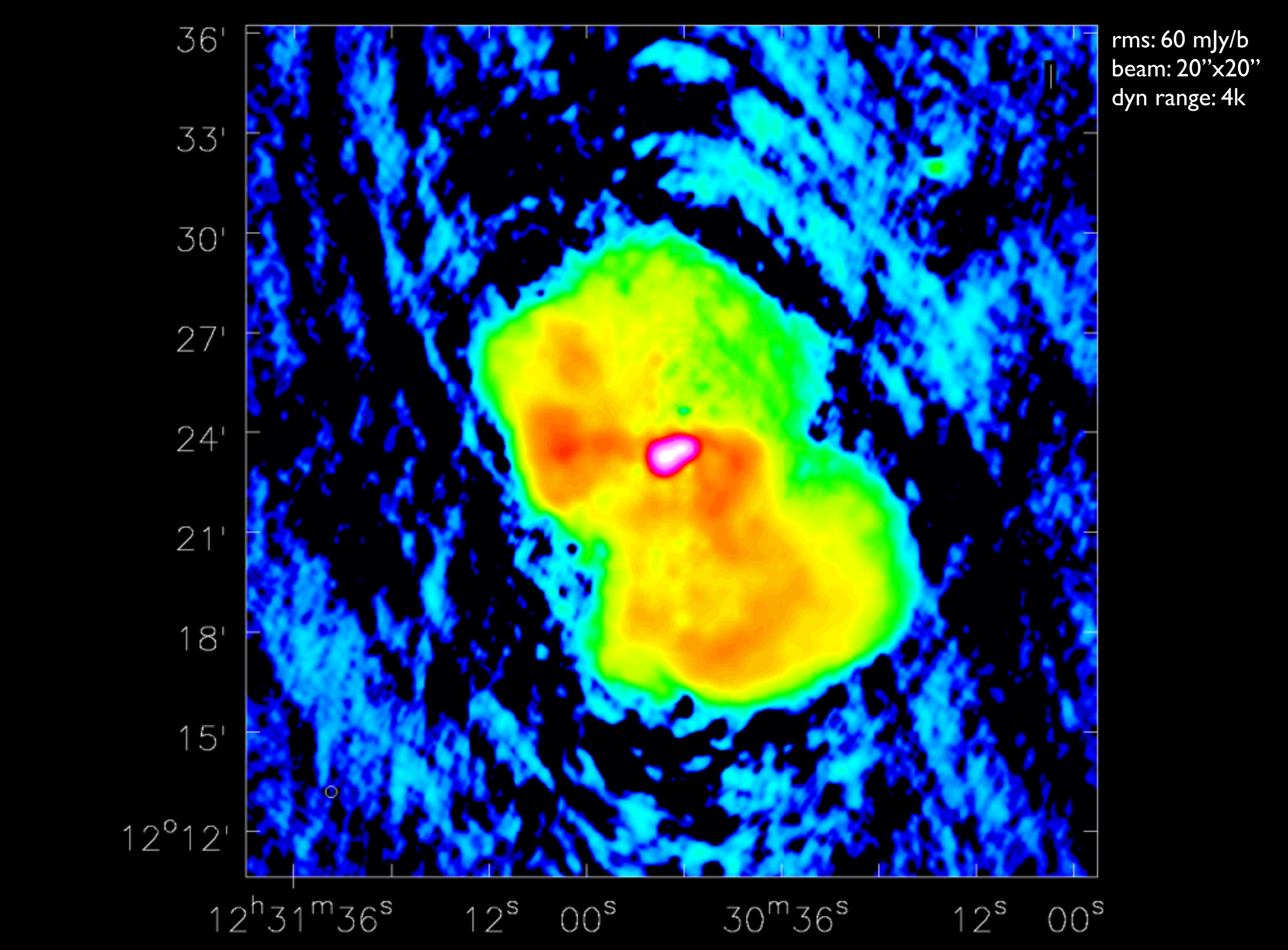
10 SBs to improve uv-coverage

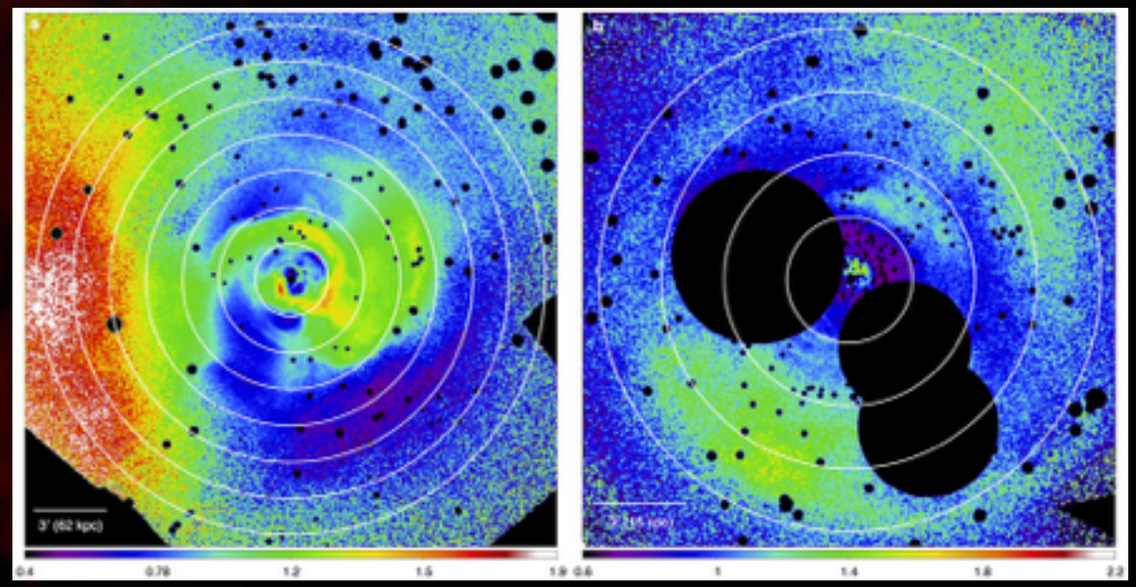
1 ch/SB to speed up

very complex target, MS-MF is fundamental. Multiple runs with different scales also required






rms: 60 mJy/b
beam: 20”x20”
dyn range: 4k
36'
33'
30'
27'
24'
21'
18'
15'
12°12'
12h31m36s
12s
00s
30m36s
12s
00s



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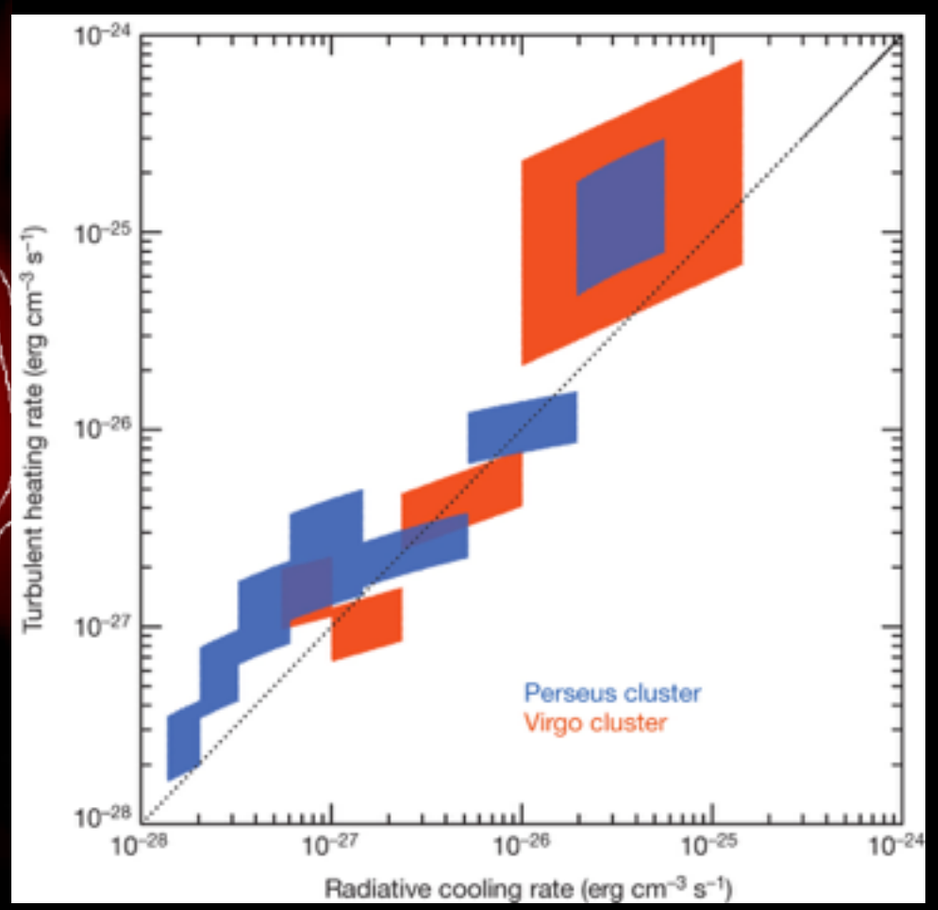


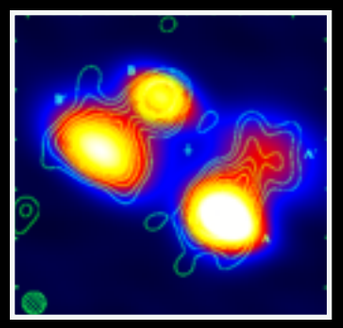
Strategy II: weak target

Preliminary

Obs strategy: 244 SB on cal, 244 SB on target

Pre processing: demix + avg to 4 chan / 1 sec

Same as for strong targets



1: calibrator (3C196) - run time: 4 days

BBS on calibrator
Diag(G) + rot ang
<30 MHz: divide SB

LoSoTo
C-T separation
(diagnostic) + flag

Cor on target
Transfer A+P (solve clock but dTEC)

Same pre-calibration of the strong target strategy

On blocks of 10 SBs

II: self-cal loop

run time: 6 h per block

Self-cal on target

Subtract field

To be repeated for each peel calibrator

Peel of bright source

BBS selfcal

Fast ScalarPhase+TEC and slow (5min) Gain

BBS selfcal

Fast ScalarPhase+TEC

Concat

10 SBs to improve S/N

Clean high-res

5x5 deg, AWimager, automasking

Clean low-res

5x5 deg, AWimager, automasking

3, 4 loop

1, 2 loop

finally

Source subtraction

Leave an empty dataset + models every 10 SBs

On blocks of 10 SBs

II: self-cal loop

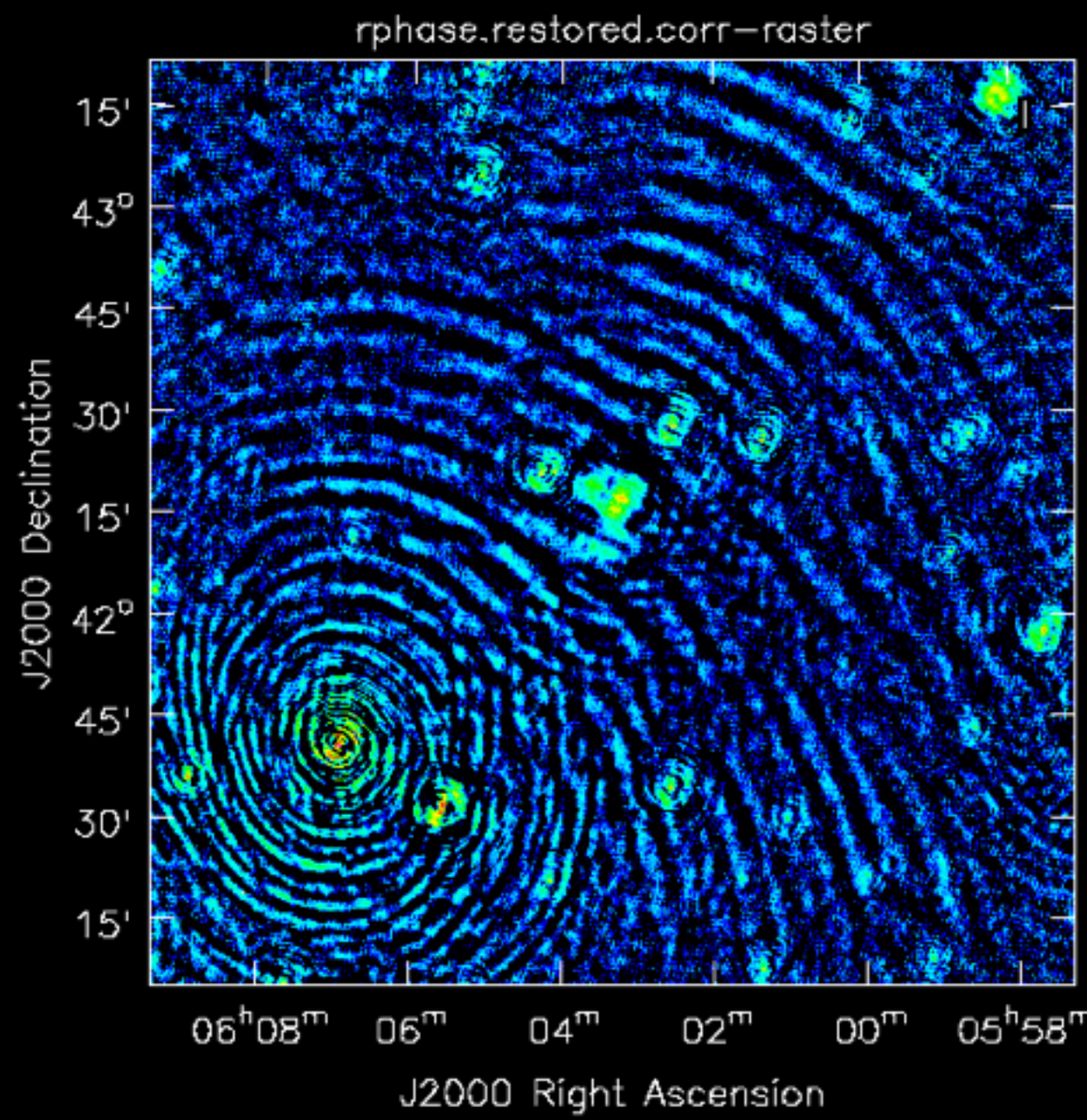
run time: 6 h per block

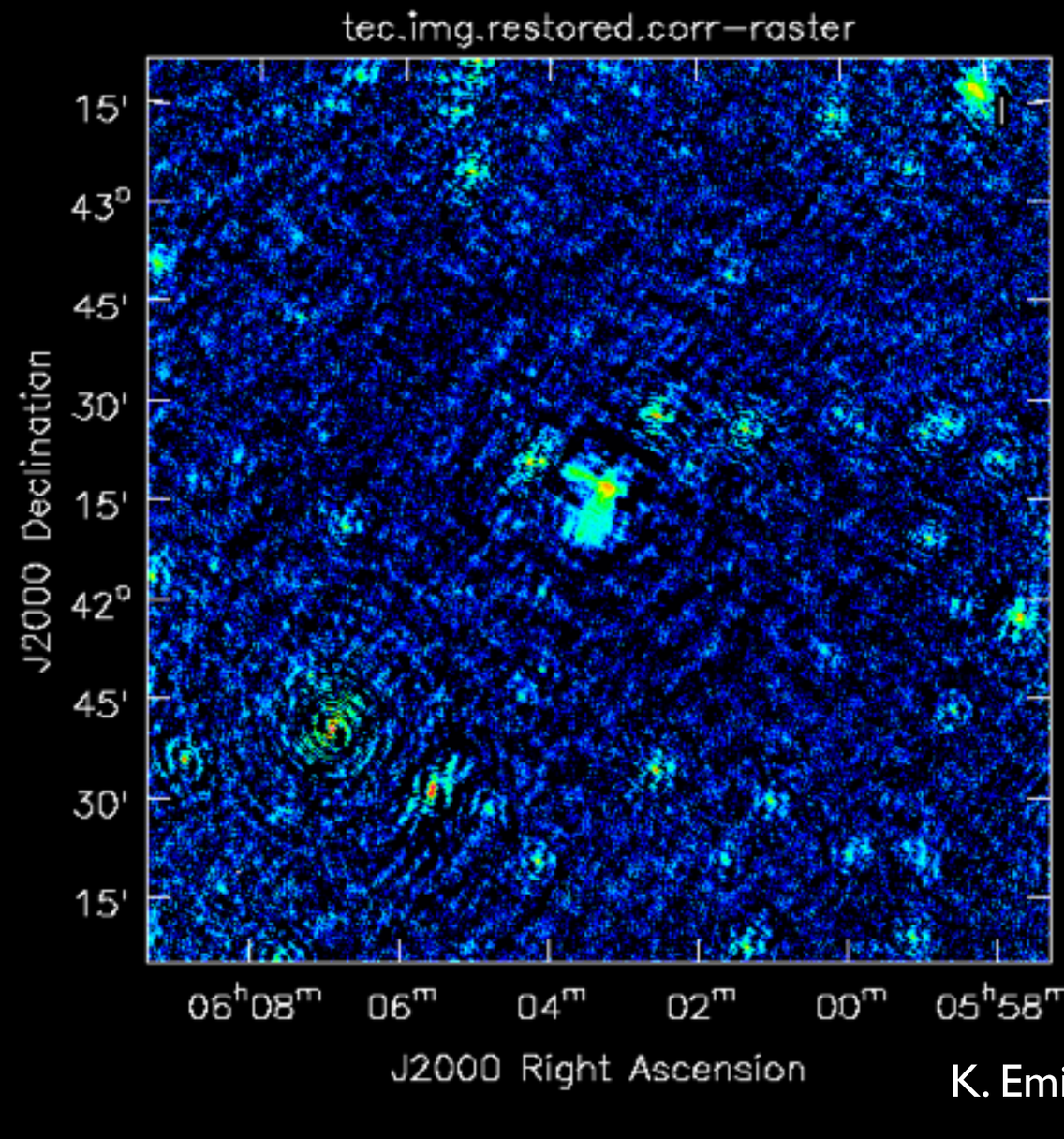
Self-cal on target

BBS selfcal

BBS selfcal

Concat





K. Emig

II: self-cal loop

run time: 3 h (30 Sbs)

On all available SBs
(now tested on 30)

Self-cal on target

Subtract field

To be repeated for each peel calibrator

Peel of bright source

Concat + ph rotate

All SBs to improve S/N, PR in source dir and add model back

Clean

CASA (nterm=2), automasking, make initial CC model

BBS selfcal

Fast ScalarPhase+TEC and slow (5min) Gain

BBS selfcal

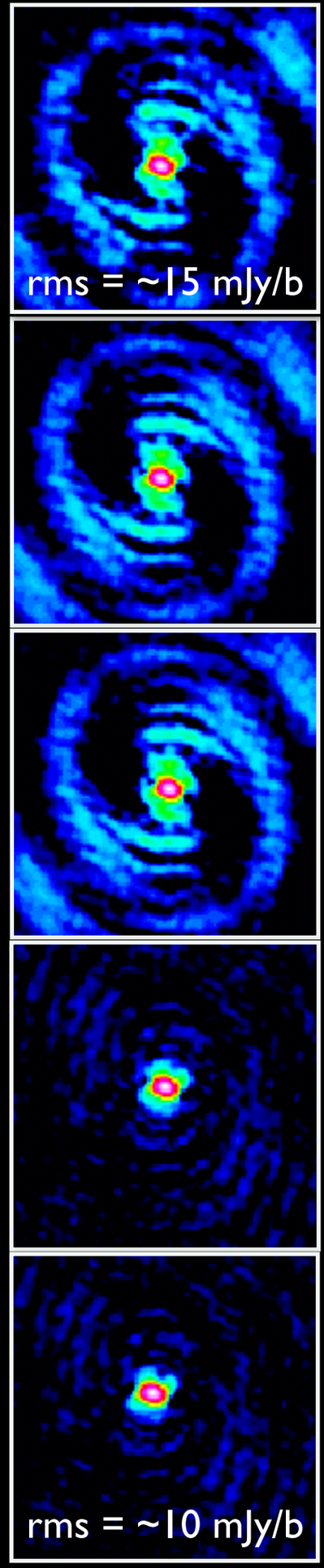
Fast ScalarPhase+TEC

Clean

CASA (nterm=2), automasking

3, 4 loop

1, 2 loop



Next steps

M87 (strong targets)

- Test circular polarisation on the calibrator
- Self-cal on other 23 blocks (how to combine them?)
- Flux normalisation (LoSoTo)
- Try DD corrections on field sources

Toothbrush (weak targets)

- Figure out how to properly do self-calibration (amp issue)
- Try peeling a second source
- Tune some important parameters (masking, source extraction…)
- Peel on 244 SBs (now only 30 used)