Lessons from Coma Cluster observations

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LOFAR survey commisioners:

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& the LOFAR Collaboration

Clusters PI: Marcus Brueggen, Gianfranco Brunetti

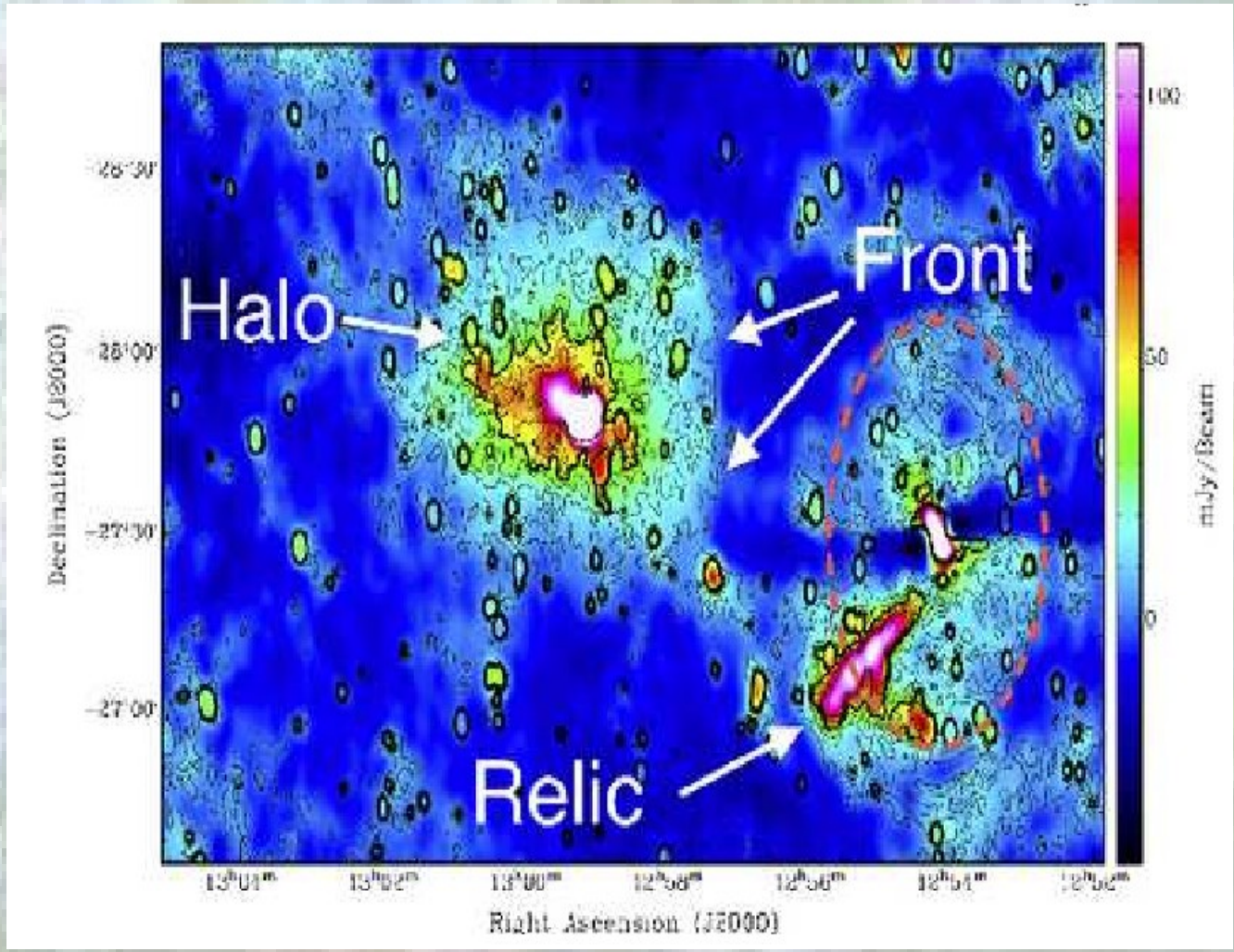
The Coma cluster

The first discovered radio halo

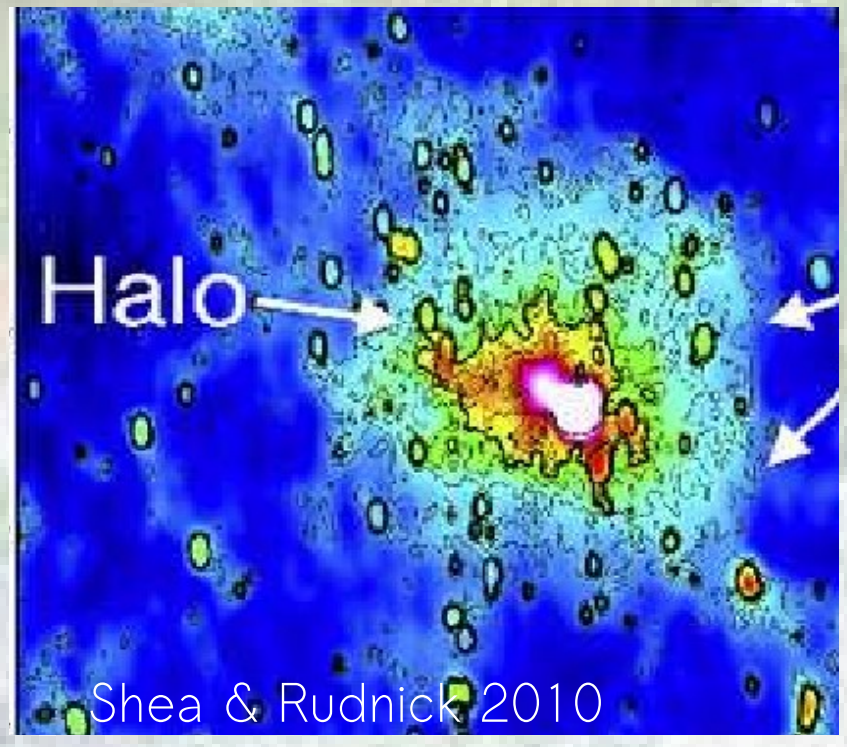
Willson 1971: 30' - 40' halo at 408 MHz

The most recent Image
Shea & Rudnick 2010

Westerbork 325 MHz



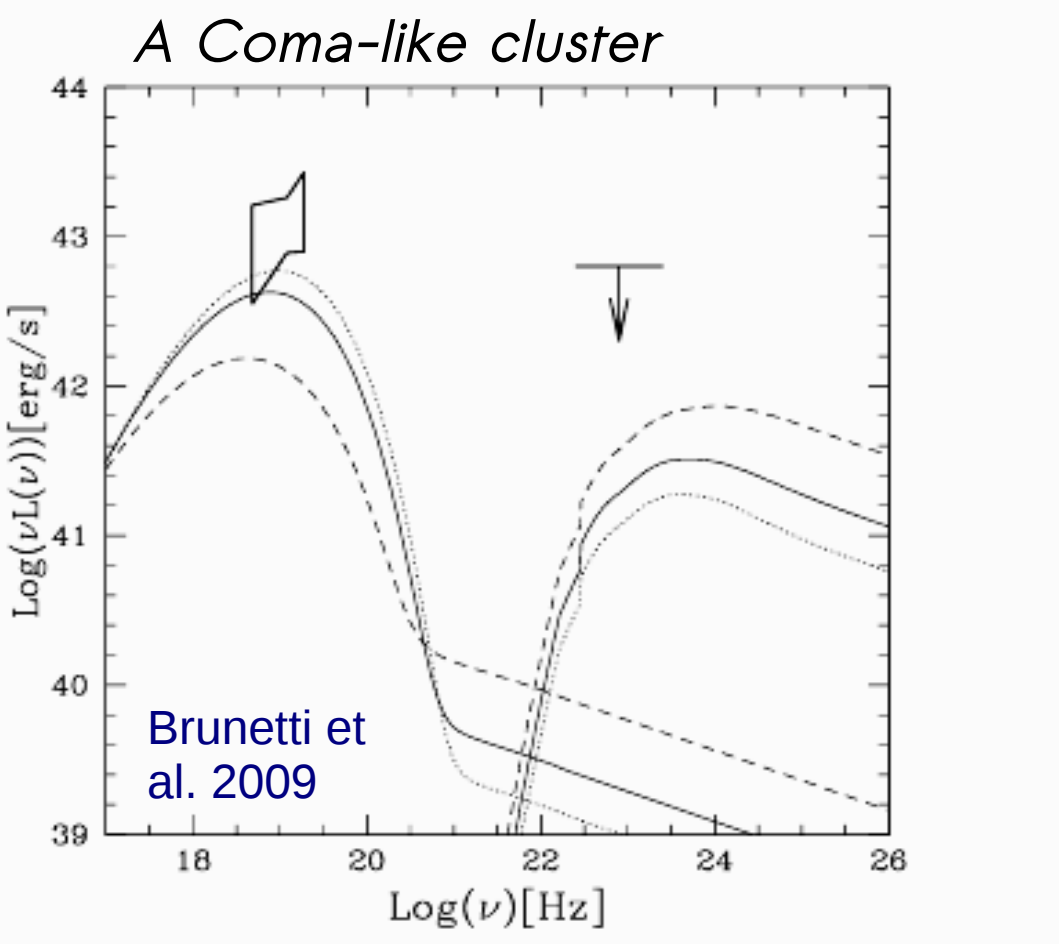
Origin of the radio halo?



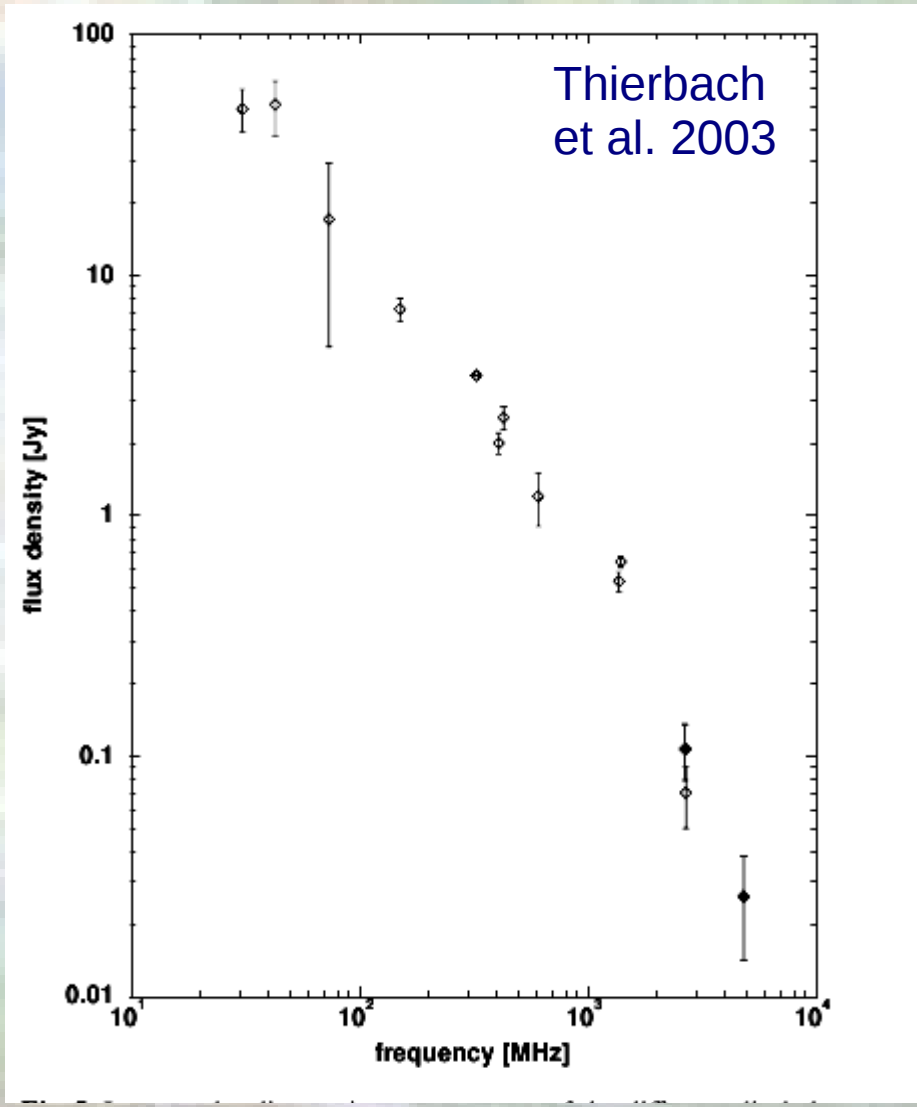
Models	process	Particle spectrum
Re-acceleration models (e.g. Brunetti et al. 2001 Petrosian 2001)	⟷ **Fermi II** mechanism Unefficient process	⟷ Curved spectral index
Hadronic models (e.g.Dennison 1980 Keshet 2010)	⟷ **Fermi I** mechanism	⟷ straight spectral index

Importance of low frequency observations

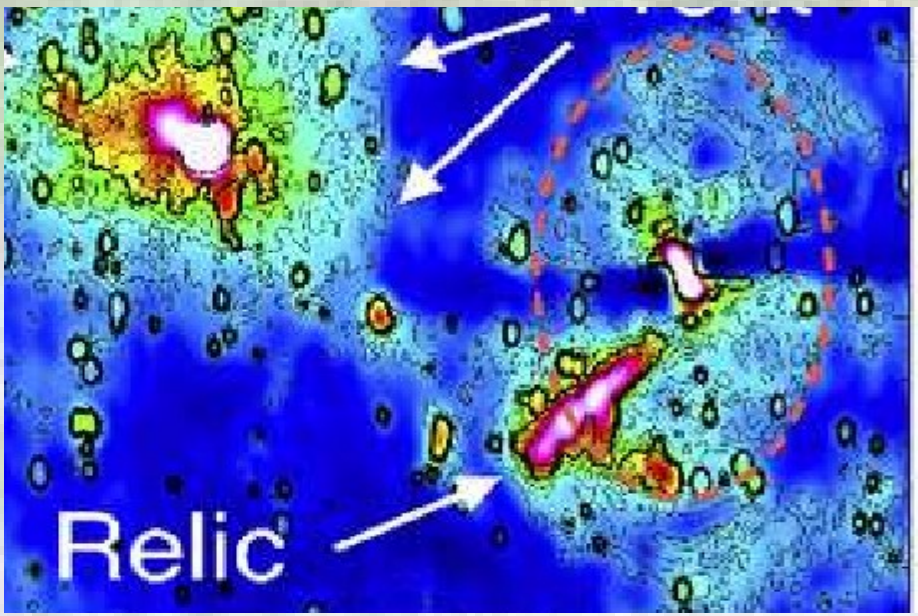
Model prediction



Observations so far...



Origin of the radio relic?



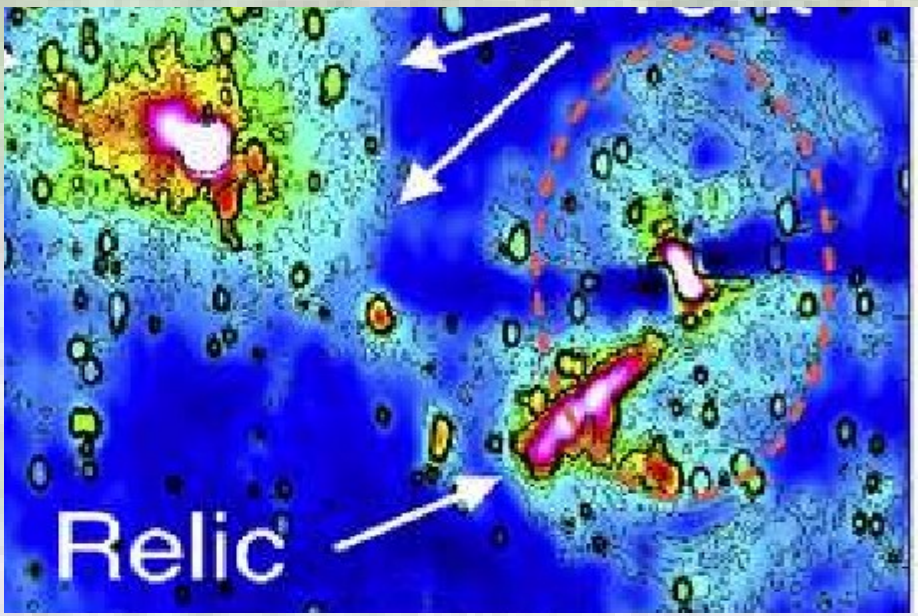
Shock acceleration (DSA)
(e.g. Ensslin et al. 1998; Roettiger et al. 1999; Hoeft & Brüggen 2007)

⇨

Spectral steepening across the relic main axis

Magnetic field aligned with the shock front -> polarized emission

Origin of the radio relic?



Shock acceleration (DSA)
(e.g. Ensslin et al. 1998; Roettiger et al. 1999; Hoeft & Brüggen 2007)

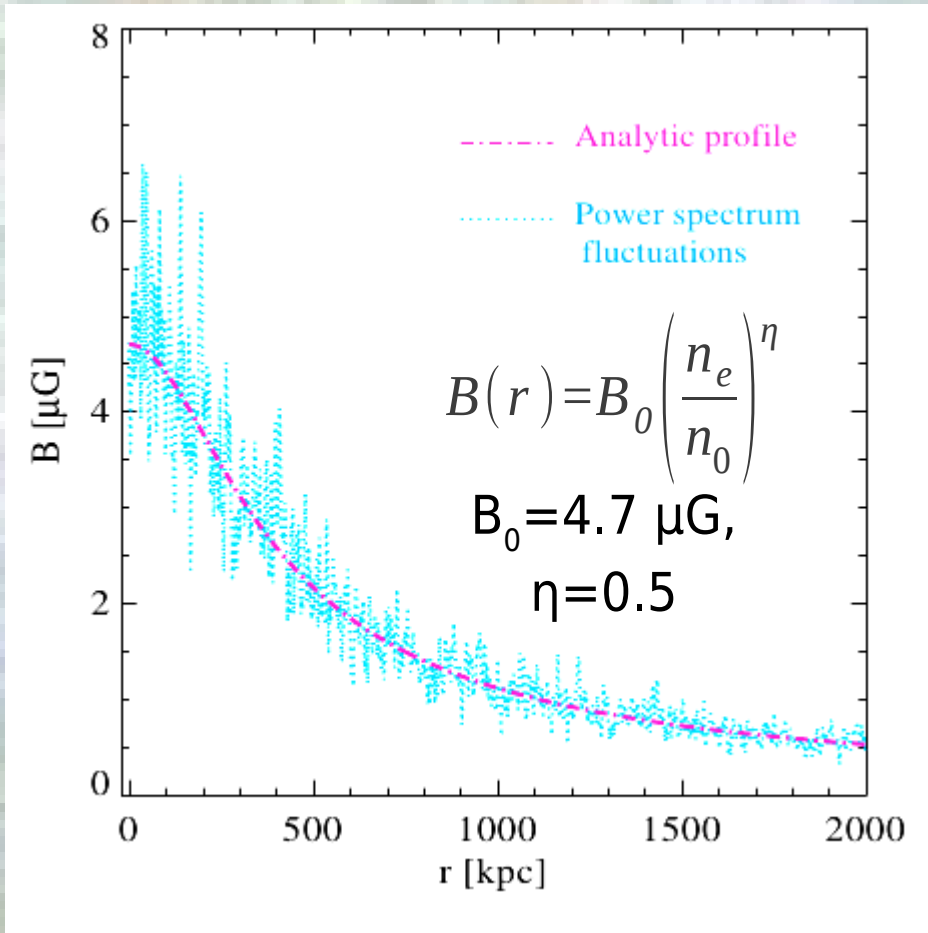
BUT

No shock detected in X-rays
(Feretti & Neumann 2006)

Halos/relics → Synchrotron emission

Magnetic field + particle (electrons) spectrum

Coma cluster:
Rotation Measure of 7 sources in the Coma field → constraints on the magnetic field profile



Bonafede et al. 2010

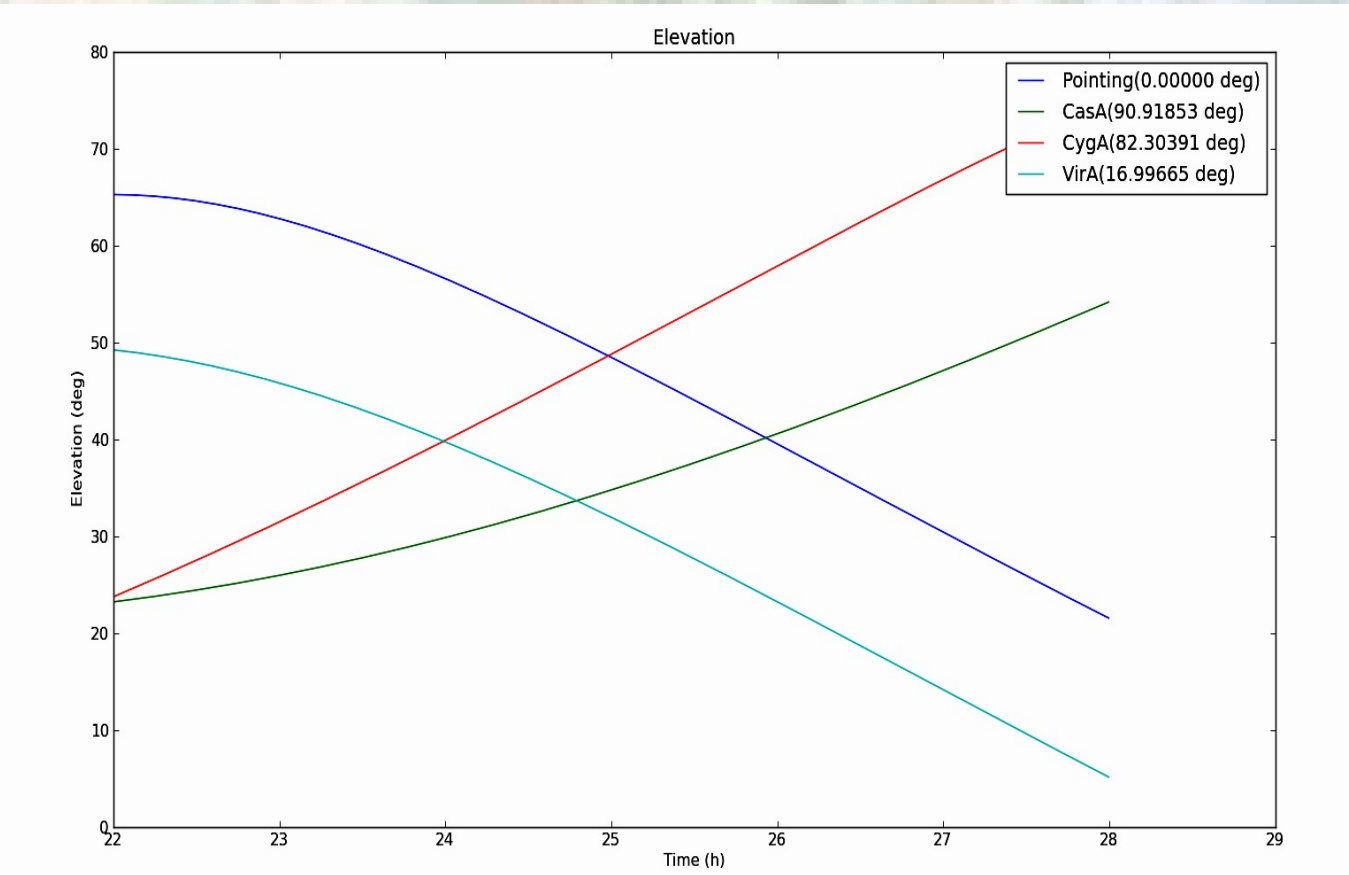
LOFAR Observations: LBA

LBA Observations: 1 May 2011

Time: 6 hours

17 Core stations + 7 Remote stations (+ 3 International stations not used)

→ 24 “antennas”

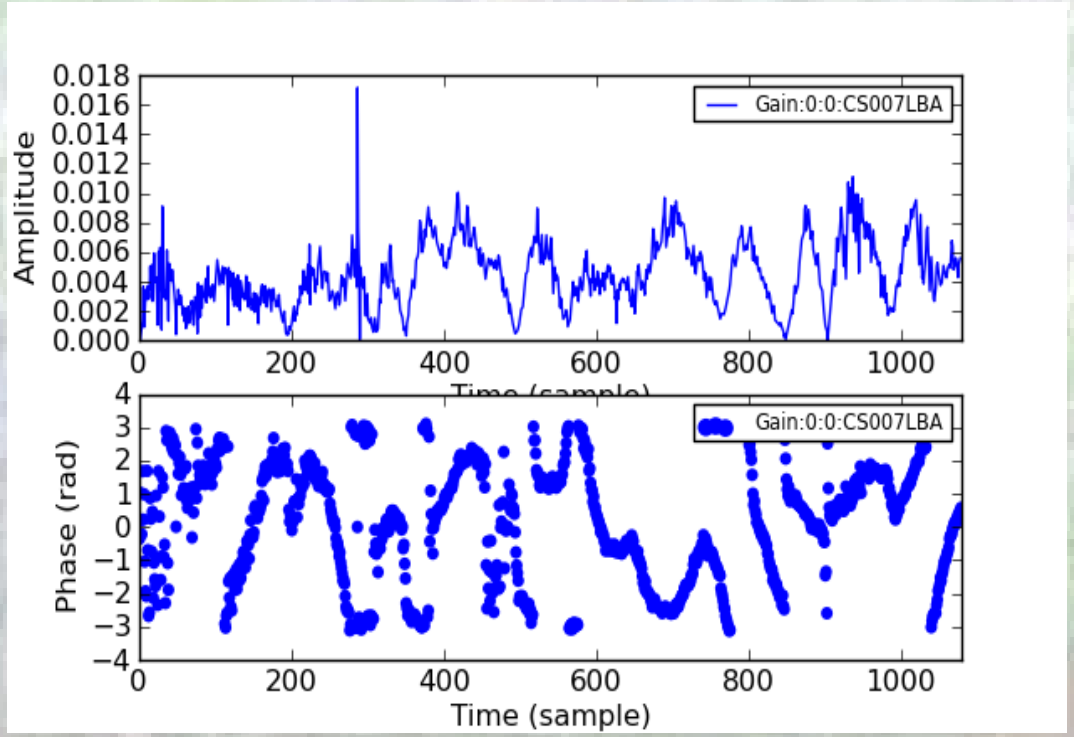


LOFAR Observations: LBA

Applying the tecnique found for other LBA observations:
- demixing of A team CasA, CygA, VirA

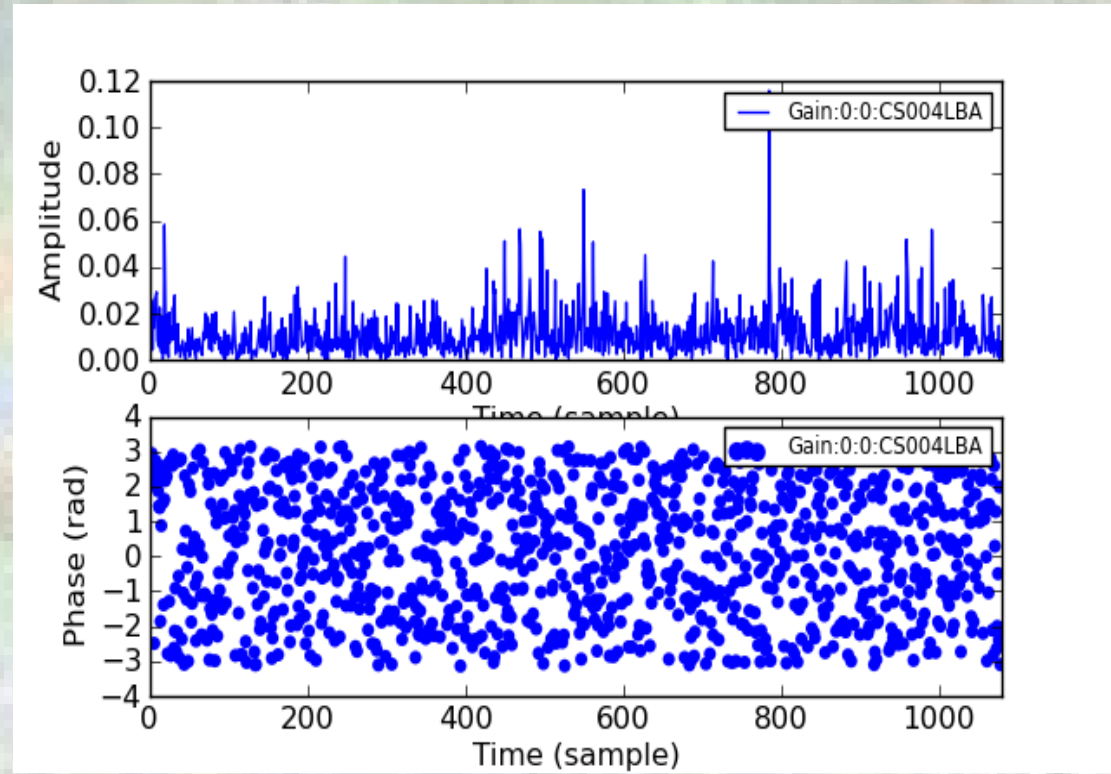
"demixing" by Bas vd Tol:
phase-shifting in the direction of the off-axis sources (A team),
calibration
subtraction them from the V of the target field

*Needs **high fringe rating** from the demixed source*
source distant from the phase center



Gain Solutions for
Cygnus A

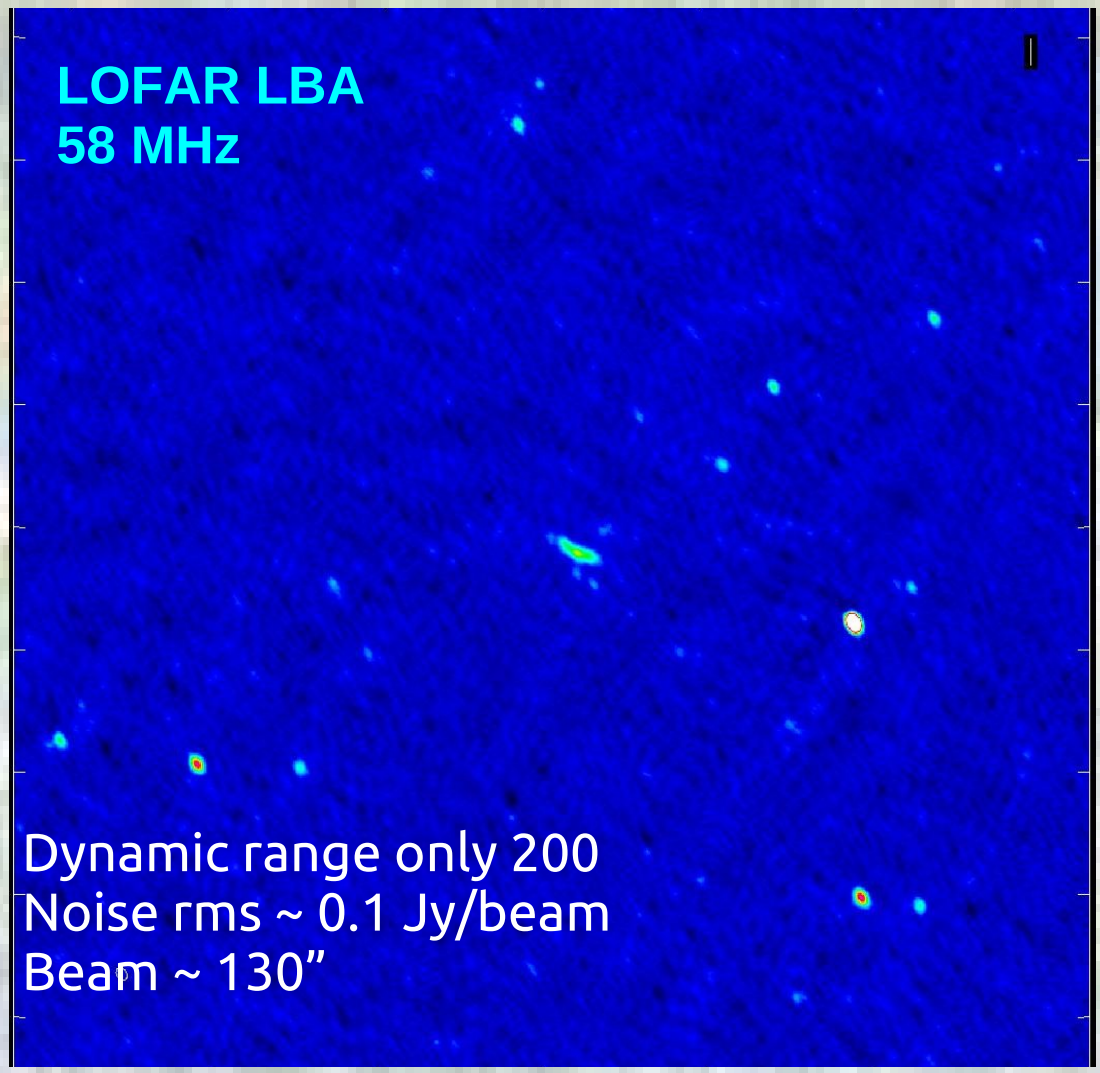
LOFAR Observations: LBA



Gain Solutions for Virgo A

Virgo A is **too close** to the phase center (16 degrees) for the demixing to properly work

LOFAR Observations: LBA



Virgo A at 16° from the phase center

+

No *strong* source

⇩

Calibration solutions have low signal-to-noise

+

VirA in the V function

⇩

The weak emission from halo/relic is not detected

LOFAR Observations: LBA

Important feedbacks for commissioning and MS^3 preparation

1) Demixing works well when source is
at d>25° from the phase center @ 58MHz

Other strategies need to be thought for sources closer to A-team

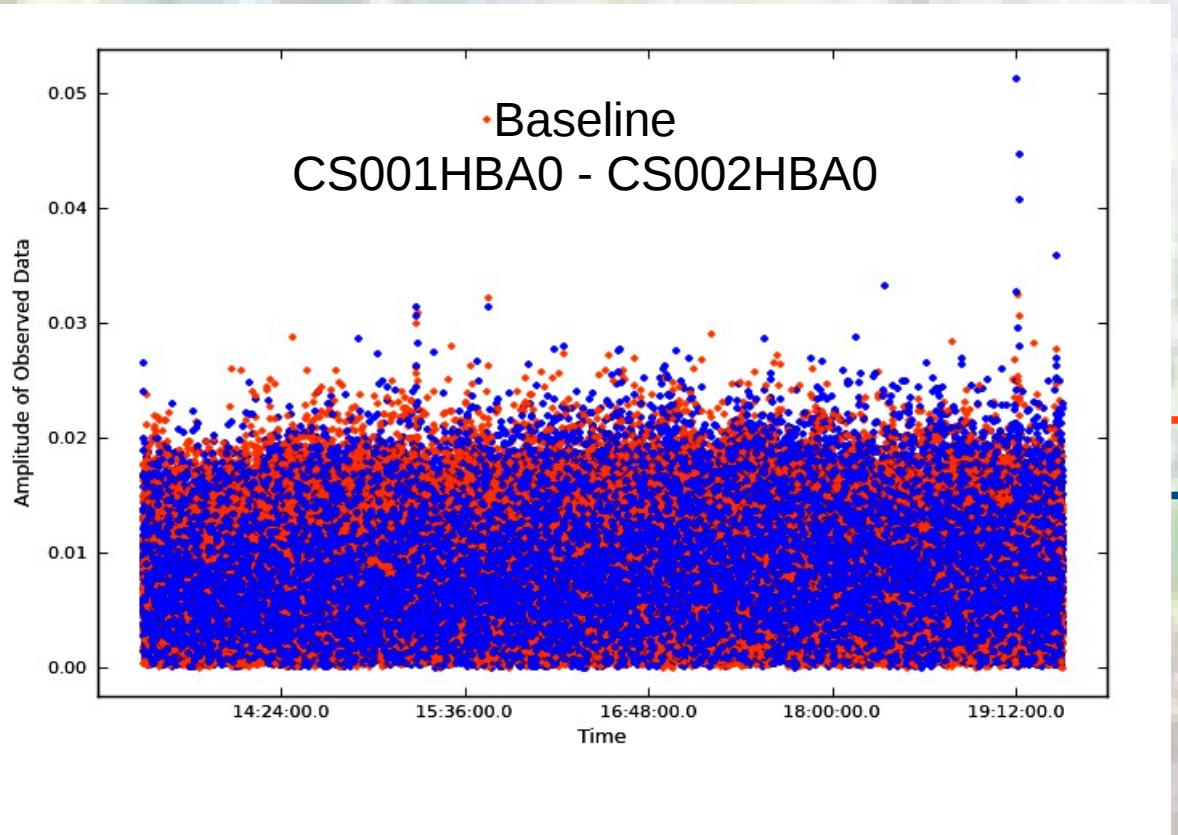
2) Calibration of field with no *bright* source present

- increase the flux in the model to achieve good S/N in the solutions
- transfer solution from a nearby calibrator
- ...

LOFAR Observations: HBA

HBA Observations: 22 July 2011
Time: 6 hours
17 Core stations + 8 Remote stations
→ 42 "antennas" (HBA Core Stations splitted in HBA0 and HBA1)

Data processed through the pipeline for flagging: NDPPP
Frequency averaging: 16 channels 12.5 kHz



Data quality good!

Correlation XX
Correlation YY

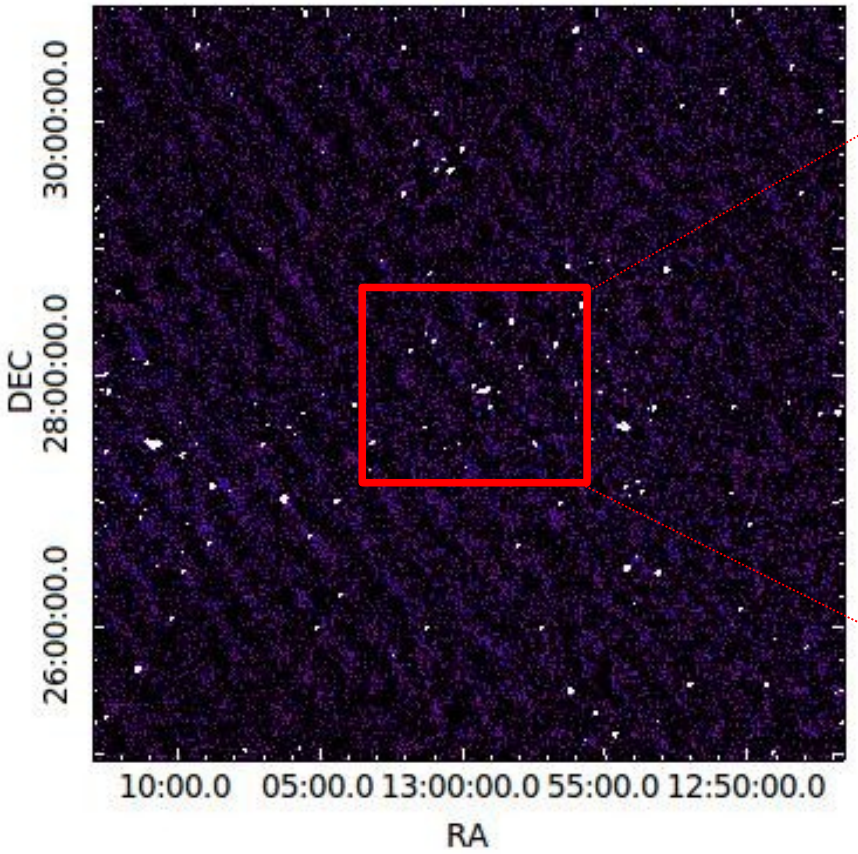
LOFAR Observations: HBA

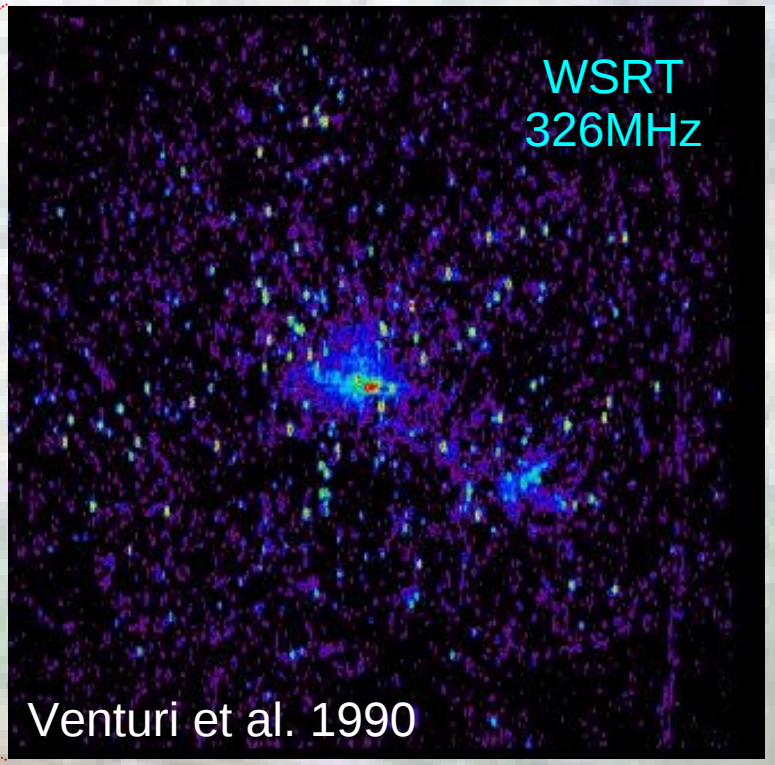
Calibration

Models:

1) VLA Low Frequency Sky Survey VLSS 74 MHz 80" resolution
   - → model from a large field
   - → resolution - model good only for Core Stations
   - → survey - rms noise 100mJy/beam

VLSS 6deg x 6deg Halo/relic not visible





LOFAR Observations: HBA

Calibration

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1) **VLA Low Frequency Sky Survey VLSS 74 MHz 80" resolution**
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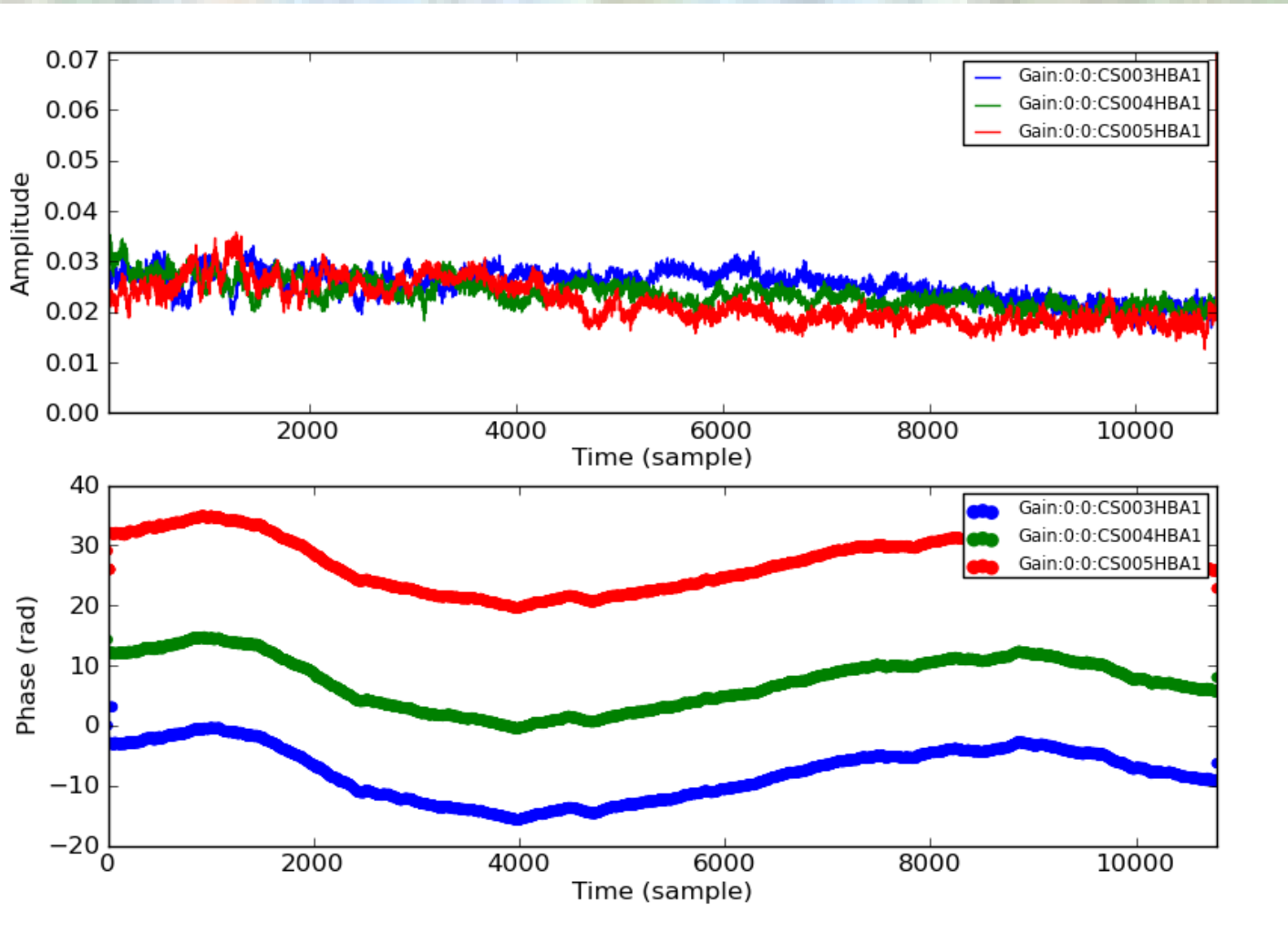
2) **WSRT Image 150 MHz** 2' x 5' resolution *courtesy of Roberto from Pizzo et al. (in prep)*
   - → close in frequency
   - → sensitivity adequate to detectd halo and relic
   - → resolution - model good only for the core stations
   - → small image compared to LOFAR HBA field of view

LOFAR Observations: HBA

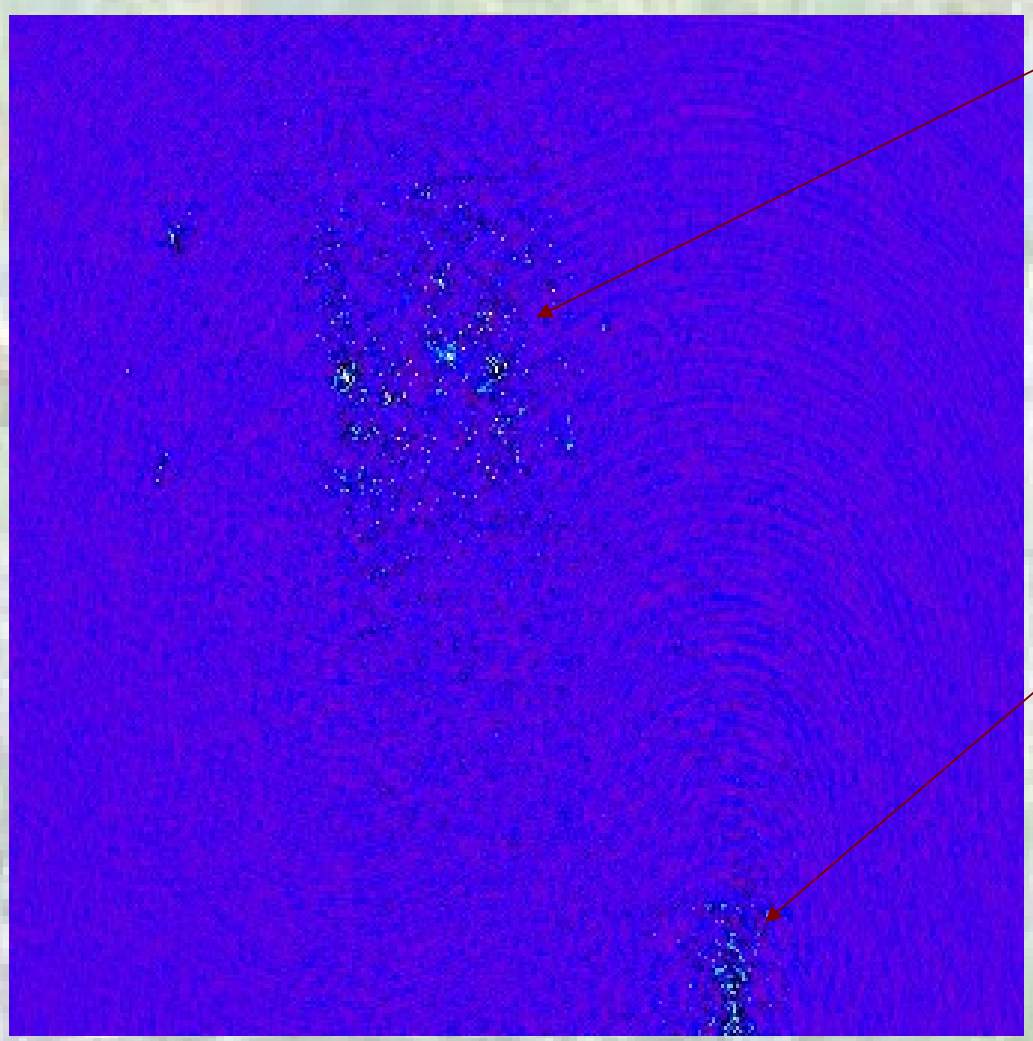
- Global solver 4 Sub bands
- Directional gain enabled

Gain solutions in direction of the central source for 3 Core Stations



LOFAR Observations: HBA

LOFAR HBA
116 MHz

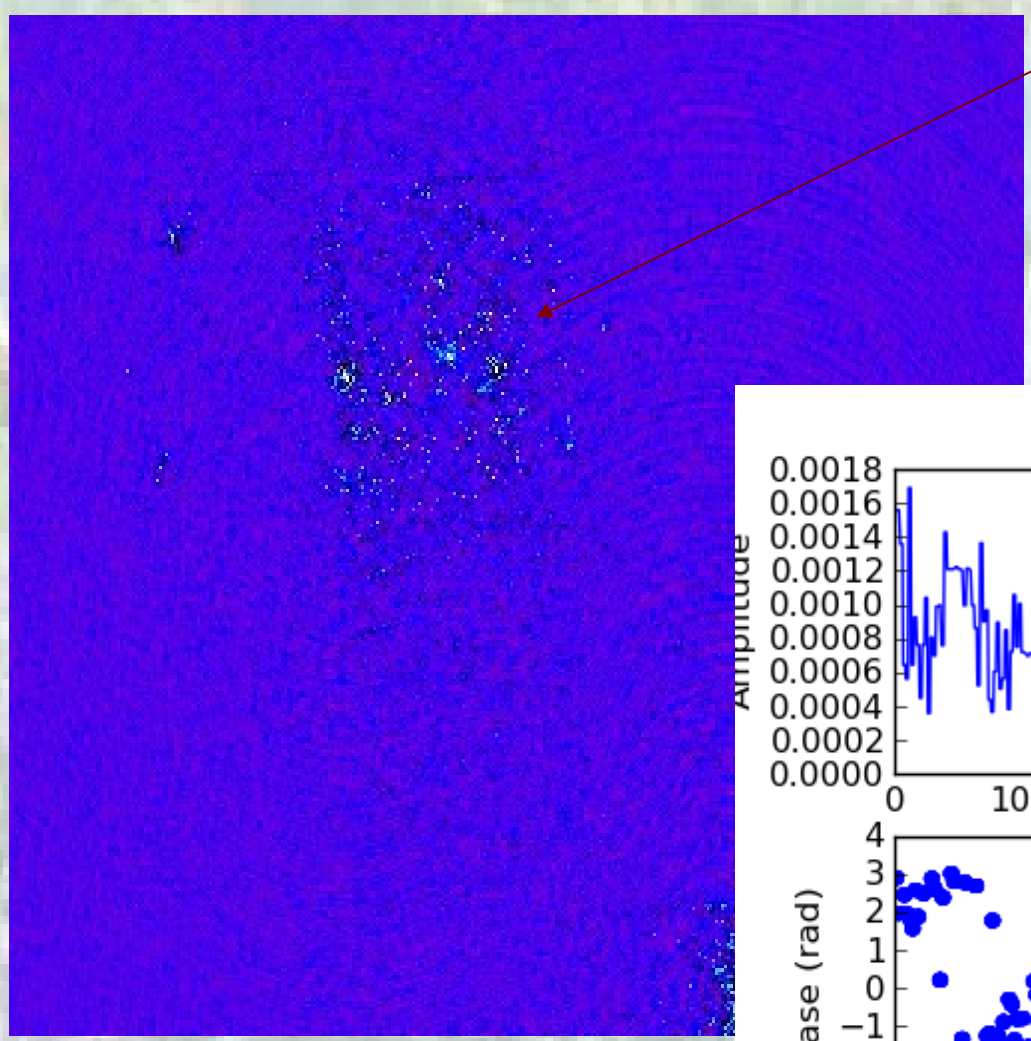


Coma
field

Virgo A

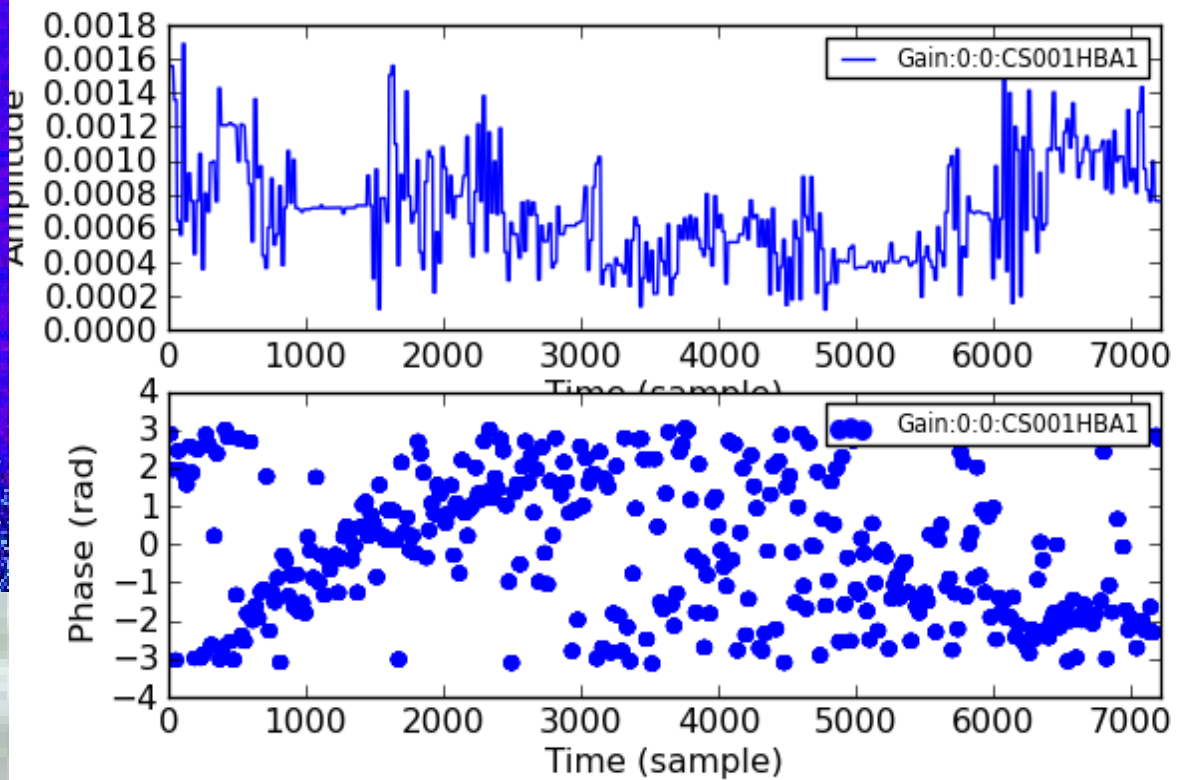
LOFAR Observations: HBA

LOFAR HBA
116 MHz

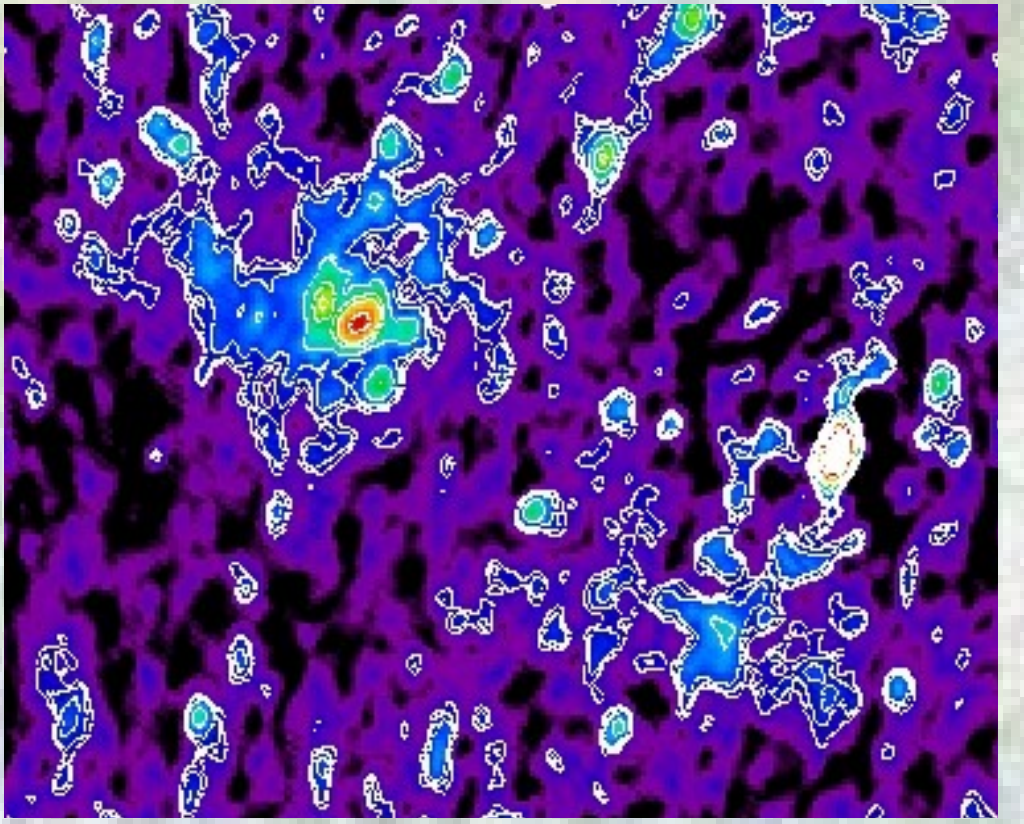


Coma
field

Virgo A
Demixing solution

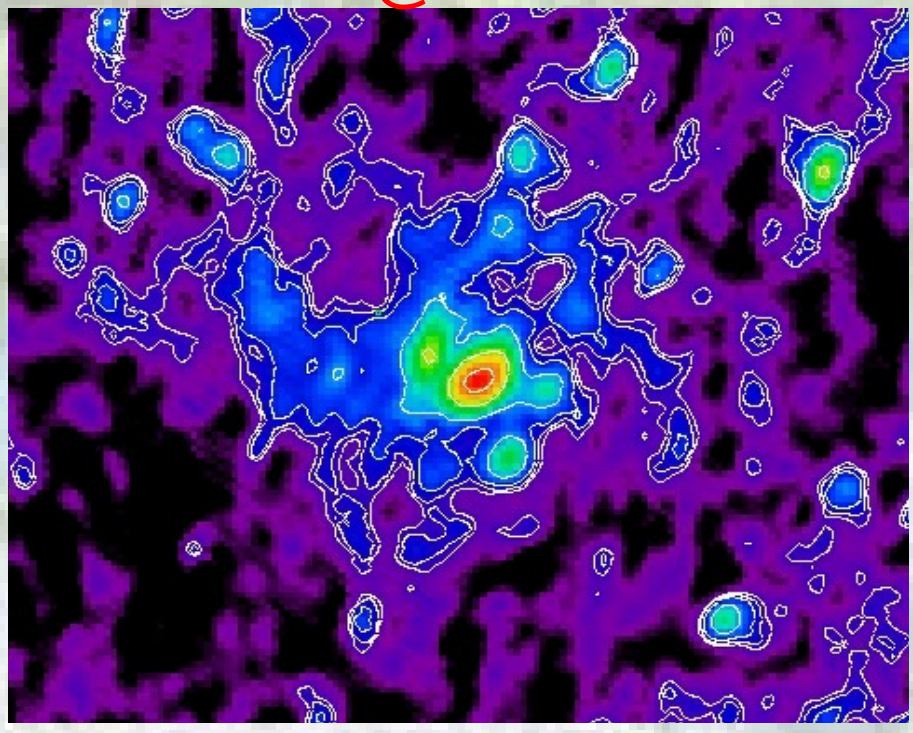


130 MHz
Beam ~ 190″ x 159″
Dynamic range ~ 500

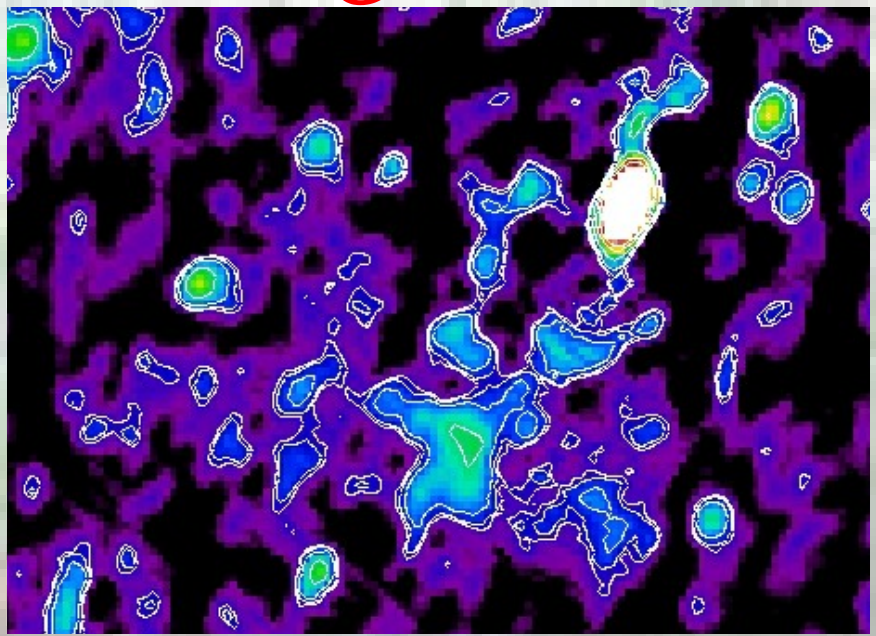


1st contour at 2sigma level

HALO @ 130 MHz



RELIC @ 130 MHz

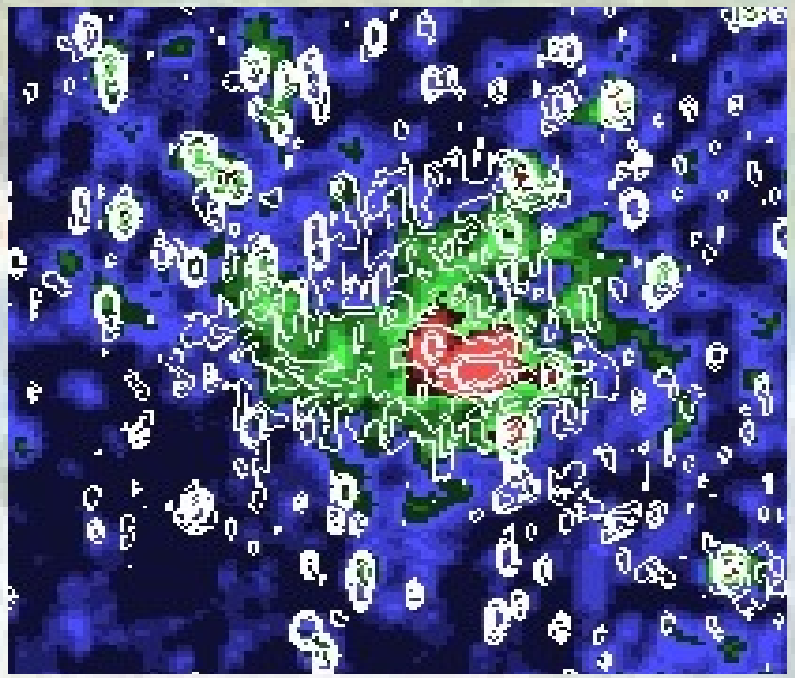


130 MHz
Beam ~ 190" x 159"
Dynamic range ~ 500

Contours from
WSRT 326 MHz
(Venturi et al. 1990)

Color: LOFAR
HBA
--- 2 sigma level

HALO @ 130 MHz



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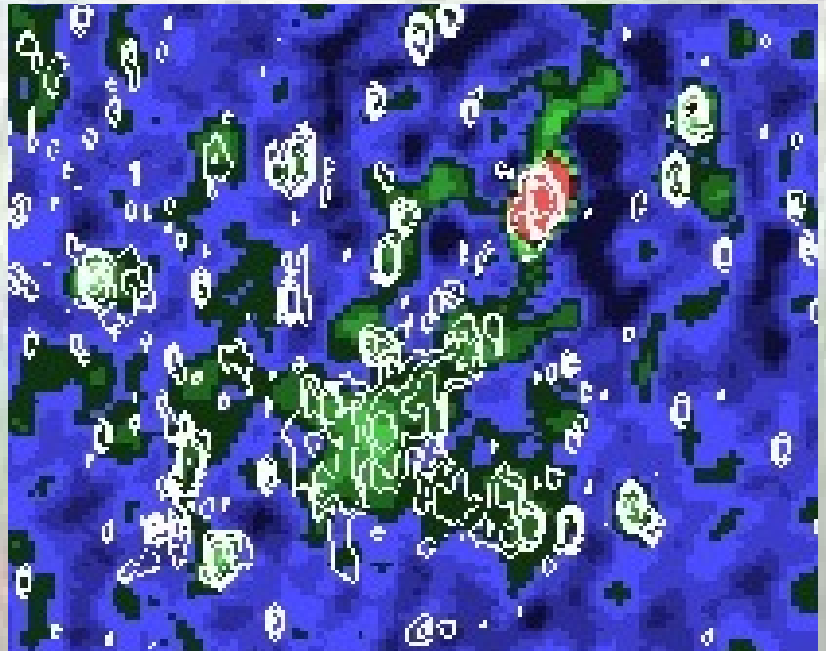

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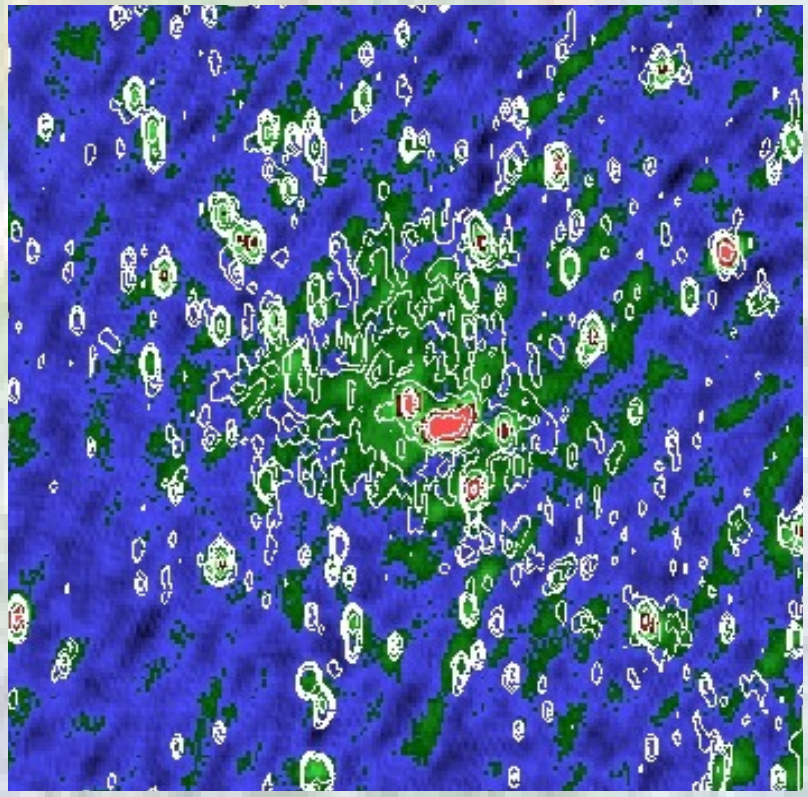
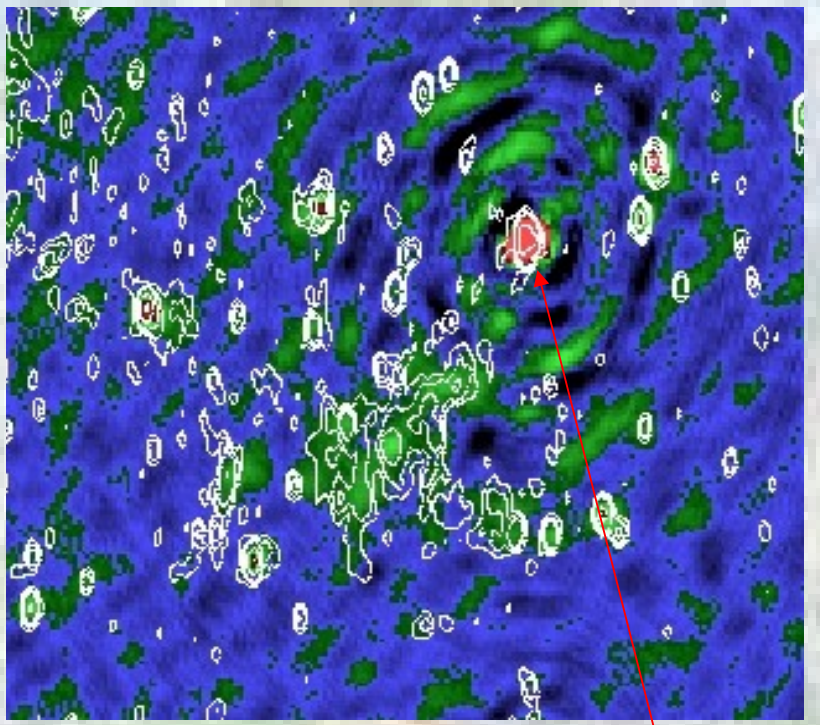


RELIC @ 116 MHz



Contours from
WSRT 326 Mhz
(Venturi et al. 1990)

Coma A
Deconvolution artifacts

Summary

complicate field to calibrate and image, as many other fields will be
→ *important feedbacks for commissioning and MS3 preparation*

LBA: more stations will provide more robust solutions
Other software implementation are required to increase the S/N of the solutions
How to deal with A team sources close to the phase center?

HBA: mainly limited by deconvolution problems + VirA
The new Imager (see Cyril talk) will be able to deal with directional dipendent gains