TPS: CRRLs resolved on 10' - scales

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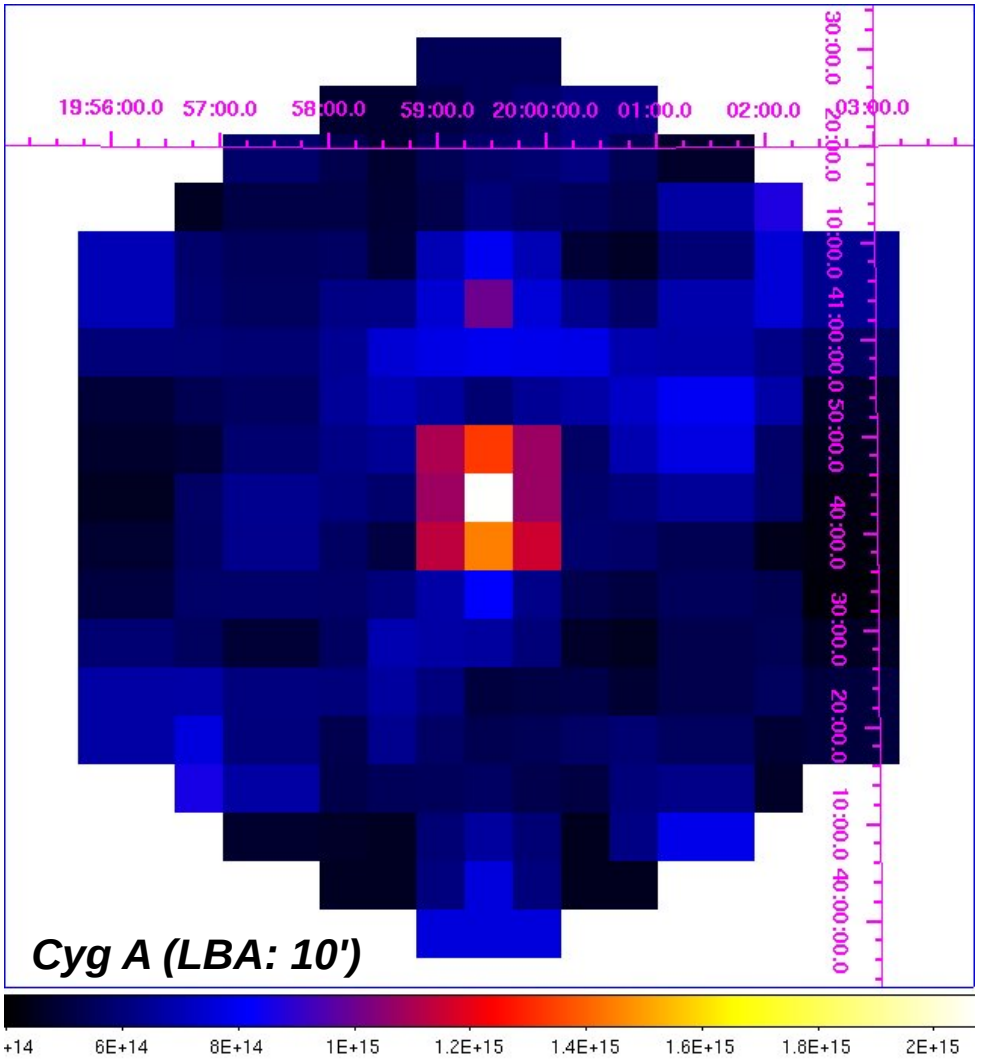
Outline

- **Introduction**
- **Commissioning (CygX, G33)**
  - * **comparison C0,1 vs. C6**
  - * **issues**
- **LC6_019 (cygnus)**
  - * **calibration**
  - * **beams**
  - * **(grid reduction) $**
  - * **(results) $**

$ => Astrolunch talk (today)



Radio Recombination Lines: LOFAR surveys

The Power of LOFAR:

Sensitivity , Resolution , FoV , BW

=> *"Survey speed"* *(α , δ , λ)*

LBA 10 - 70 MHz : 400 RRL α-lines
HBA 105 - 250 MHz : 100 RRL α-lines

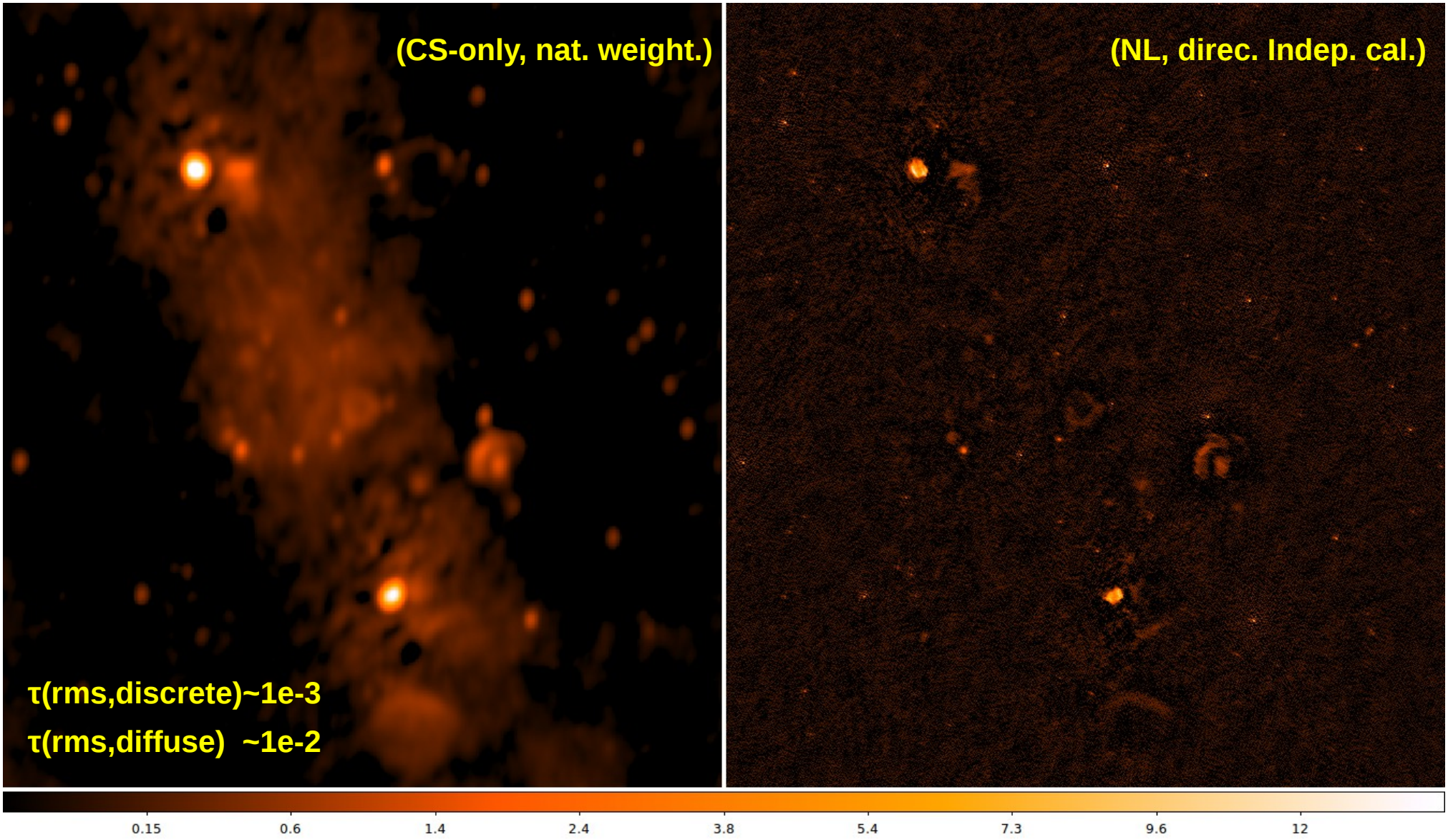
A) Medium resolution Galactic survey

From degree-scales to >10'-scales

B) Galactic pinhole survey (<10')

C) Extragalactic survey

RRL surveys: Why we need total power ?! (tied-array)



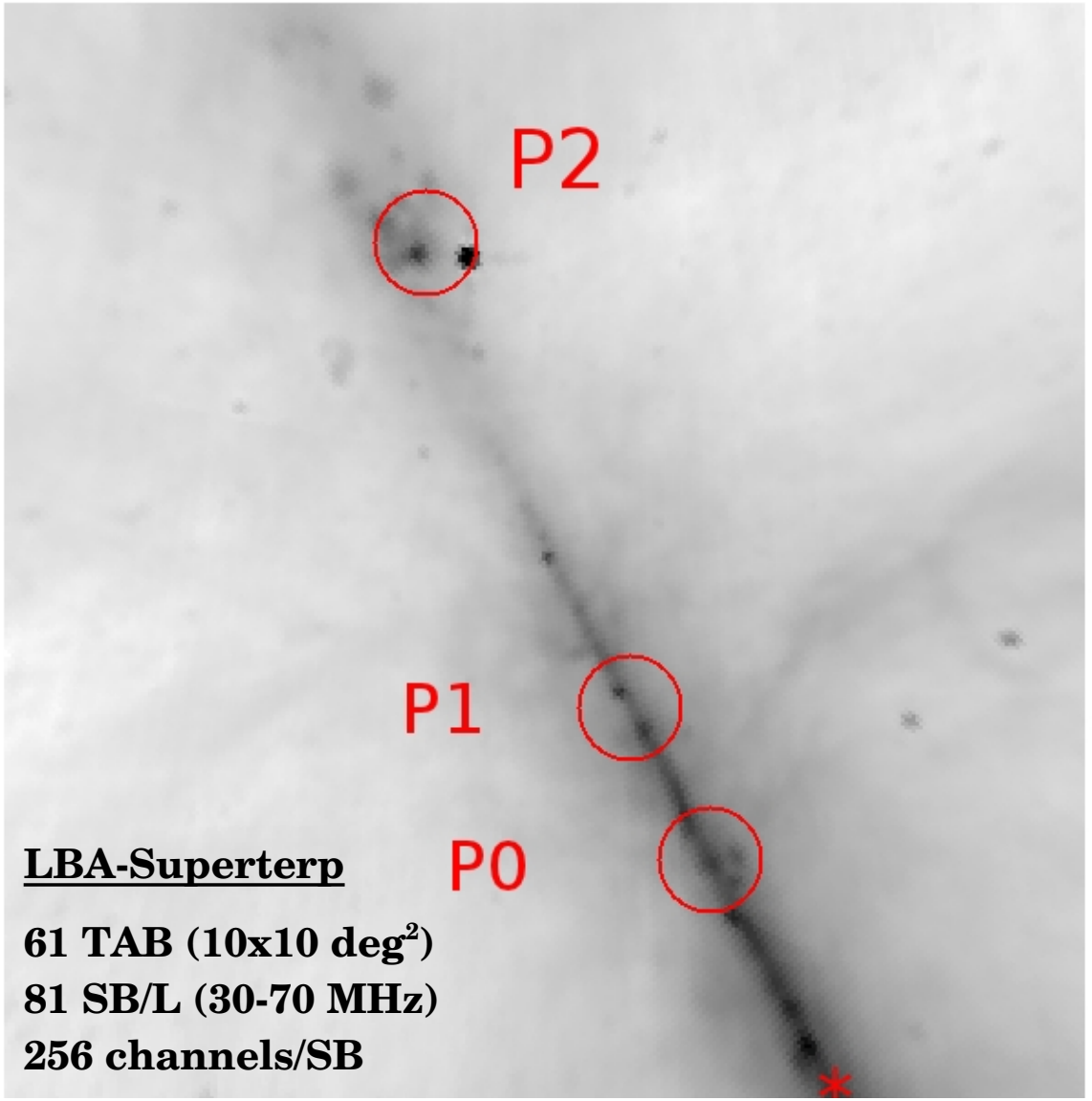
* CRRL basic quantity is optical depth, diffuse MW provides natural screen
  - < 10-20% continuum recovered in interferometric LOFAR HBA and LBA
  - continuum scale (degrees) is very different from gas scale (arcmin)

Commissioning

(Cycle 0,1 vs. 6)

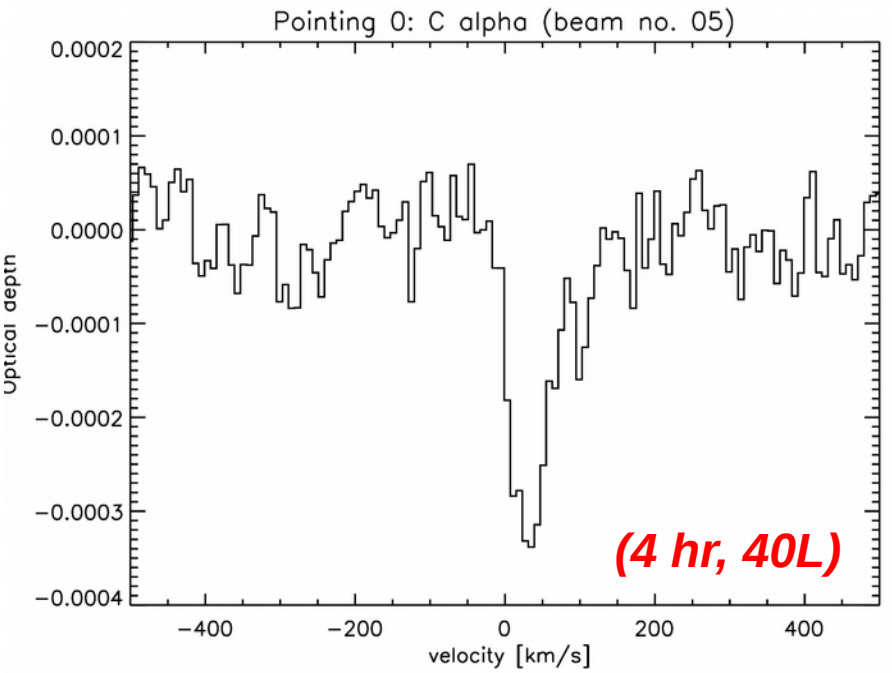
Galactic TA CRRL Survey: (TA mode: BG – LC 0,1)

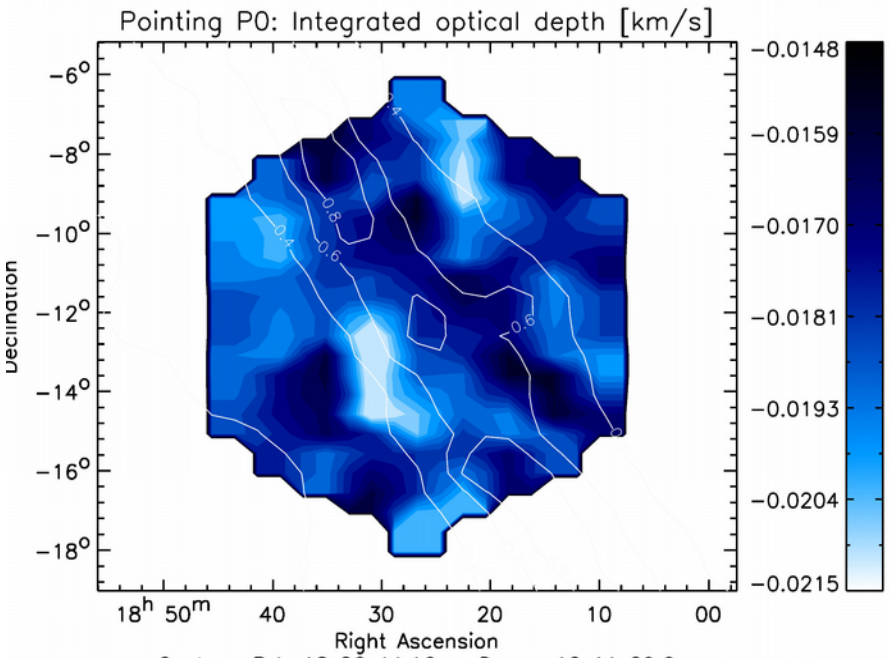
Haslam+1982 (408 MHz) map



LBA-Superterp

61 TAB (10x10 deg^2)
81 SB/L (30-70 MHz)
256 channels/SB





Galactic TA CRRL Survey: (summary)

LOFAR (50 MHz) results

P:	$\int \tau$	τ_{peak}	VEL*
0:	0.018	3.5e-4	+30
1:	0.015	2.5e-4	+55
2:	0.011	5.0e-4	+1

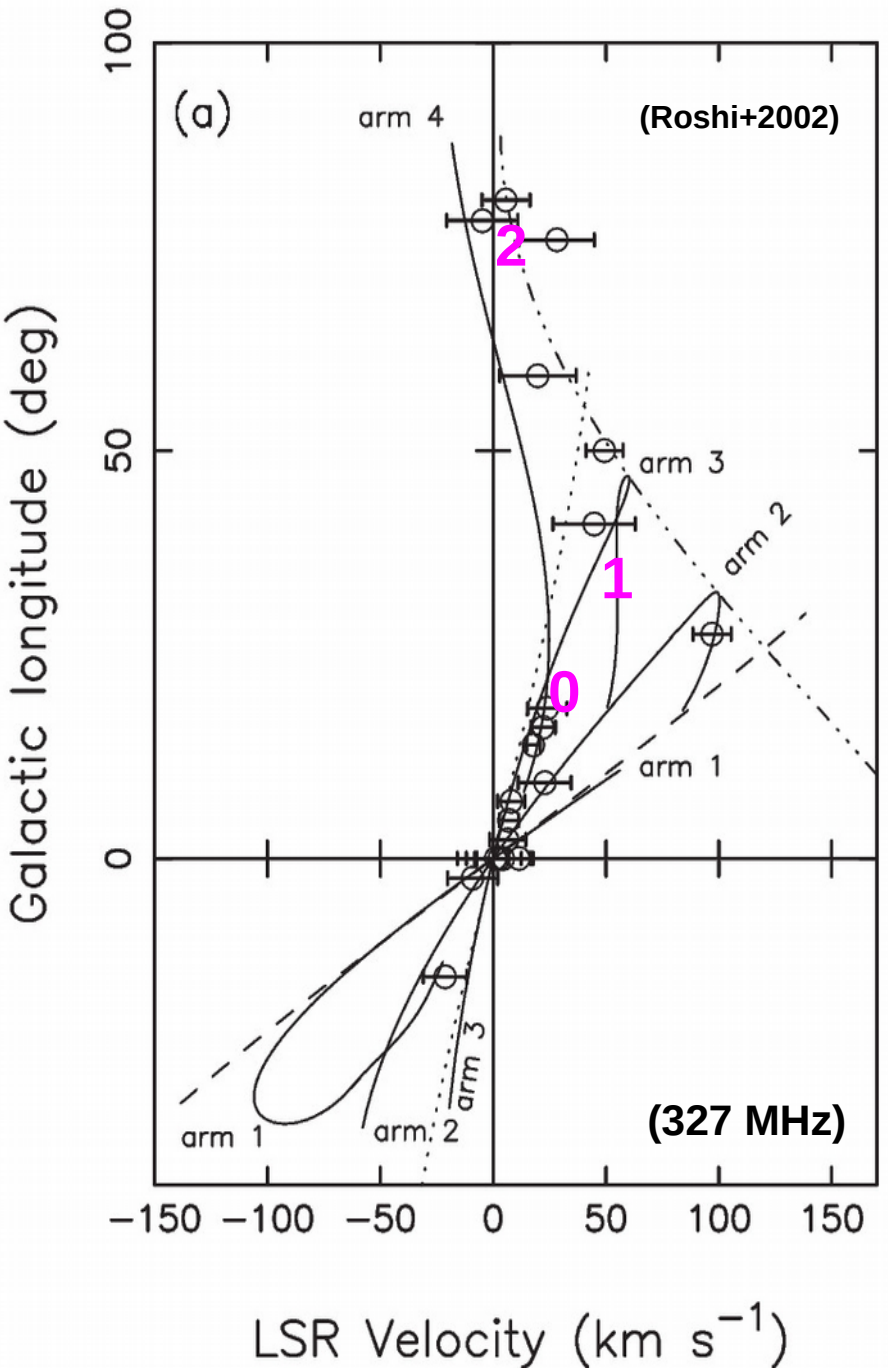
* after correcting for doppler (matches Roshi+2002)

Comparing surveys τ_{peak}

Ro00	(327 MHz, 2º)	(3 - 6)e-4
Er95	(76 MHz, 4º)	(5-10)e-4
Lofar*	(50 MHz, 1º)	(3 - 5)e-4

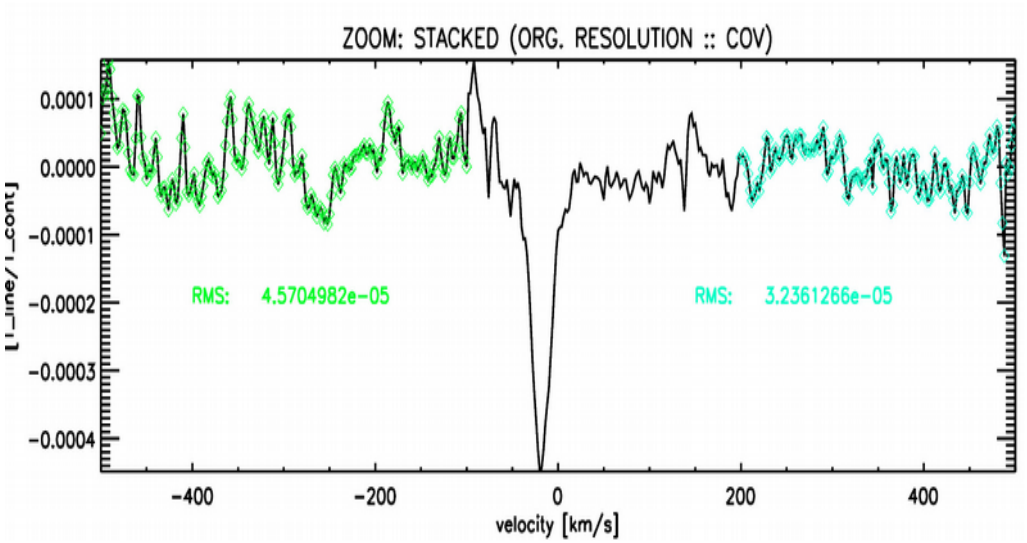
* LOFAR TA : CRRL dilution , due to instrumental noise

(i.e. needs to be corrected for instrumental zerolevel)

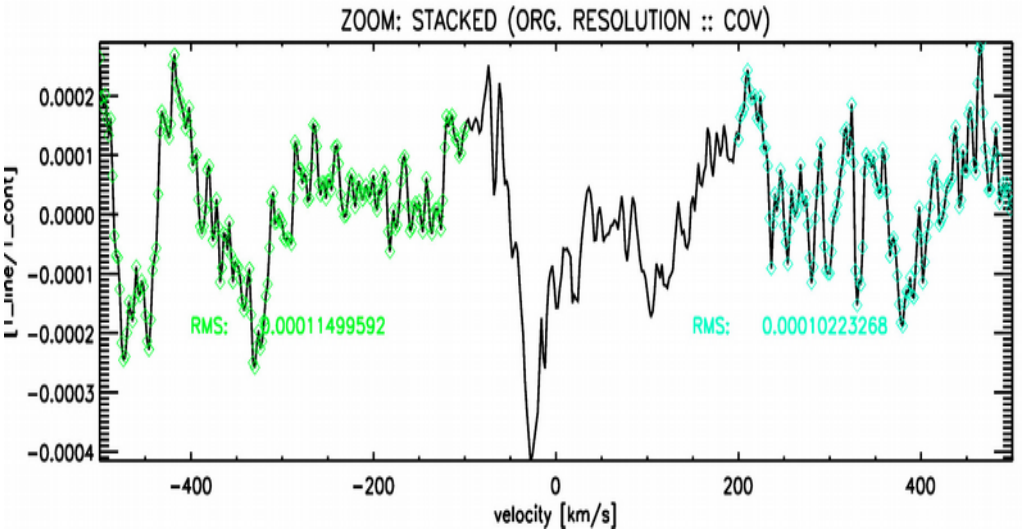


Commissioning Cygnus: Cycle 0,1 vs. Cycle 6 *(4 hr, 40L)*

BG: Flagging & Averaging only



C: Flagging, Averaging, 256chn corr

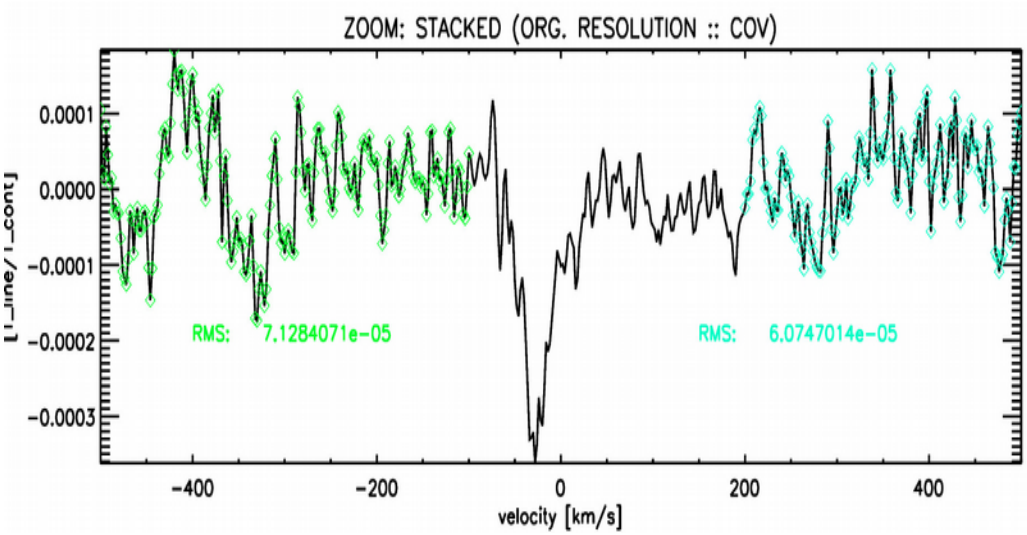


Fair comparison of BG vs. Cobalt

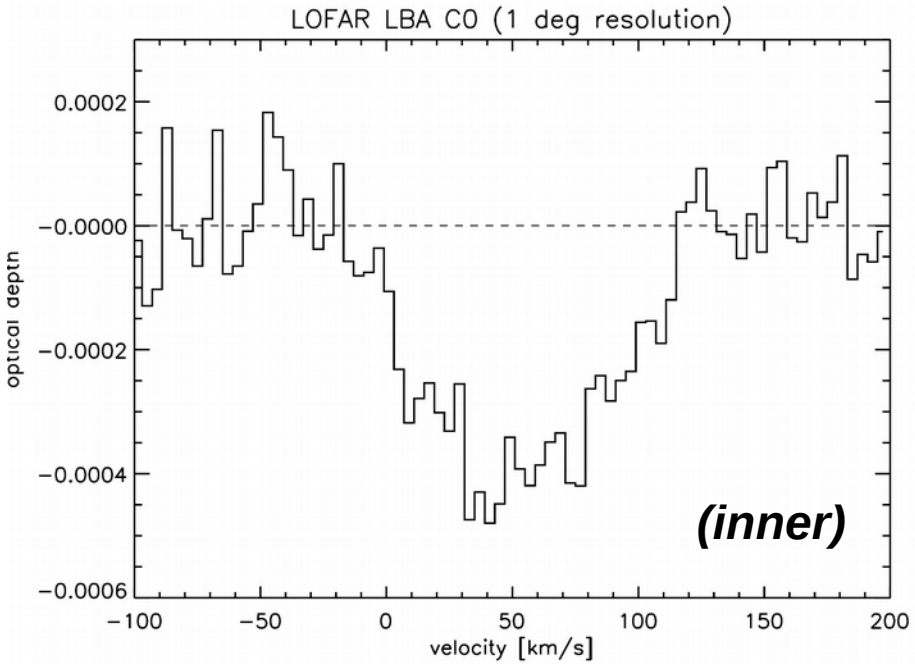
(NEW Cobalt w. OFF correction) =>

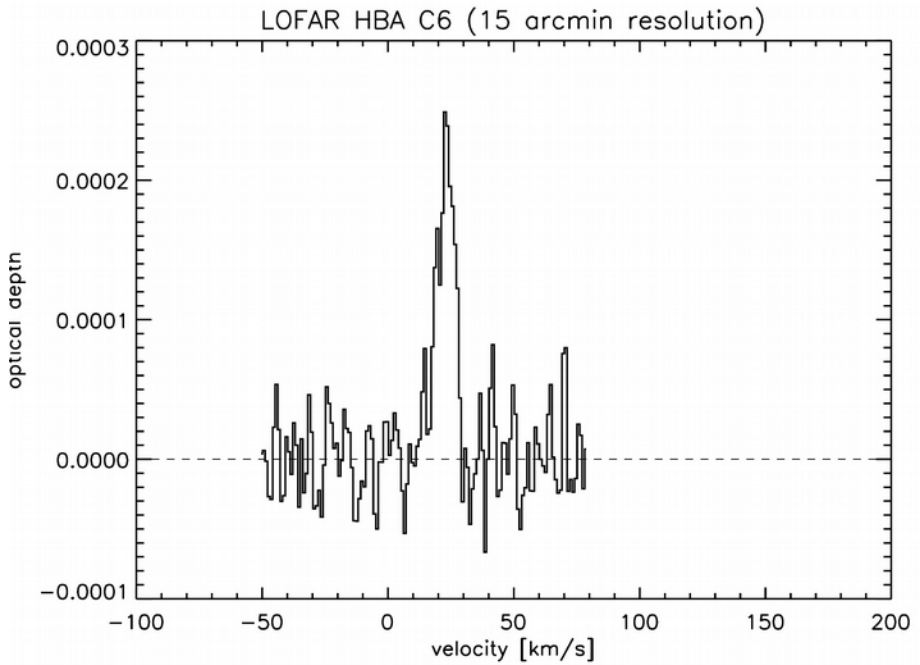
C: Flagging, Averaging, 256chn corr
+ bandpass correction from 'off'

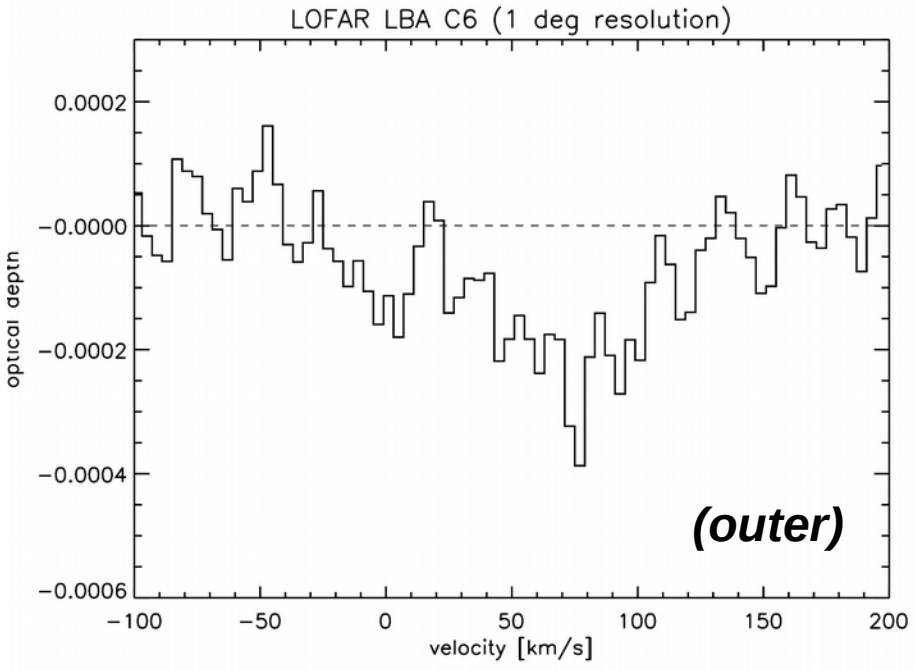
Lost: factor 2 in SNR (i.e. 4 in time !)



Commissioning G33: Cycle 0,1 vs. Cycle 6 *(4 hr, 40L)*







LBA 1 deg comparison is not fair:

*** Different beams**

, but:

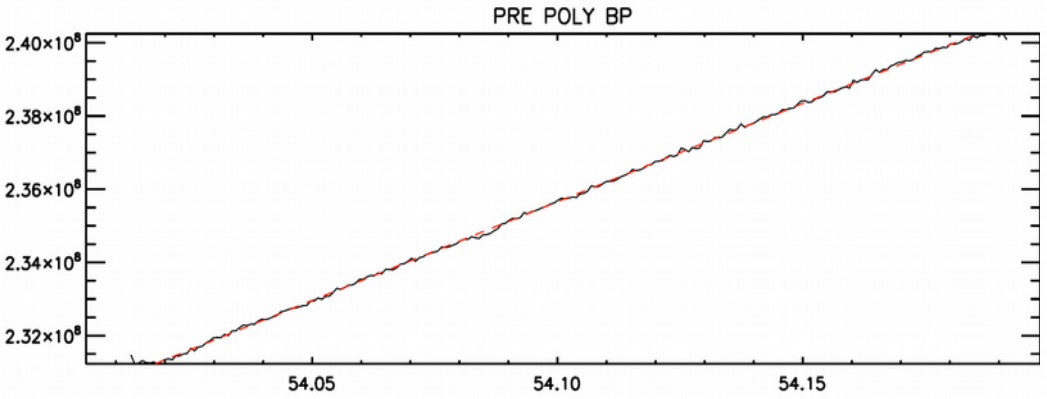
HBA result is promising
(needs more velocity coverage)

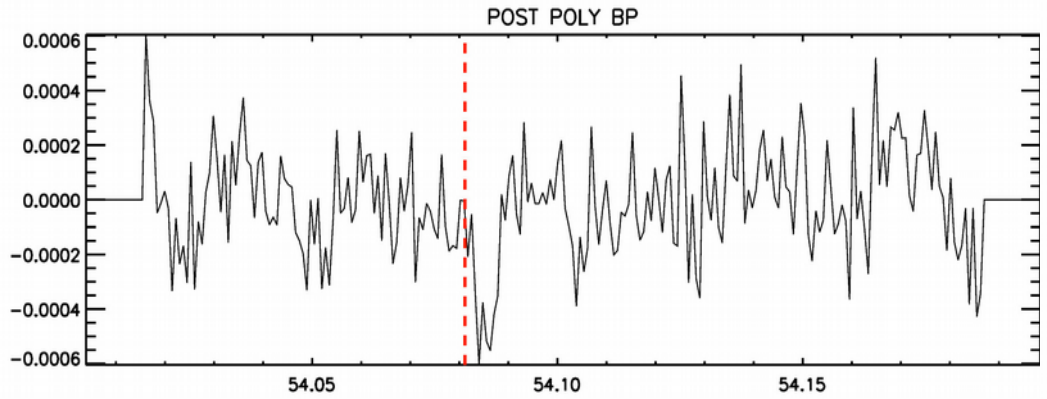
Issues

- PPF residuals in TA bandpass
- Frequency gradients over 1 SB

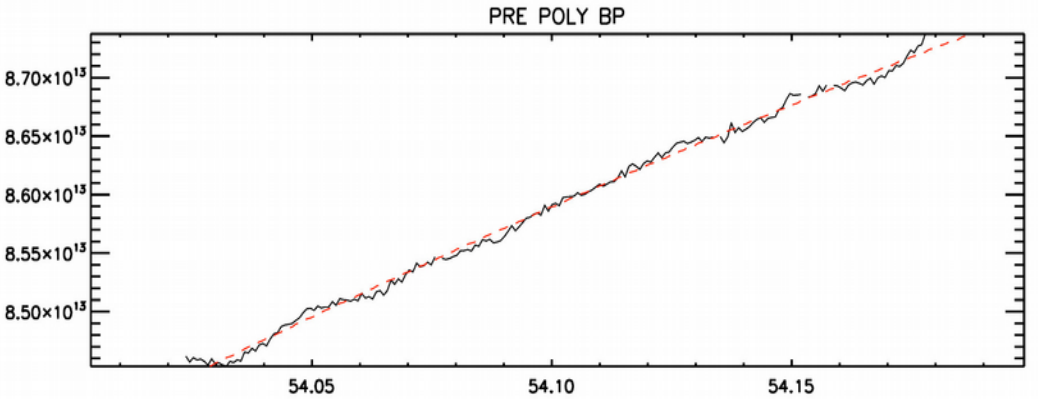
Correlator (Cobalt): Residual bandpass has PPF ripple

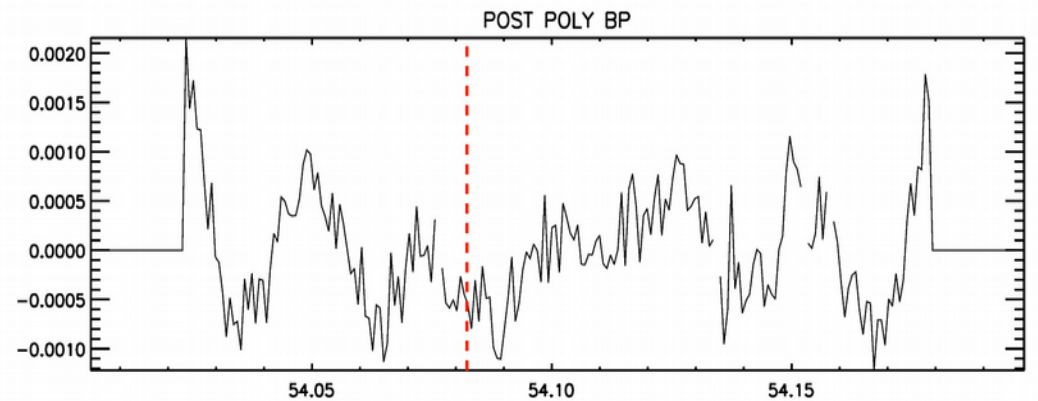
BG: Flagging & Averaging only





C: Flagging, Averaging, 256chn corr

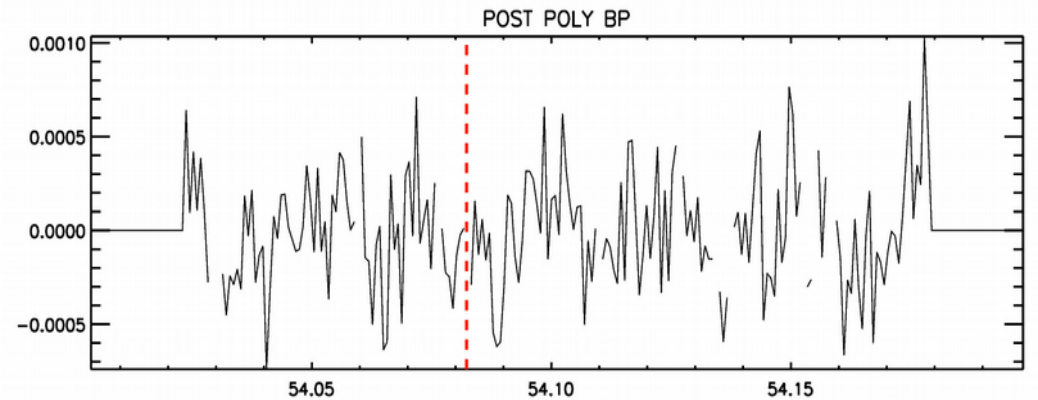




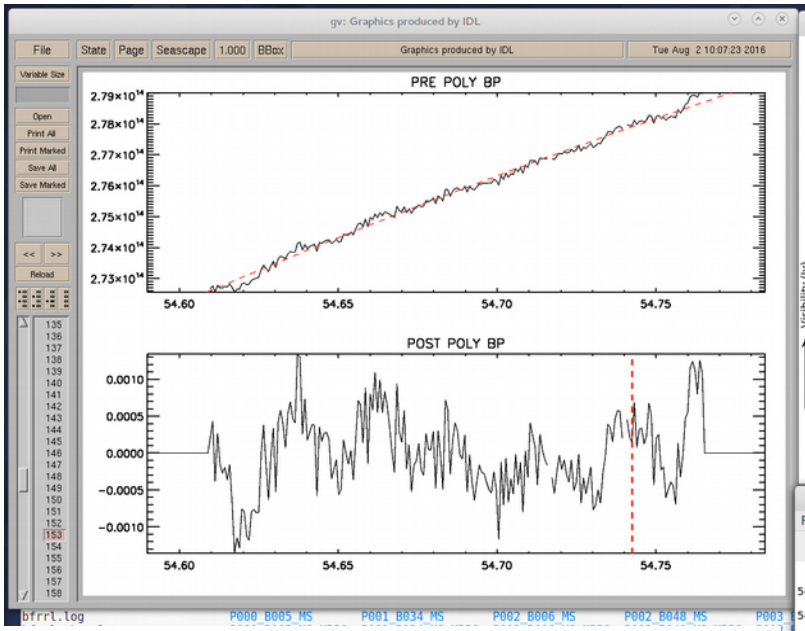
Cobalt Bandpass ('off') corrected =>

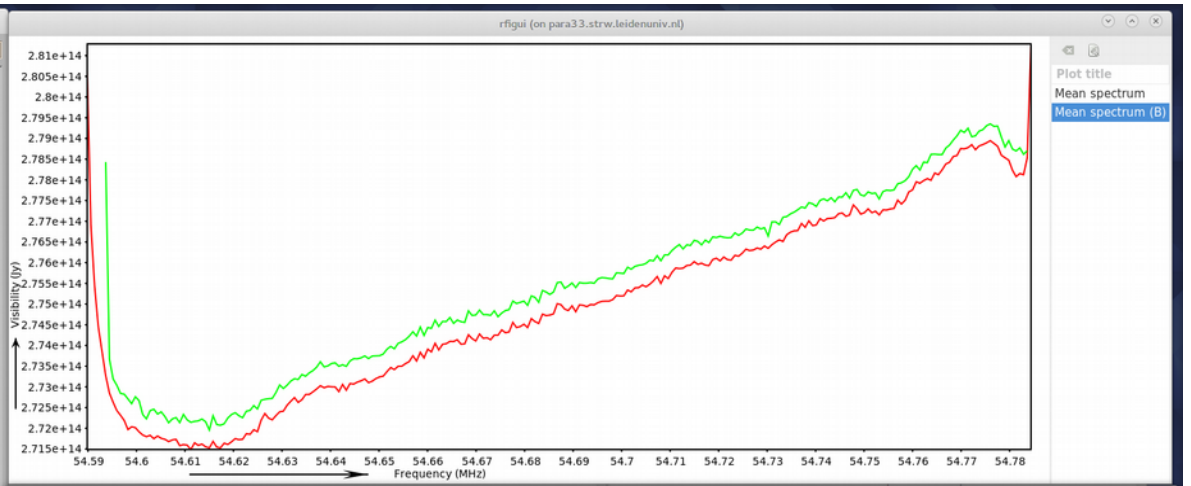
- **spectral rms factor ~2 worse**
- **bandpass adds sqrt(2) noise**
- **problem for LBA and HBA !**

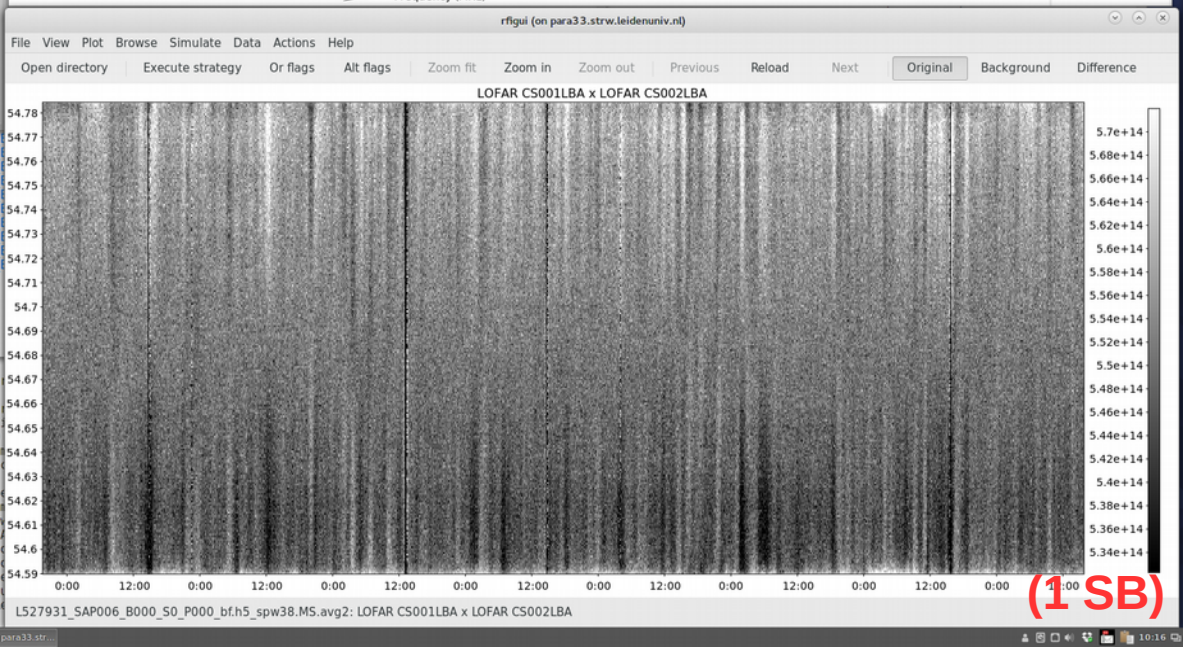
“ ONGOING INVESTIGATION ”



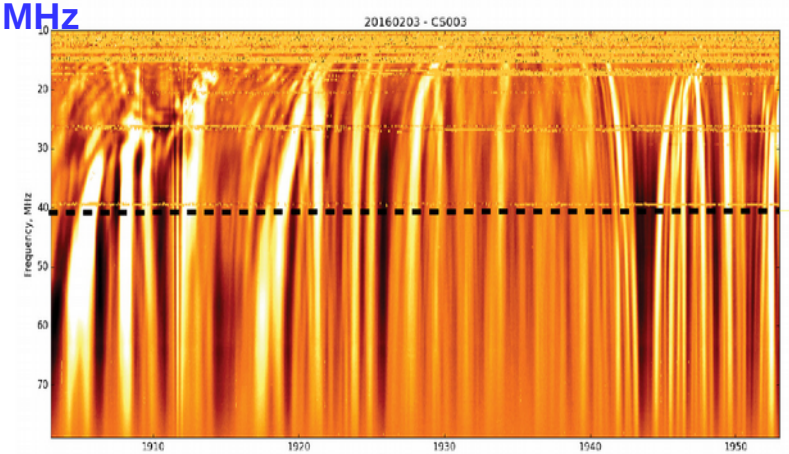
New Issue II: Time dependent, frequency gradients







10 MHz



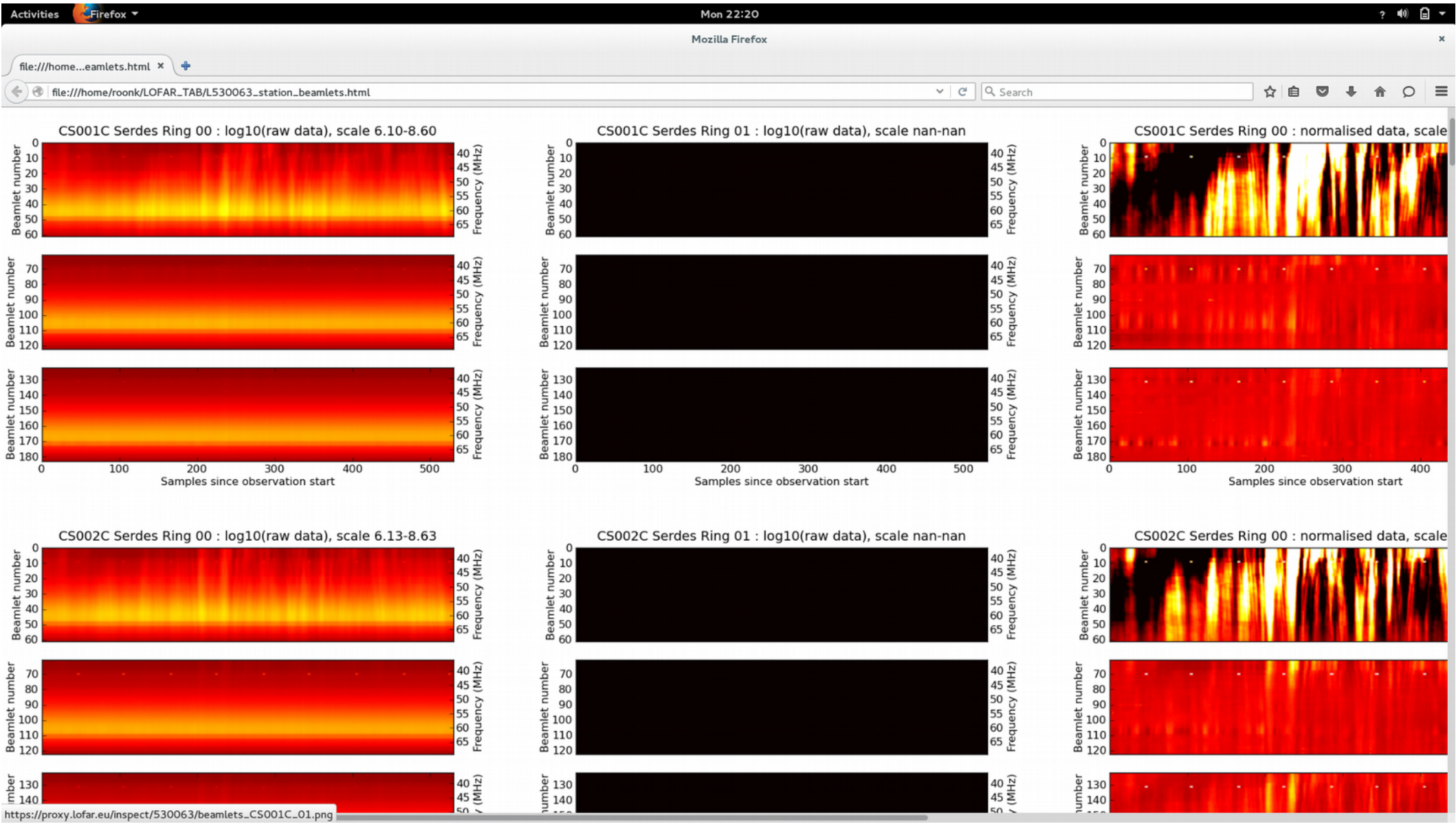
80 MHz (scintillation, courtesy R.fallows)

*** Bottom-right shows dynamic spectra (signal in freq vs time) for a single subband:**

- signal has frequency gradient (bandpass) but its fluctuates rapidly in time

- this was not seen cycles 0,1 for LOFAR – scintillation is being investigated

Scintillation: TA data is also affected (L530063 - LBA)



(10m observation of Cygnus A: inspection plots)

LC6_019 (despite issues we went ahead)

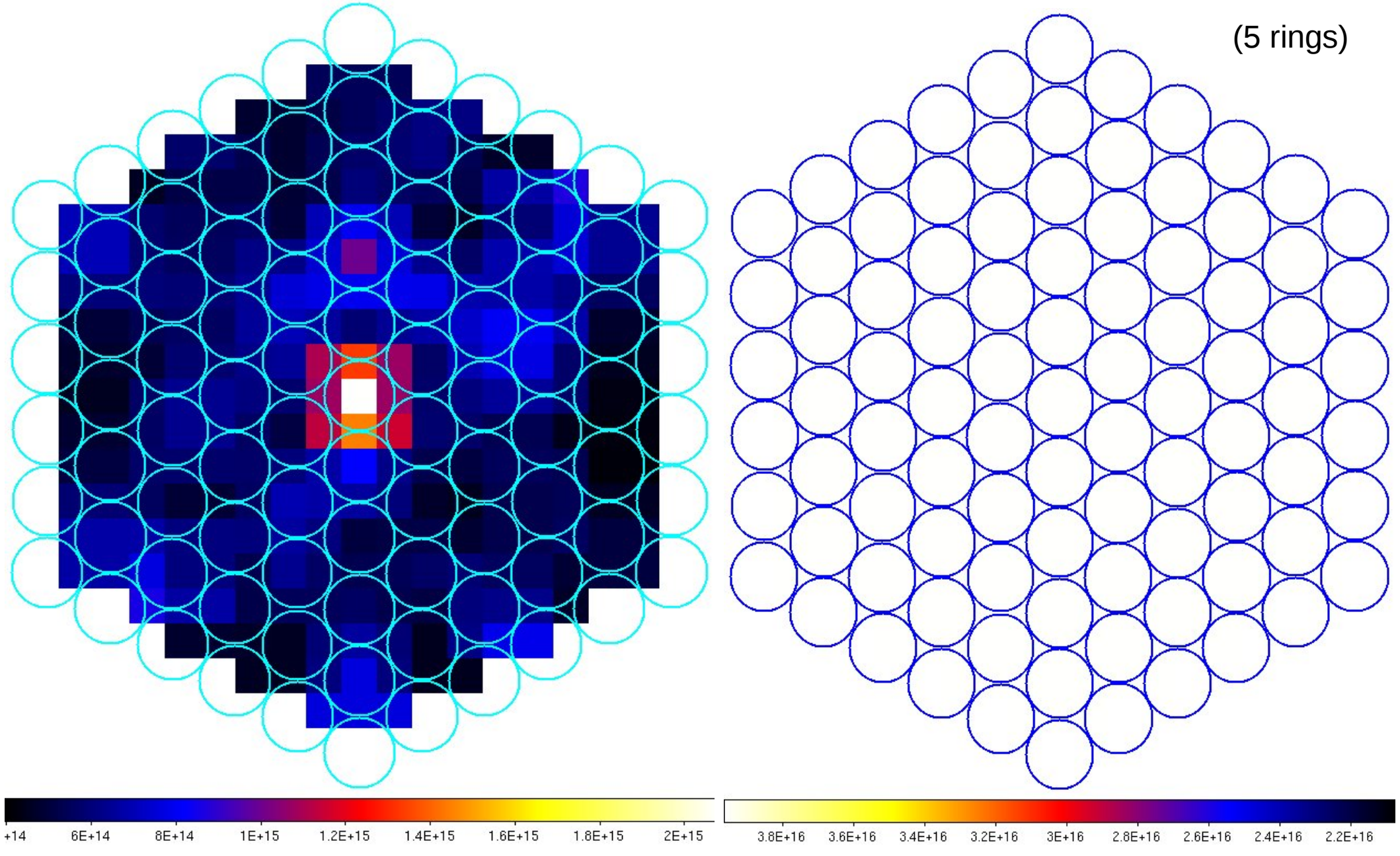
- CRRL TA 10' measurements of Cygnus

LBA: 22 CS
HBA: 9 CS
HGH: 6 CS

note: previous literature > 2 deg
previous LOFAR TA = 1 deg

LOFAR LC6_019: Calibration - Beam

*** LBA Cygnus A (10m obsv: 1.5 deg FoV covered with 10' beams)**



LC6_019: Beams

1) Tile (HBA,HGH) / Dipole (LBA) beam

→ tile beam (about 20 degrees)
→ dipole beam (“all sky”)

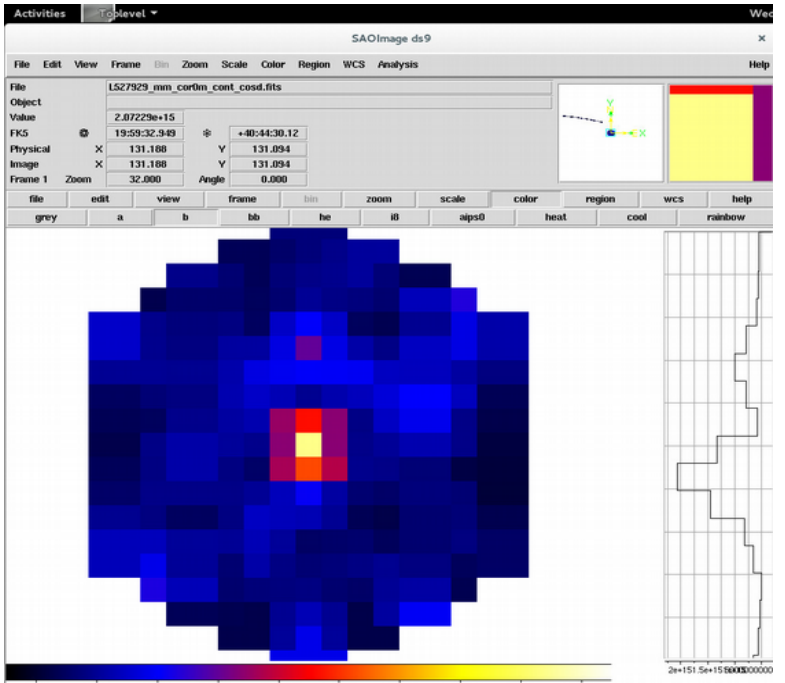
2) Station beam

→ few degrees (see LOFAR website)

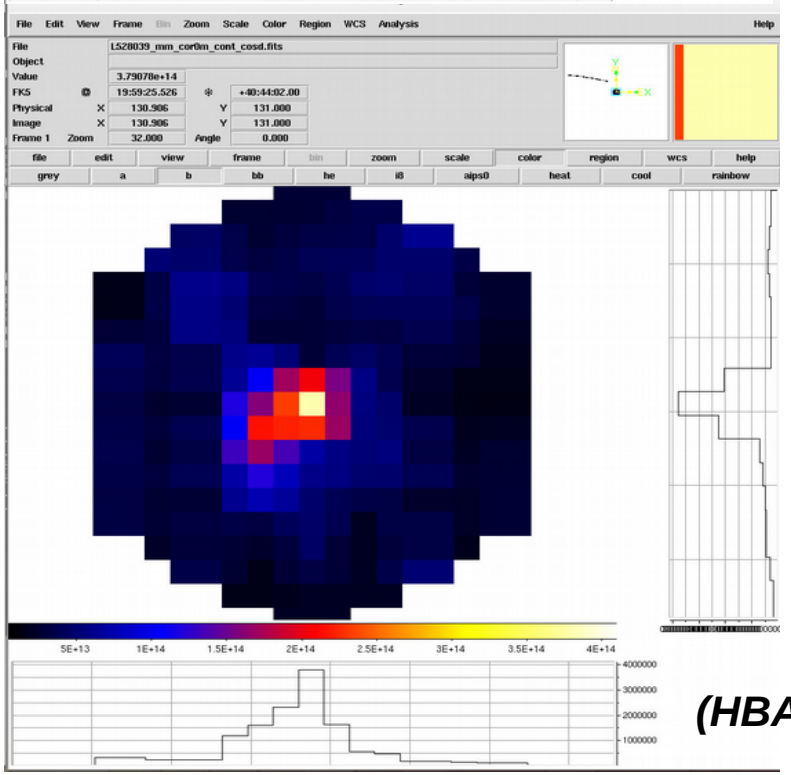
3) Tied-array (synthesized) beam (TAB)

→ depends on #stations included

* LBA – large sidelobe (delay issue?)
* HBA – asymmetric shape



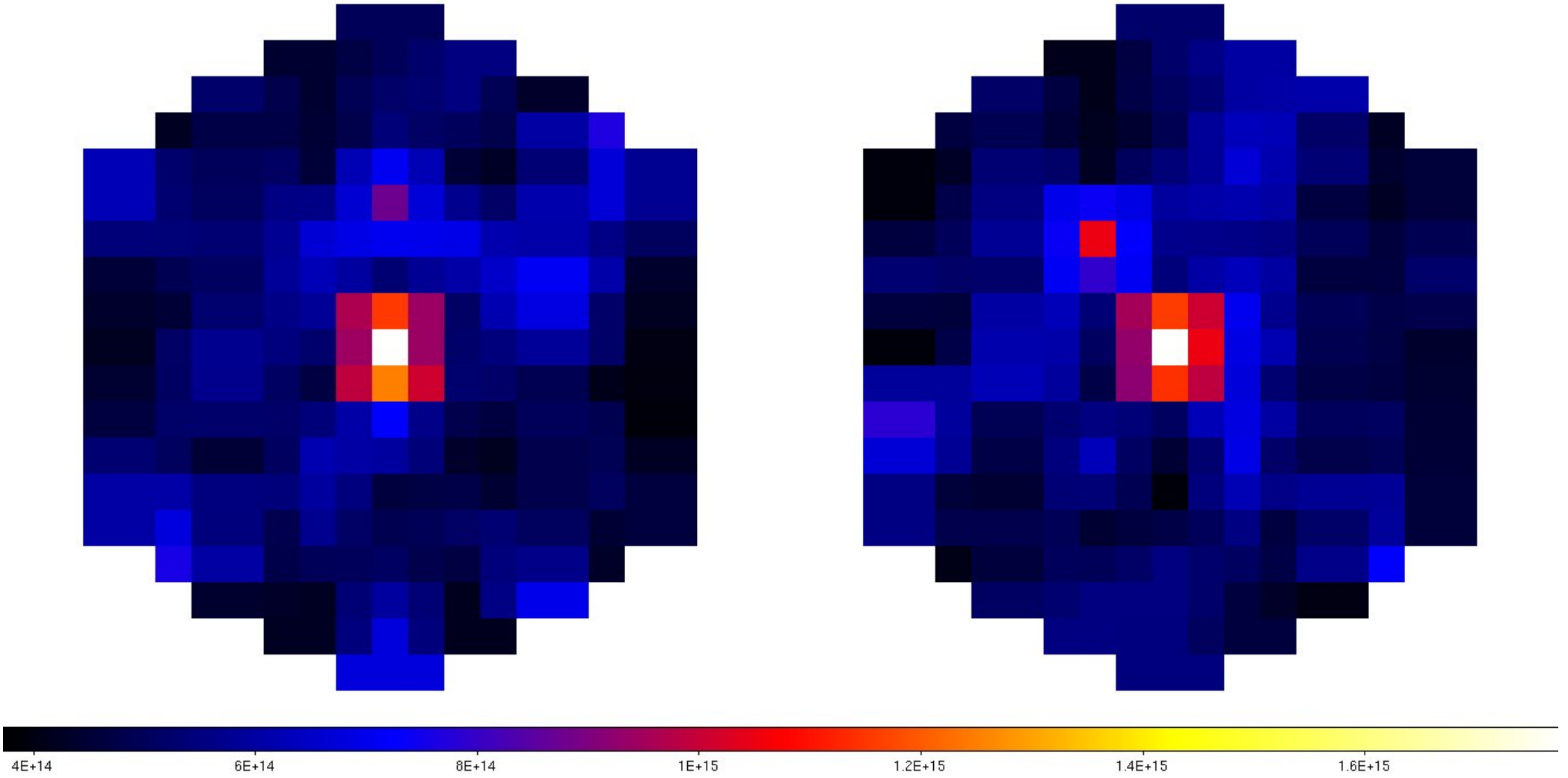
(LBA)



(HBA)

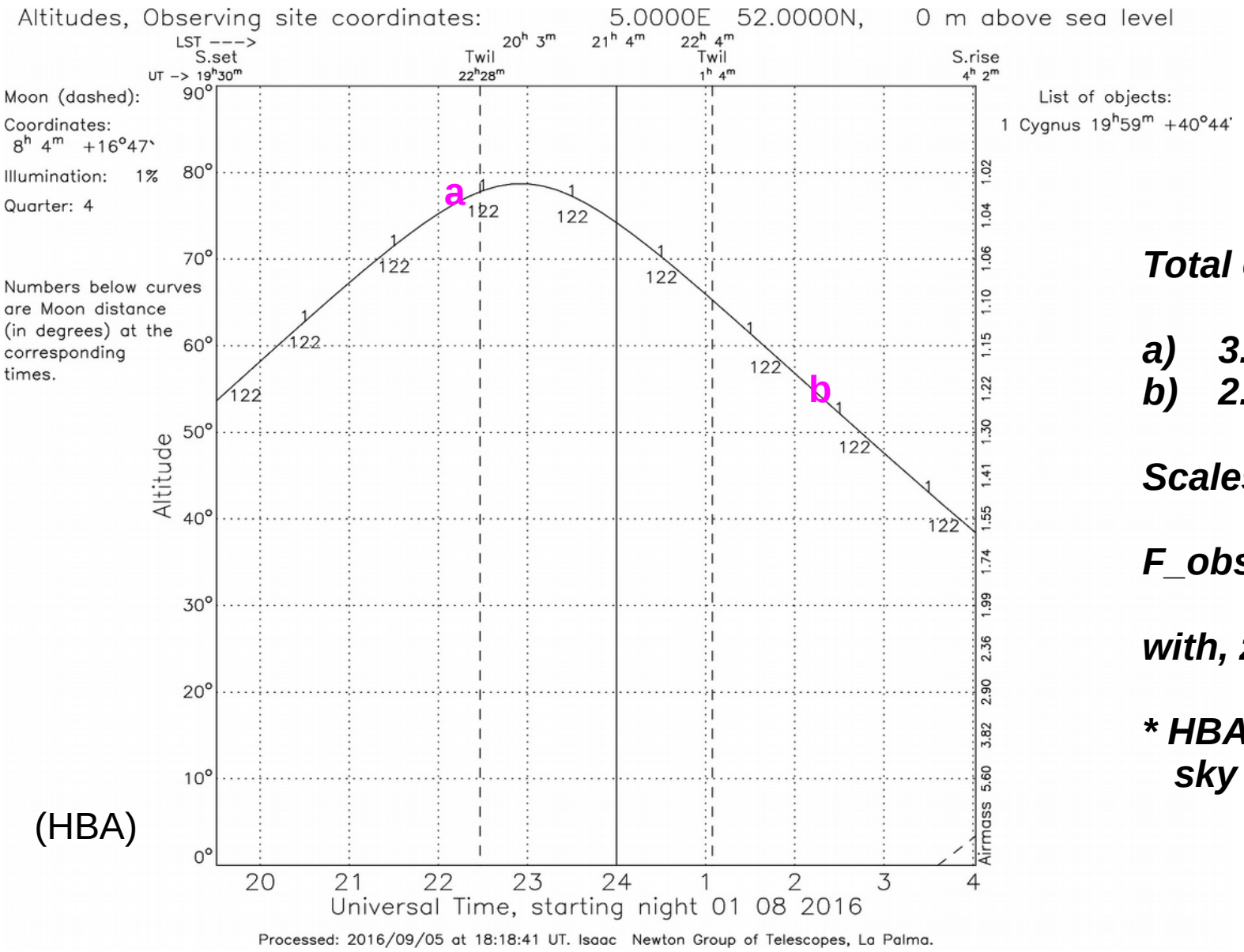
LC6_019: TAB beam rotation

(LBA: tracking Cyg A - sidelobes rotate)



LC6_019: Flux scales

Elevation dependent total flux (due to array projection, i.e. system gain)



(HBA)

Total observed flux

a) 3.8
b) 2.4

Scales roughly as:

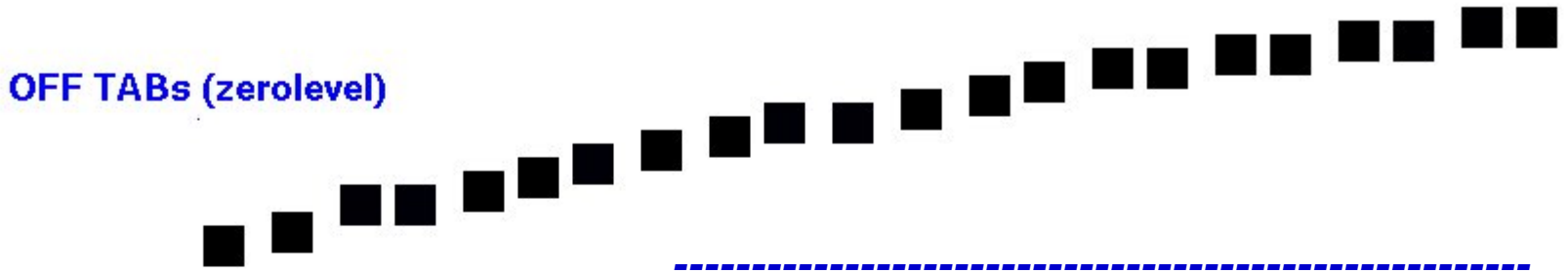
F_obsv = F_intr * cos(z)

with, z = zenith angle

**** HBA total signal is sky dominated***

LC6_019: Calibration

Calibration of TA data is similar to '<u>single dish</u>' calibration



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1. Calibrate system noise via OFF TAB

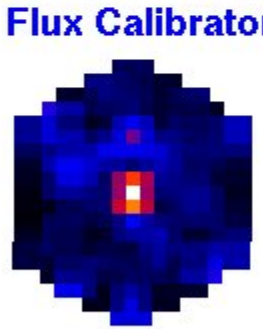
- System noise (mostly) <u>additive</u>

- True zero does not exist, at low Frequencies (use MW model)

2. Set flux scale via Cal (<u>multiplicative</u>)

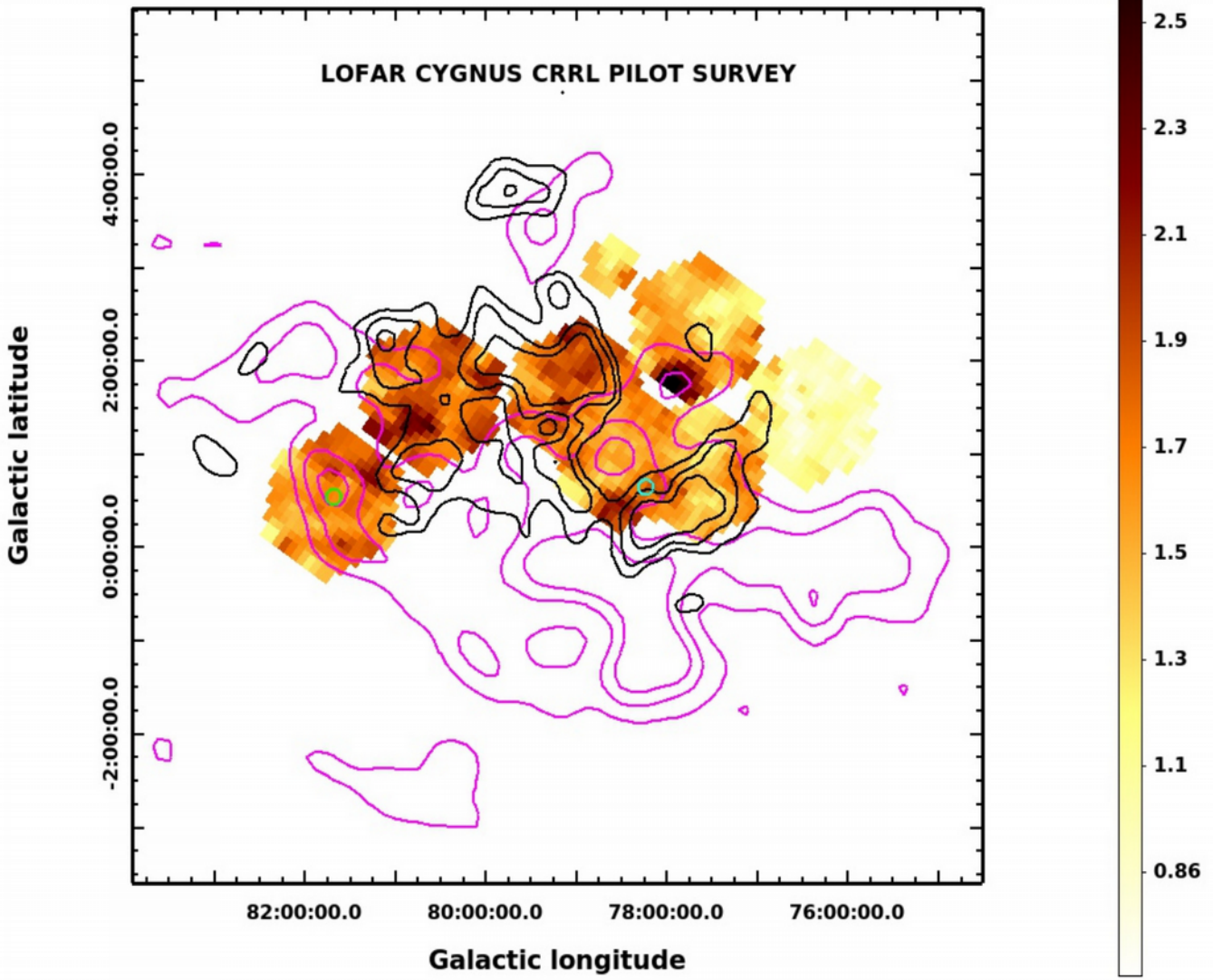
- Requires bright calibrators

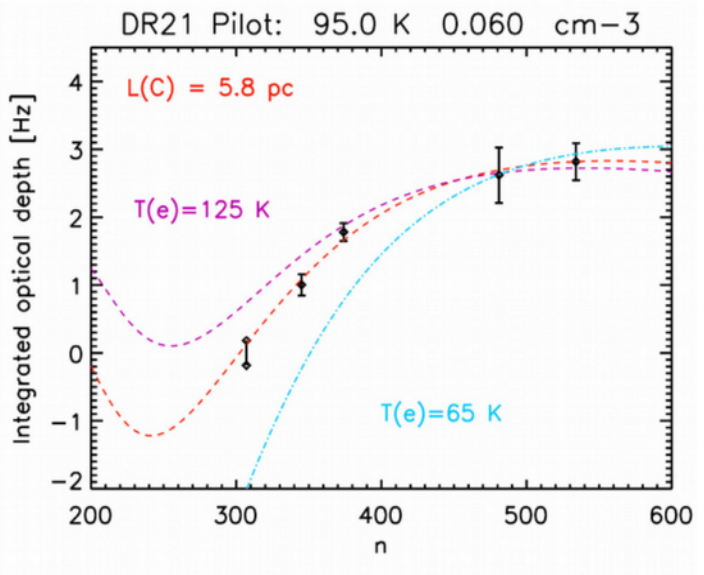
****[1,2] time dependent, or alternatively perform time normalization first.***

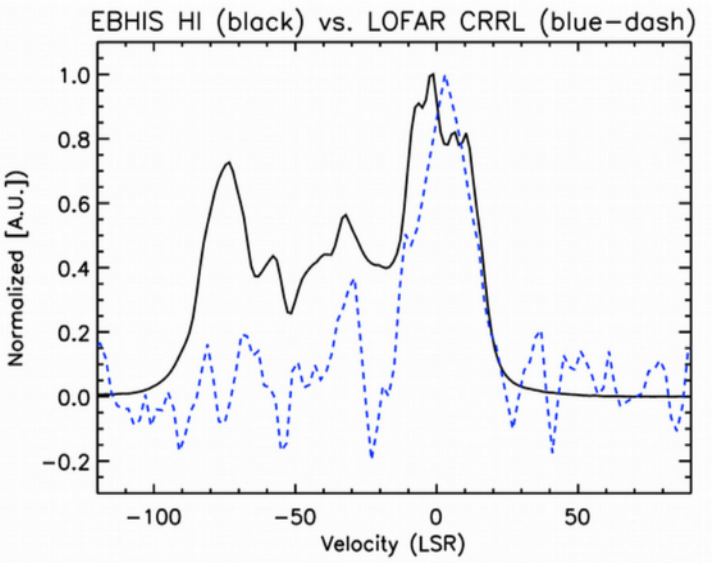


LC6_019: Result(s)

HBA Cygnus map (LBA map is similar)



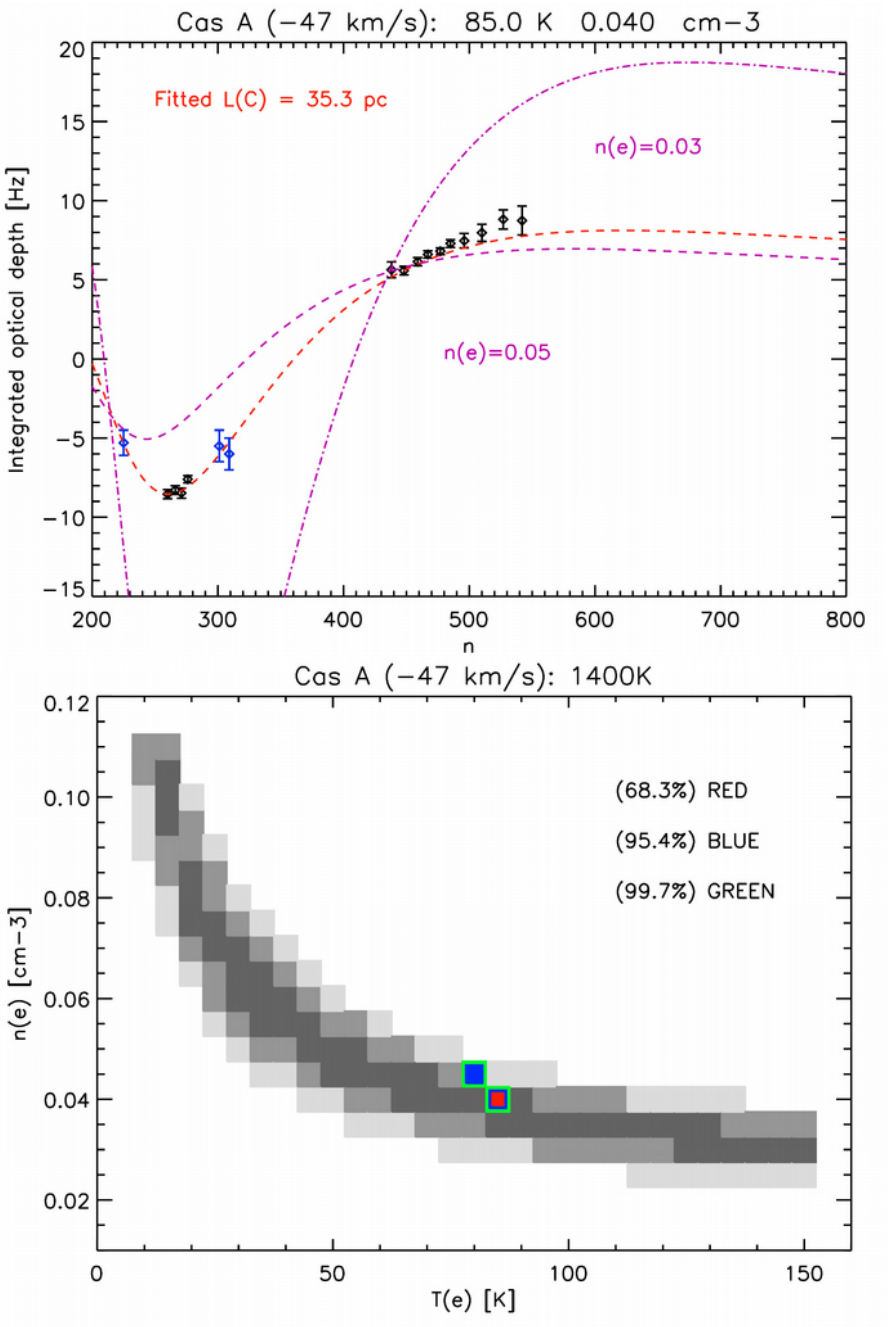




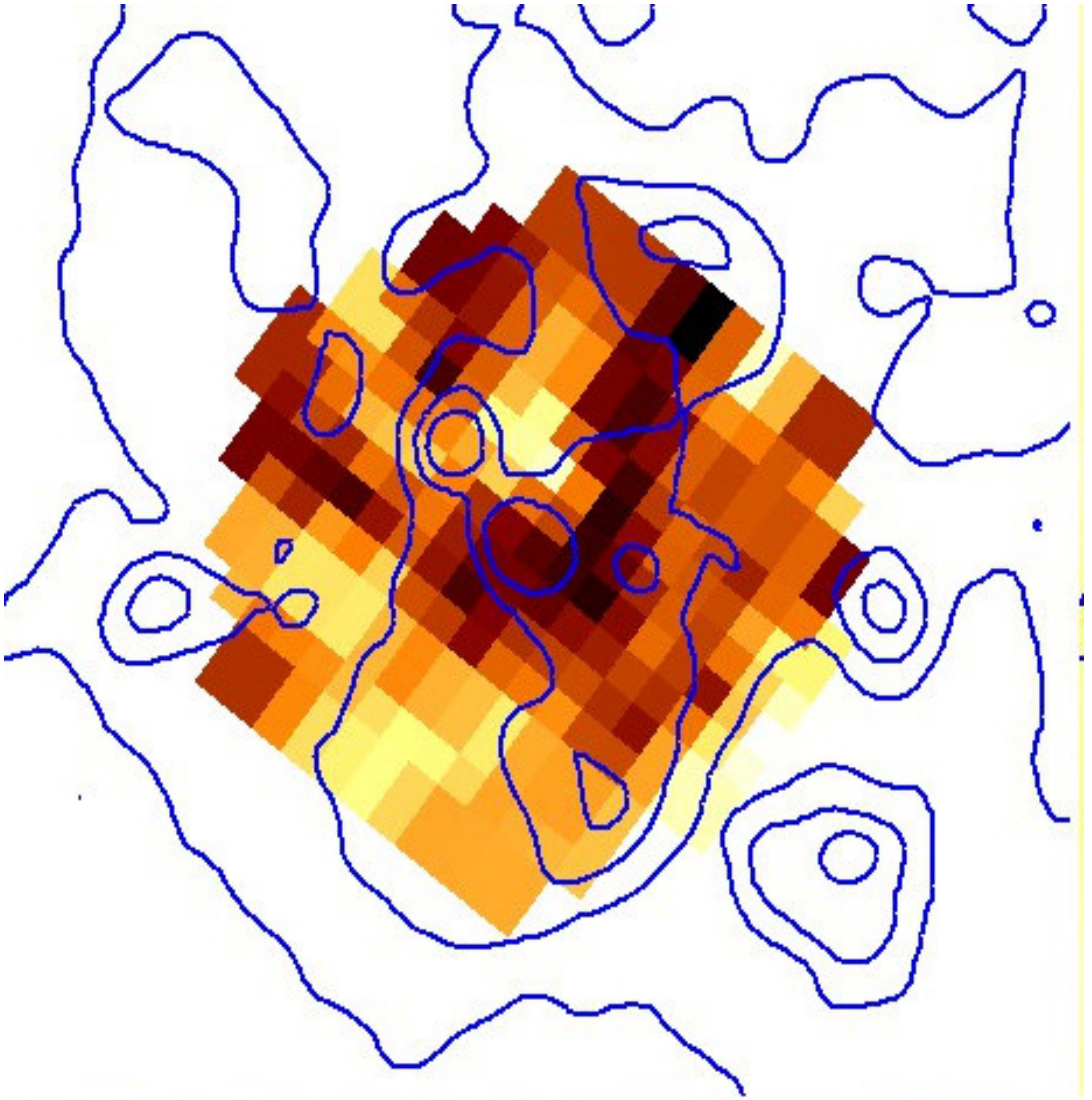
*** **Cycle 6 : CRRLs resolved on 10' scales (*LSM talk on 28/09/2016*) ***

Cycle 7 : 60 hrs (LBA,HBA,HGH) expand Cygnus and start Inner GP

LC6_019: Result(s)



Cassiopeia A (-47 km/s)

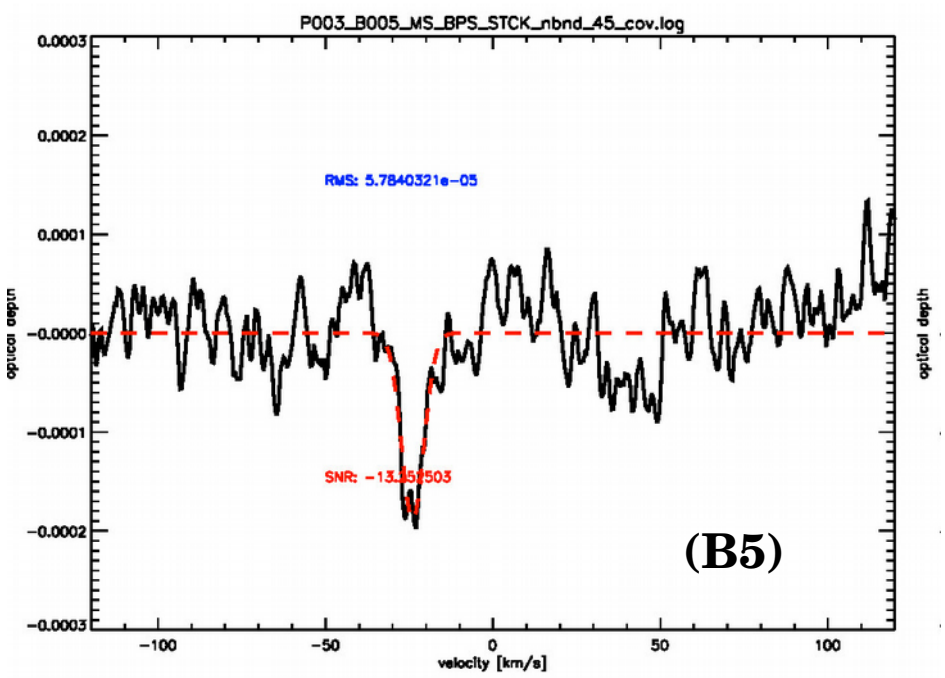


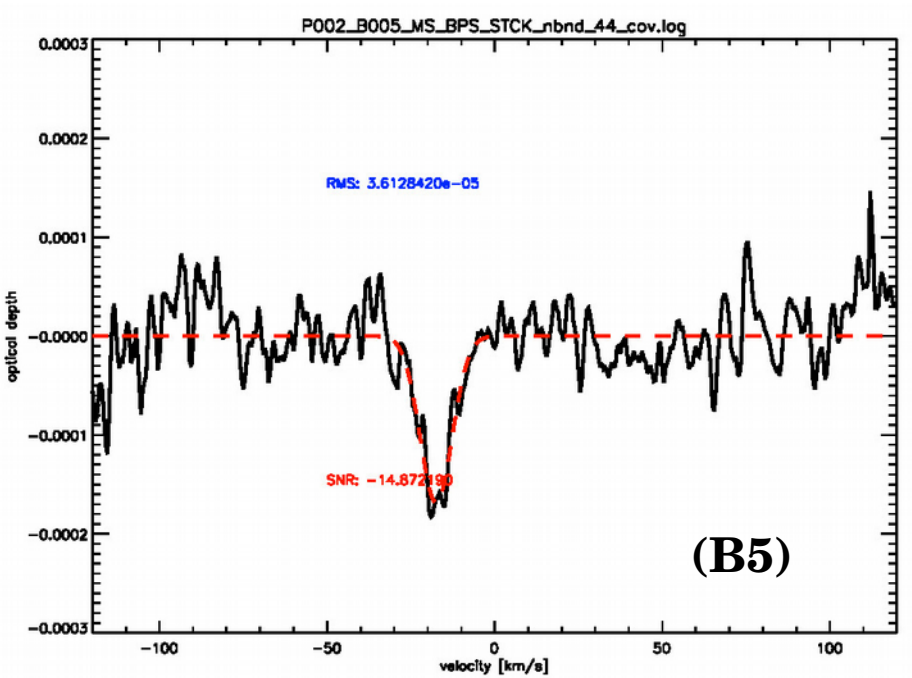
Cygnus LBA zoom on DR21 CRRL map

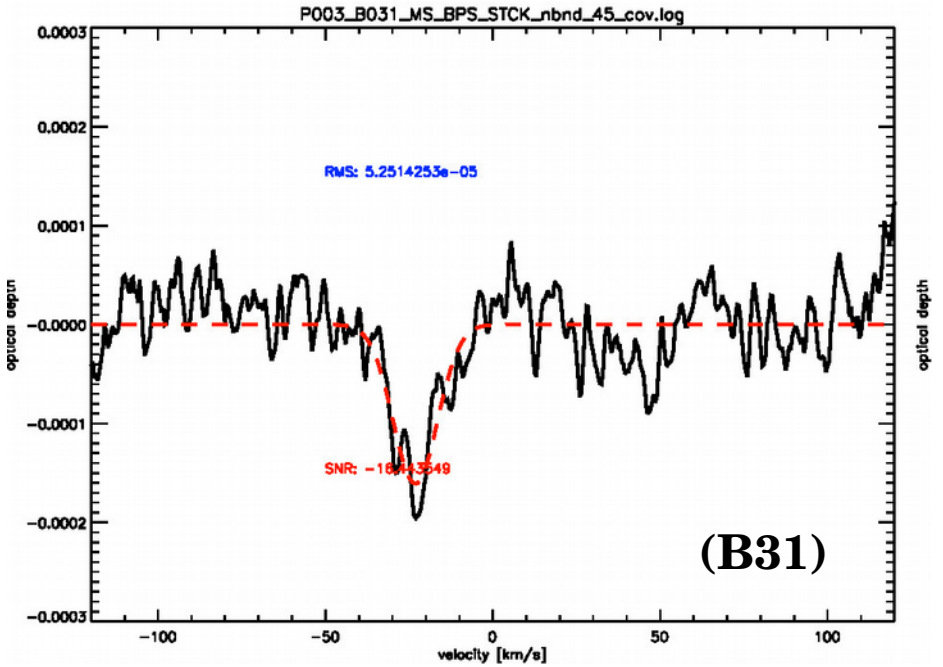
(with IRAS 100 um contours in blue)

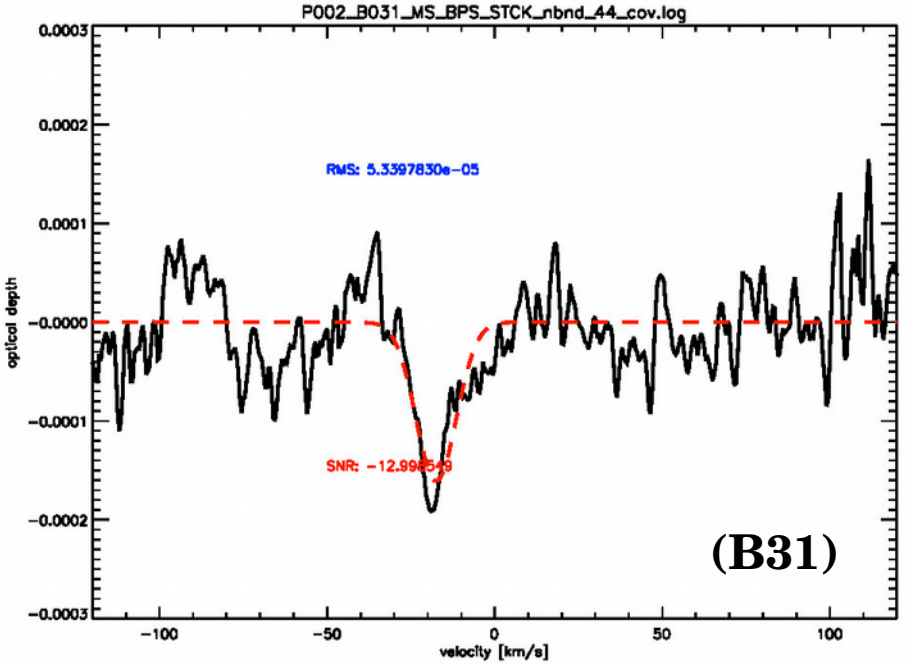
LC6_019: DR21 comparing two HBA-low runs

(consistent)

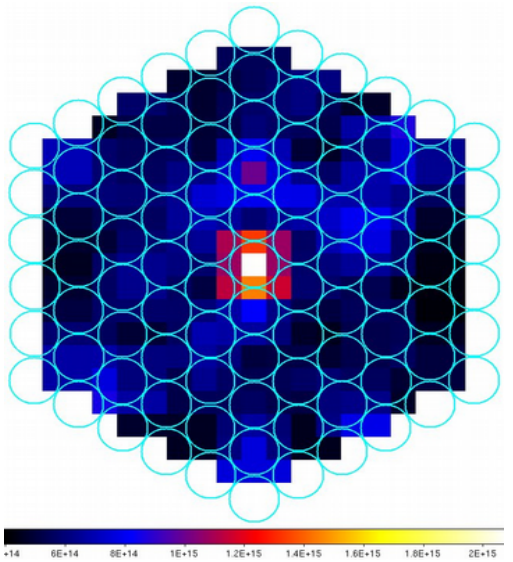








Conclusions:



1. Tied-Array mode for LOFAR,

- ***10' CRRL are detected!***
- ***GP CRRL survey can be done (ERC)***
- ***DR21 CRRL gas is dense (HISA)***
- ***CRRL: CO , CO-dark , HI ? (Cycle 7)***

2. Absolute flux calibration of TA data is possible,

- ***high-cadence (or simultaneous) flux and off obsv.***
- ***apriori MW model and/or multiple calibrators***

3. Some issues remain in the current data,

- ***residual PPF waves in the bandpass***
- ***time dependent, frequency gradients***

=> if solved could gain a factor 4 in time !

LOFAR