

The Coma cluster at LOFAR frequencies

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Outline

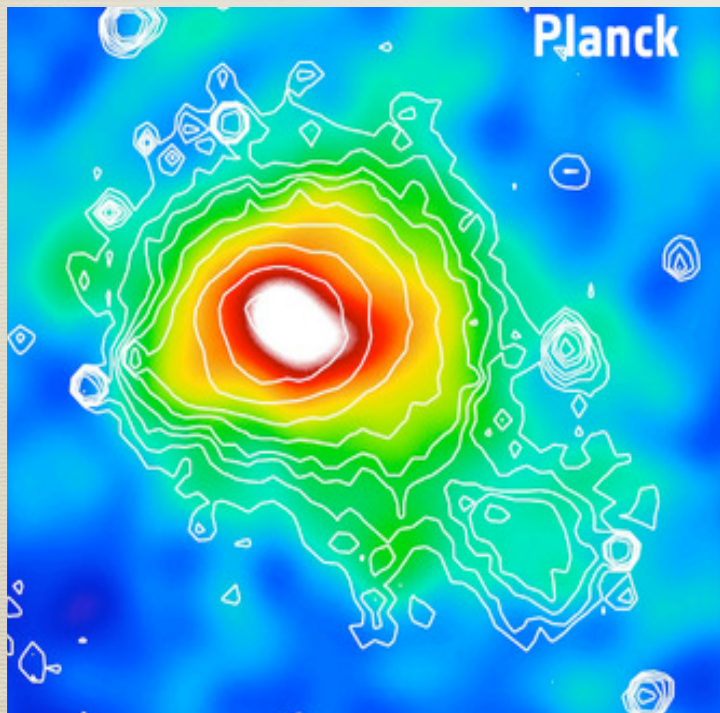
- ✦ *The Coma cluster*
- ✦ *LOFAR HBA observations*
- ✦ *First results & preliminary considerations*
- ✦ *Conclusions*

The Coma cluster

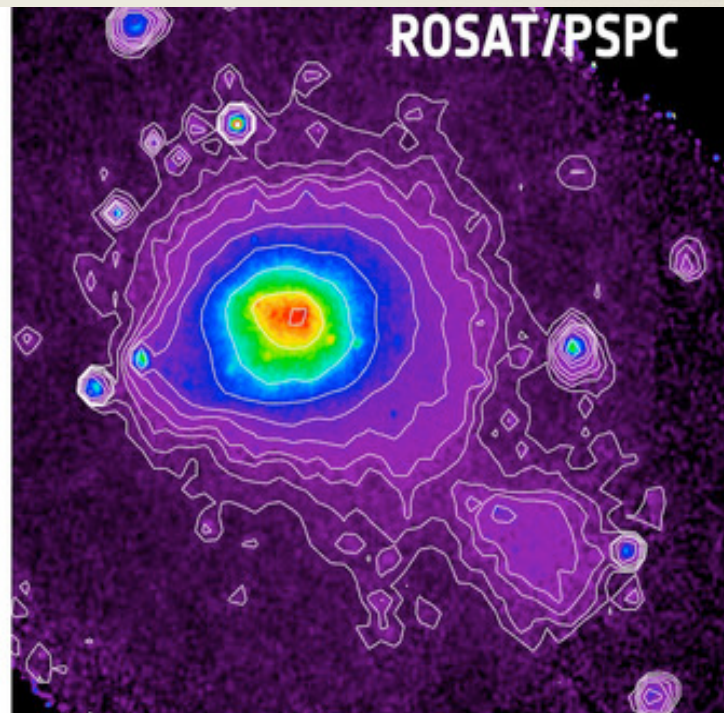
One of the most studied clusters at all wavelengths:
the thermal gas

Pressure from *Sunyaev–Zel'dovich*

Thermal Brehemsstrahlung



Planck collaboration 2012



ROSAT image (Briel et al 1992)

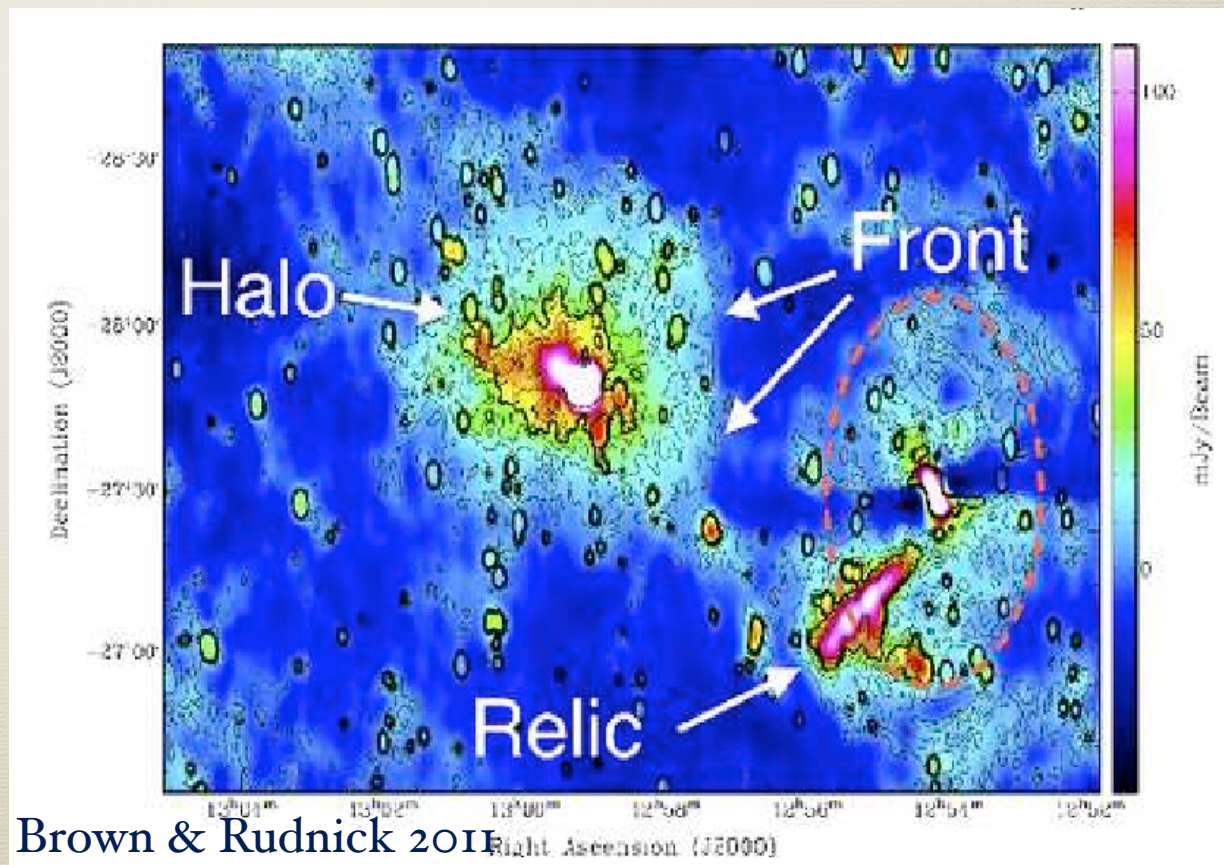
The Coma cluster

One of the most studied clusters at all wavelengths:
the Non-thermal component

The first discovered radio halo Willson 1971: 30' – 40' halo at 408 MHz

The most recent Image
Brown & Rudnick 2011

Westerbork 350 MHz



Origin of the radio emission?

Particle radiative
lifetime $\approx 10^8$ y

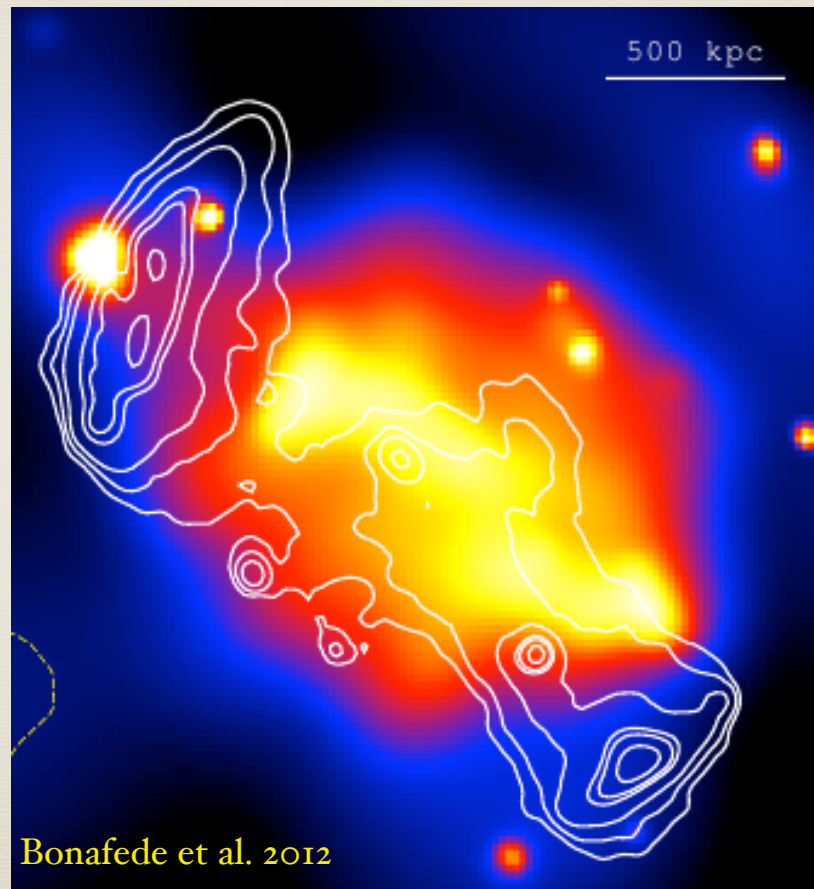


Diffusion velocity
 ≈ 100 Km/s



10 kpc in their
radiative life

Radio emission in MACSJ 1752 +4440



Mpc size!

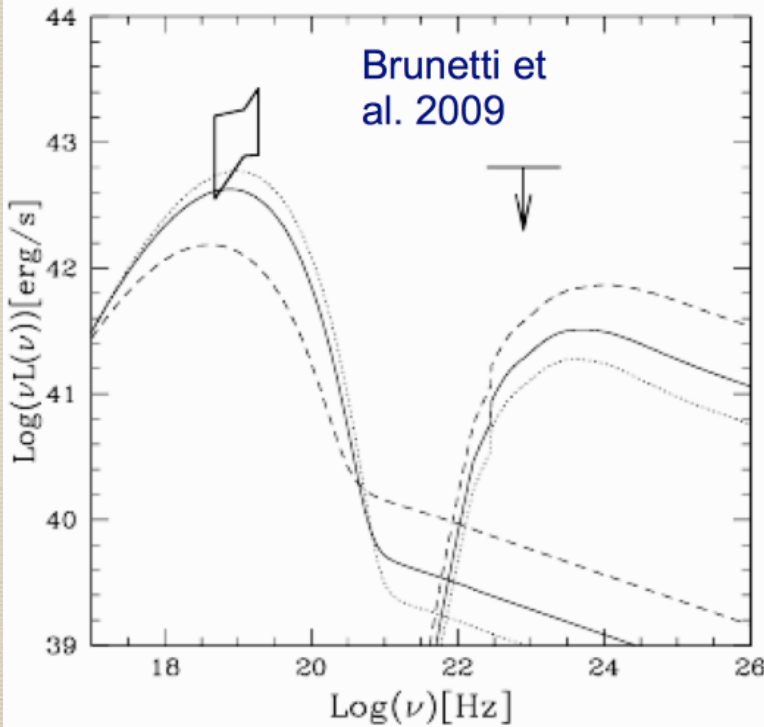


continuous
injections
or
(re)acceleration

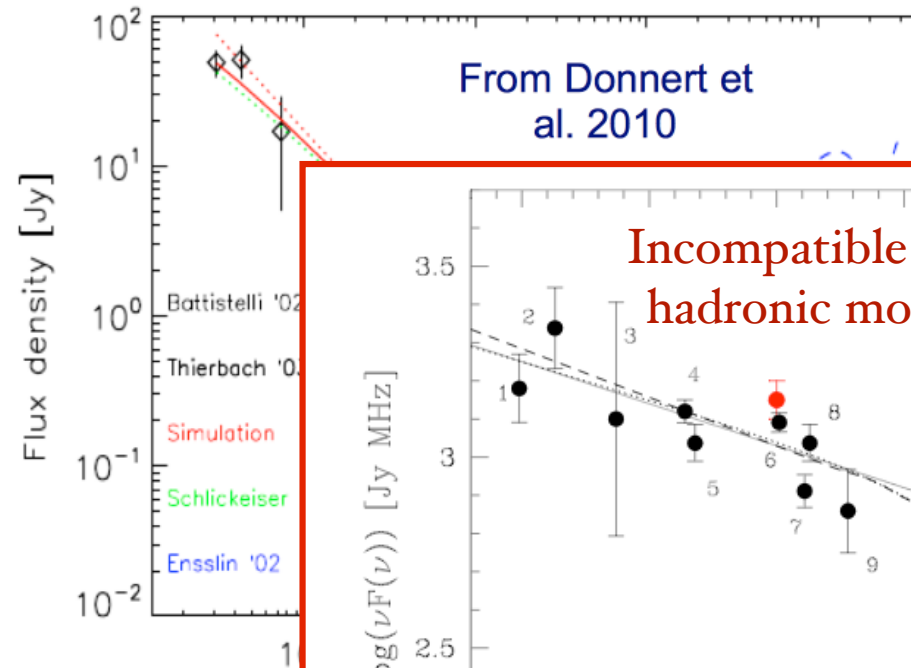
Origin of the radio halo?

Re-acceleration models

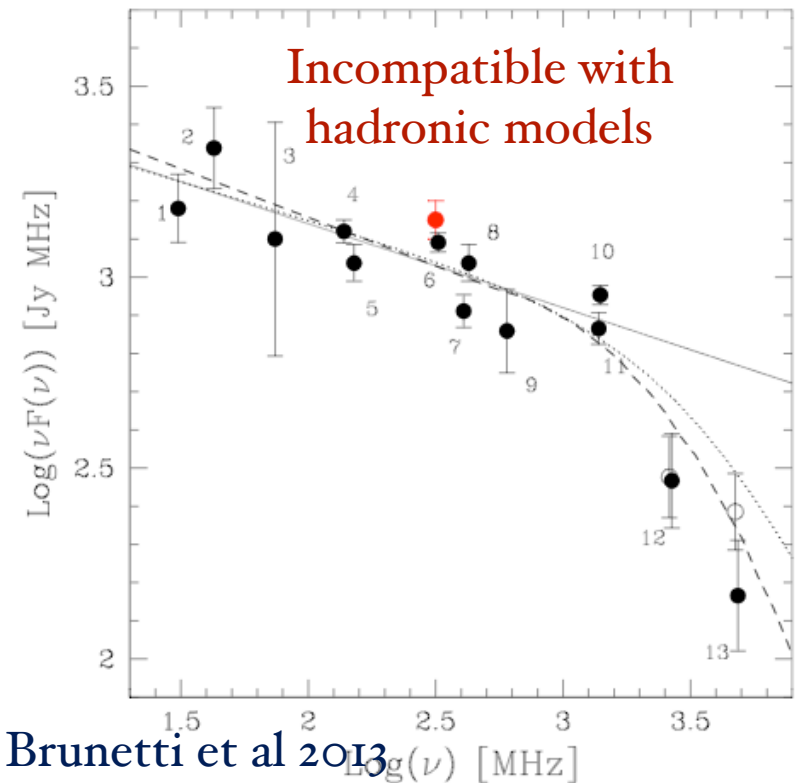
A Coma-like cluster



Hadronic models



Incompatible with hadronic models

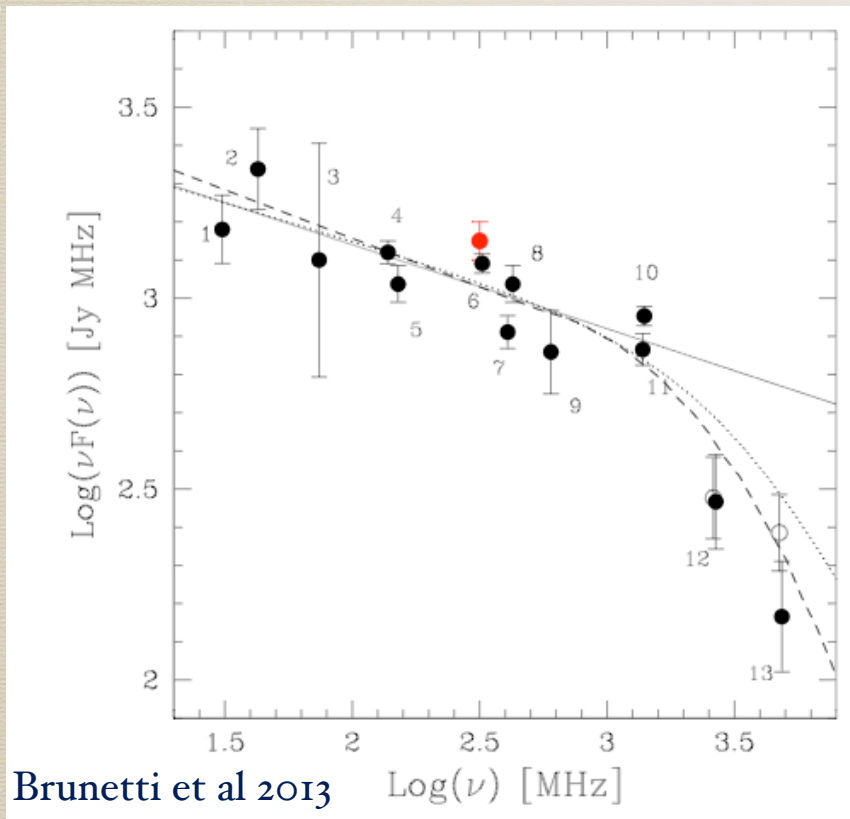


...but this is not the end of the story

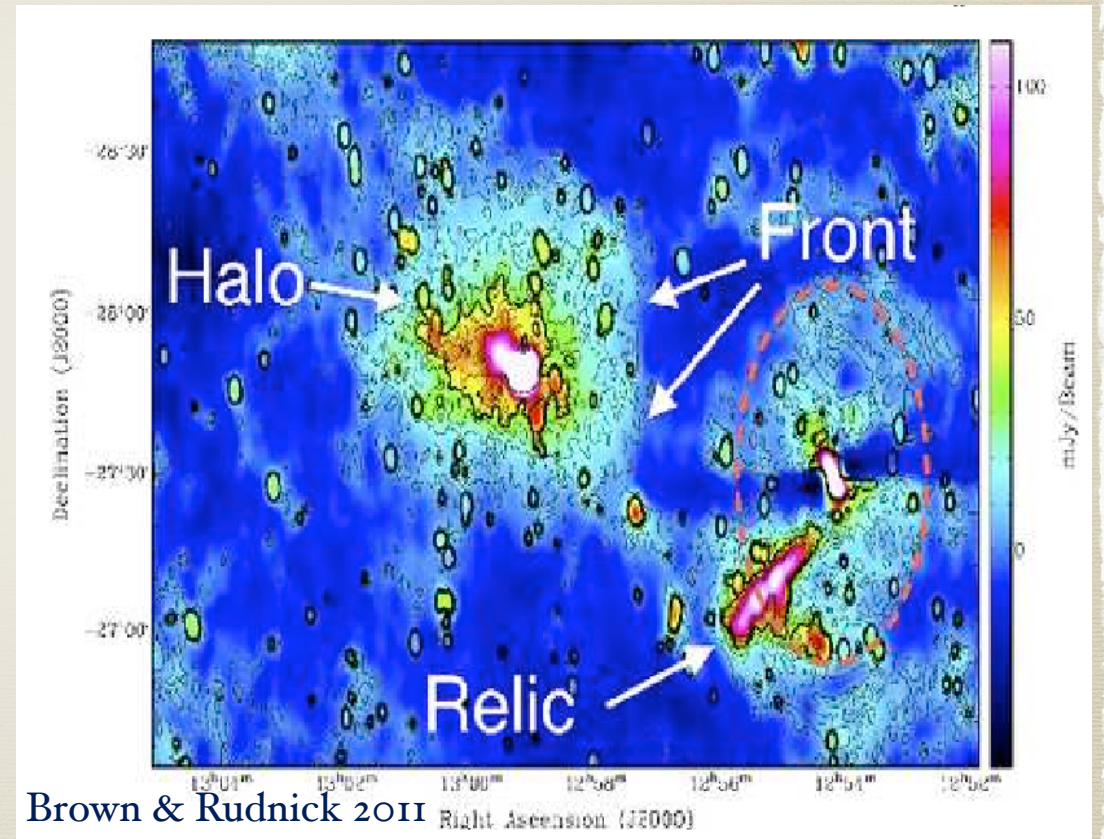
Brunetti et al 2013

Origin of the radio halo?

There is more to learn



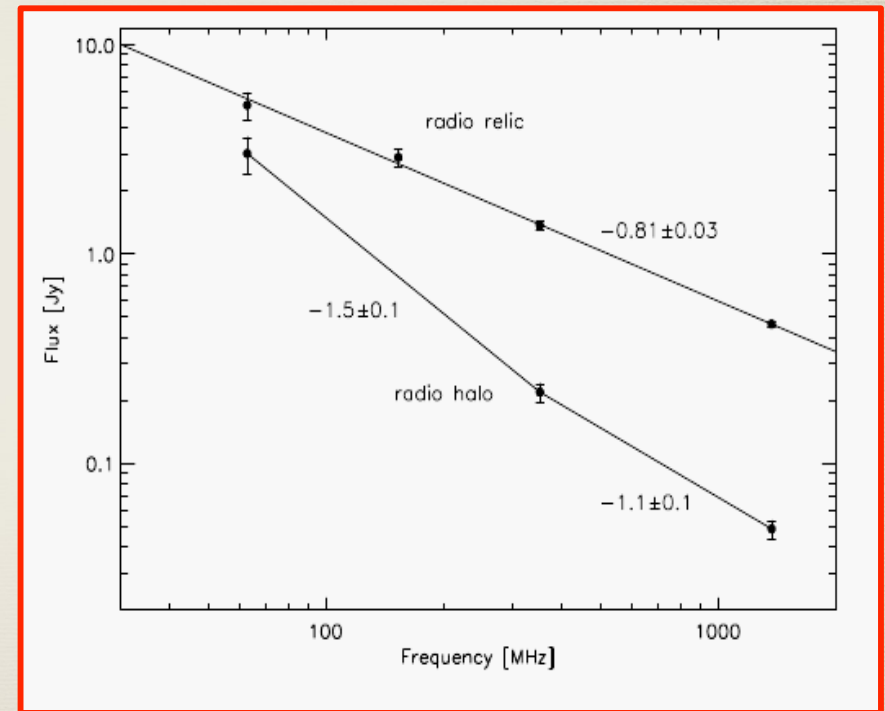
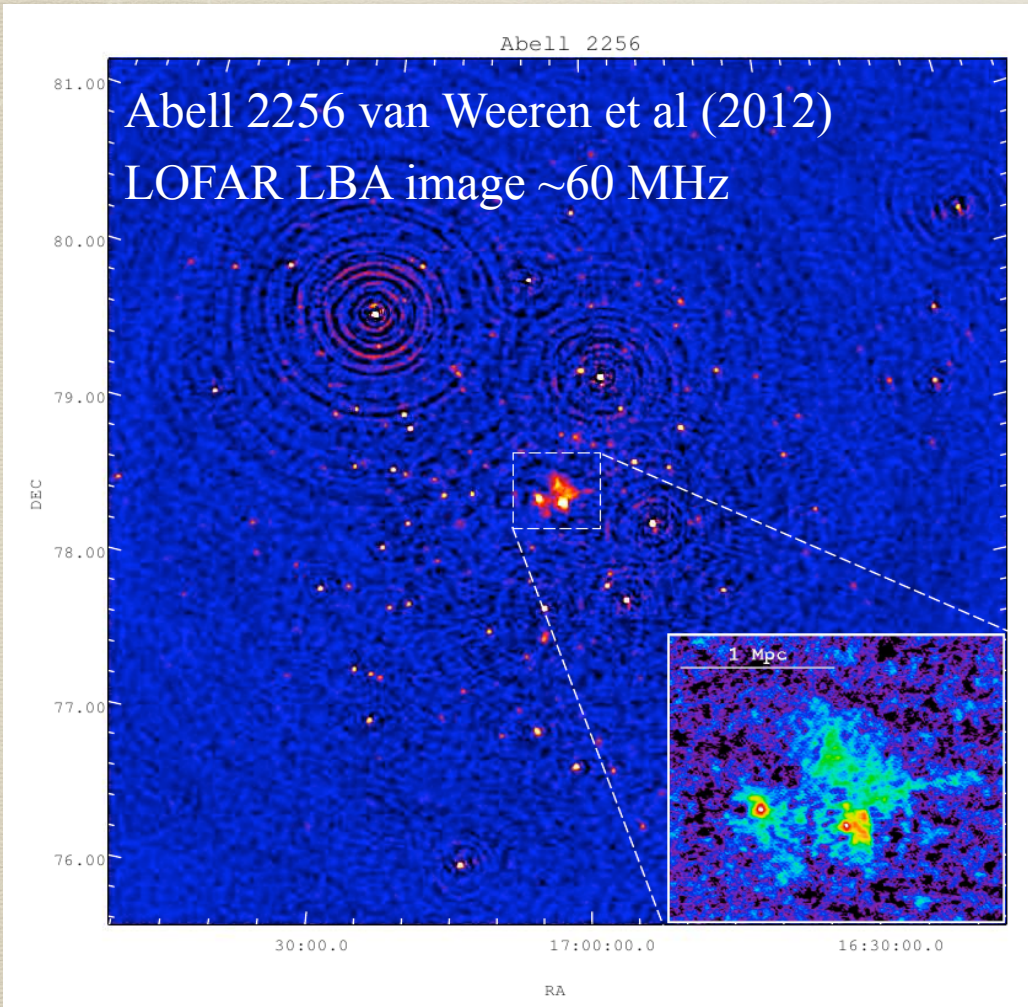
Spectrum of the central halo emission



Most of the flux emitted at $r > 25'$

Why low radio frequencies?

Spectrum of halo and relic from 60 MHz to 1.4 GHz



→ low frequency spectra → new inputs to theoretical models

LOFAR Observations

Cycleo Observations

25 March 2013

HBA Dual-inner mode

Observing time: 10h

Dual beam: 3C286

(7 degrees from Coma)

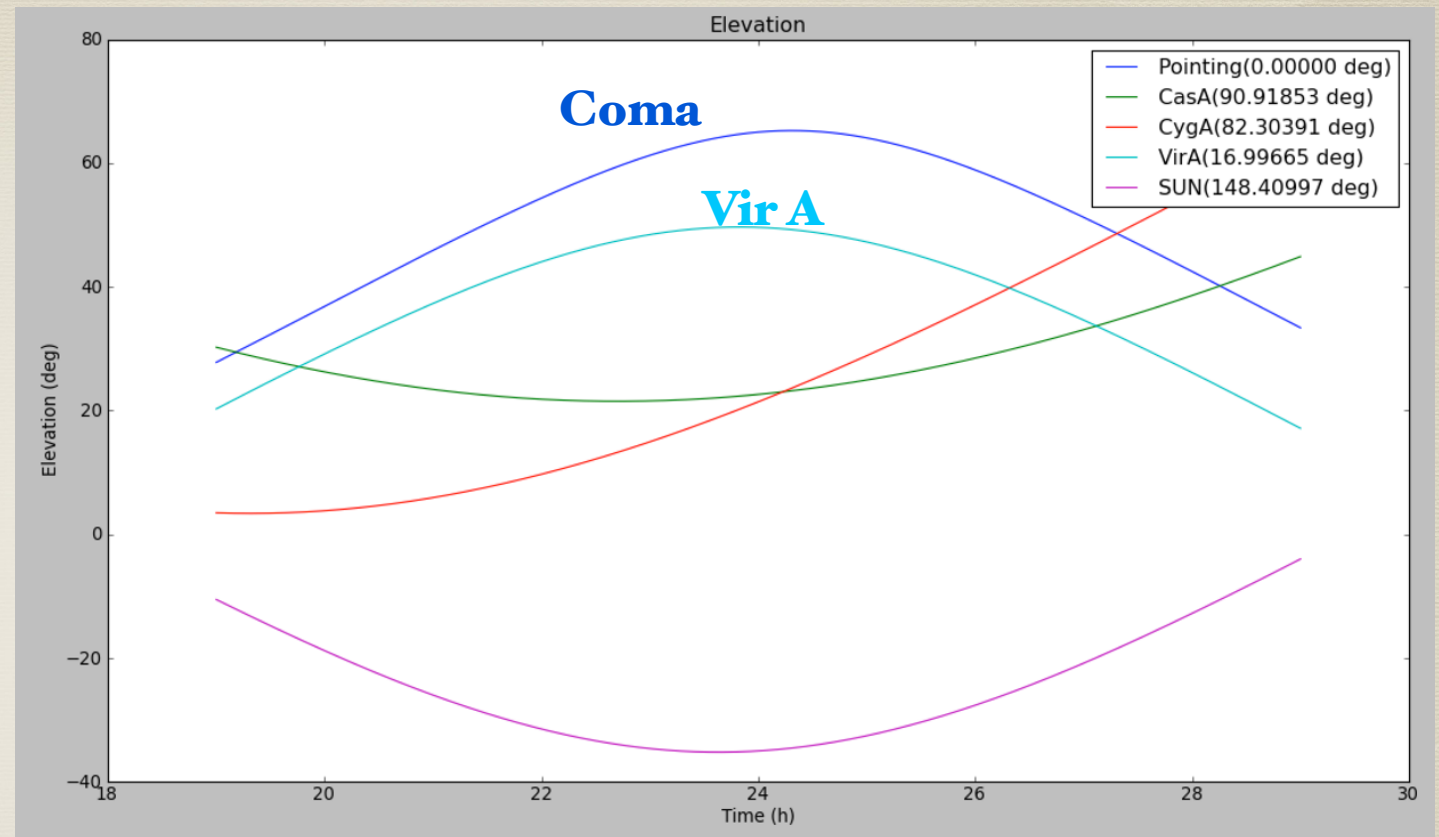
Coma cluster

A-team

flagged when present,

not demixed

Issues with VirgoA (17deg)



Non-standard observing mode

Coma:

112 to 184 MHz continuous --> 72 MHz bandwidth

3C286:

Sub-Bands randomly spread 112 - 184 MHz --> 24 MHz bandwidth

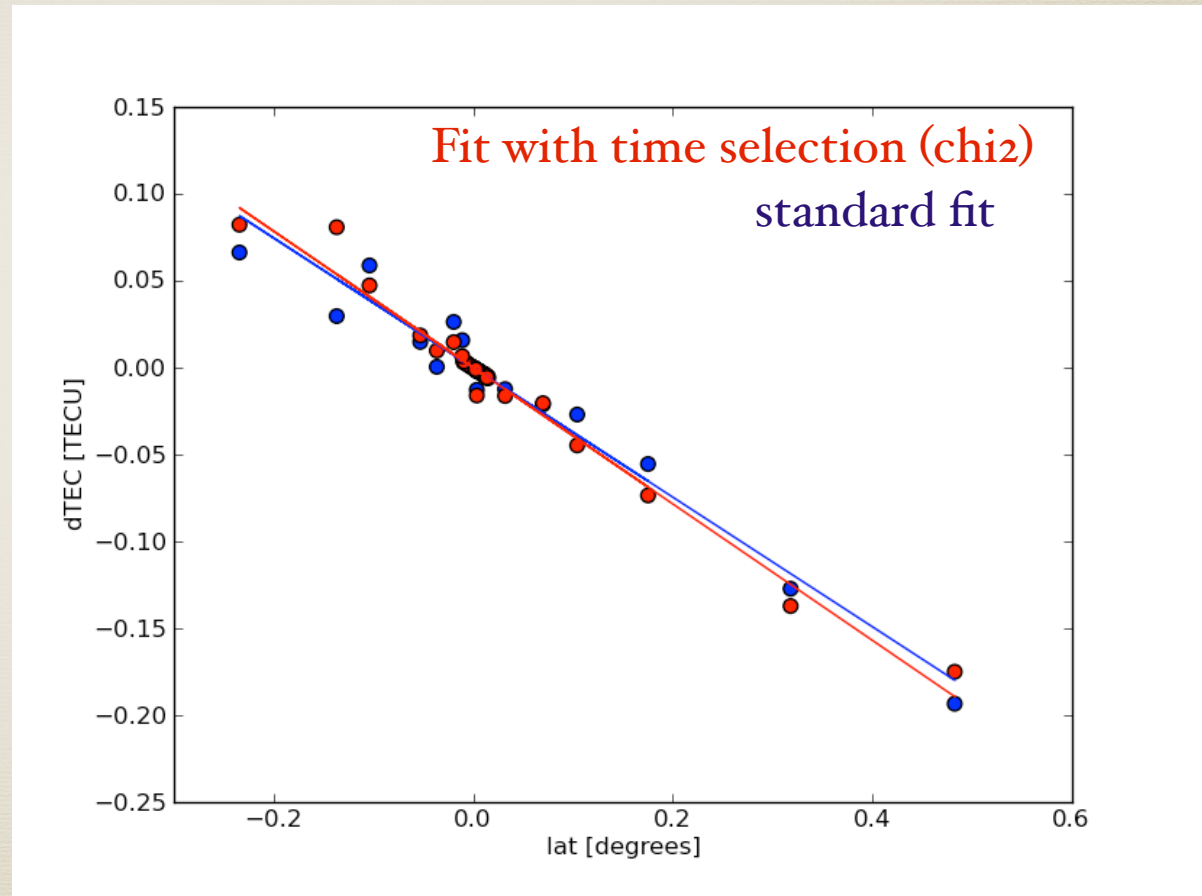
Calibrator: Clock TEC and offset

$3C286$: Clock - TEC

Differential TEC vs
piercepoints
(latitude)

piercepoint: points
where the line of sight
between a station and
the source intersects the
ionospheric screen

Final fit (only time-chunks when
ionosphere shows a linear behaviour)

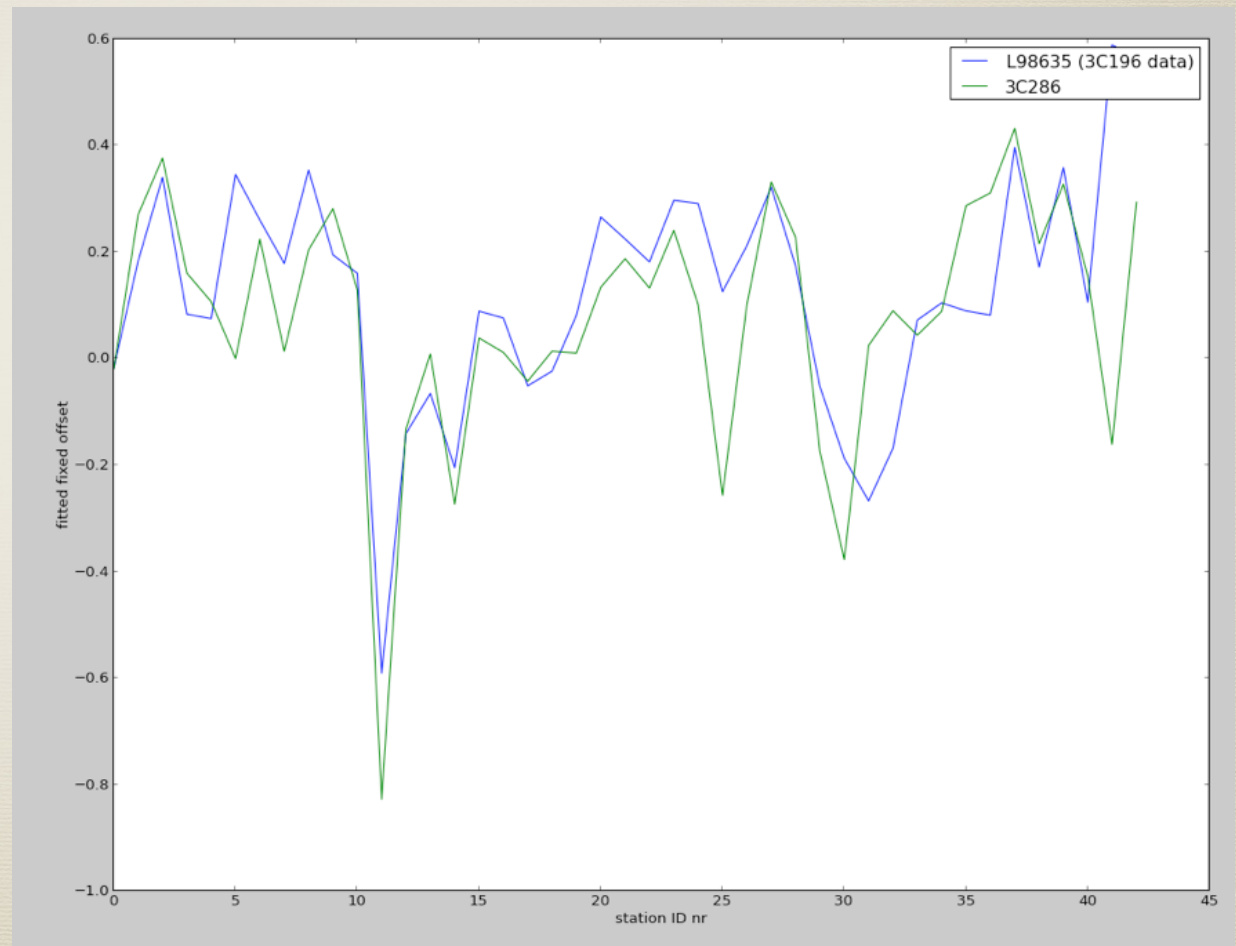


Calibrator: Clock TEC and offset

3C286: Clock - TEC and offset

Instrumental Offset

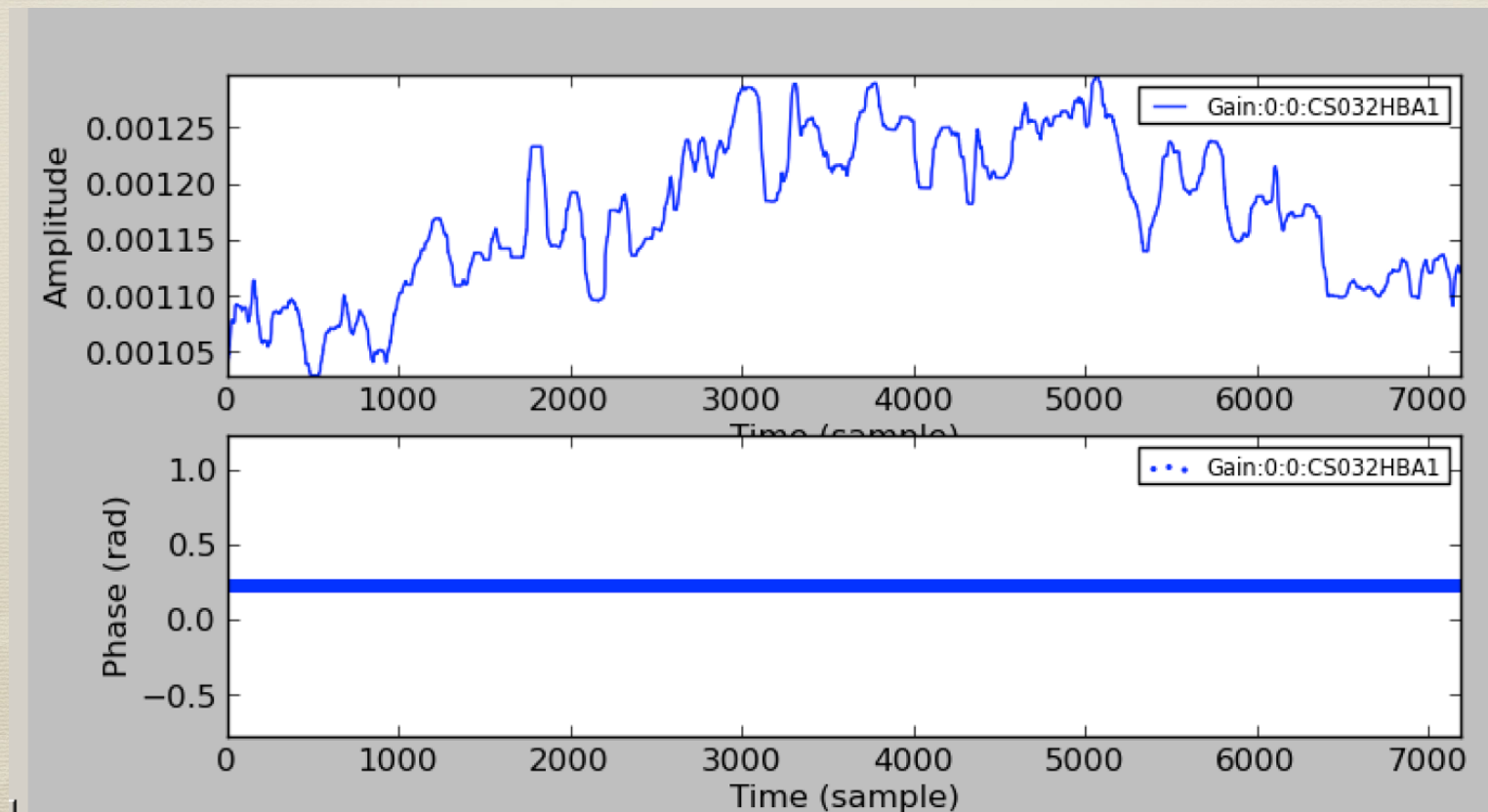
Constant offset (time and freq)
fitted for the CS for 2
observations
several weeks apart



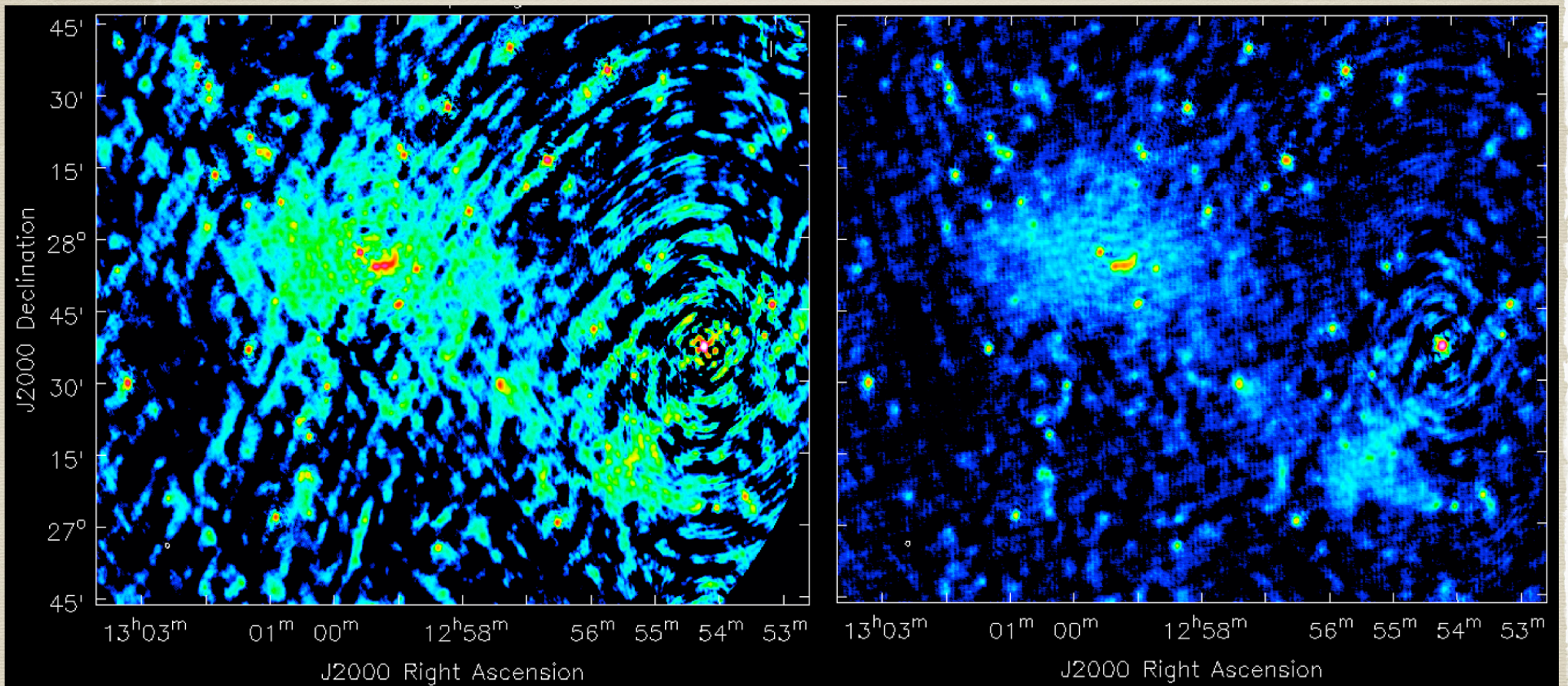
Finally the target field

Clock and offset removed

Amplitude Gains from 3C286 smoothed and interpolated over frequency
--> applied to Coma



Clock and offset removal



No Clock and offset removal
phase cal vs gsm model

Clock and offset removal
phase cal vs gsm model

Results

Coma cluster HBA

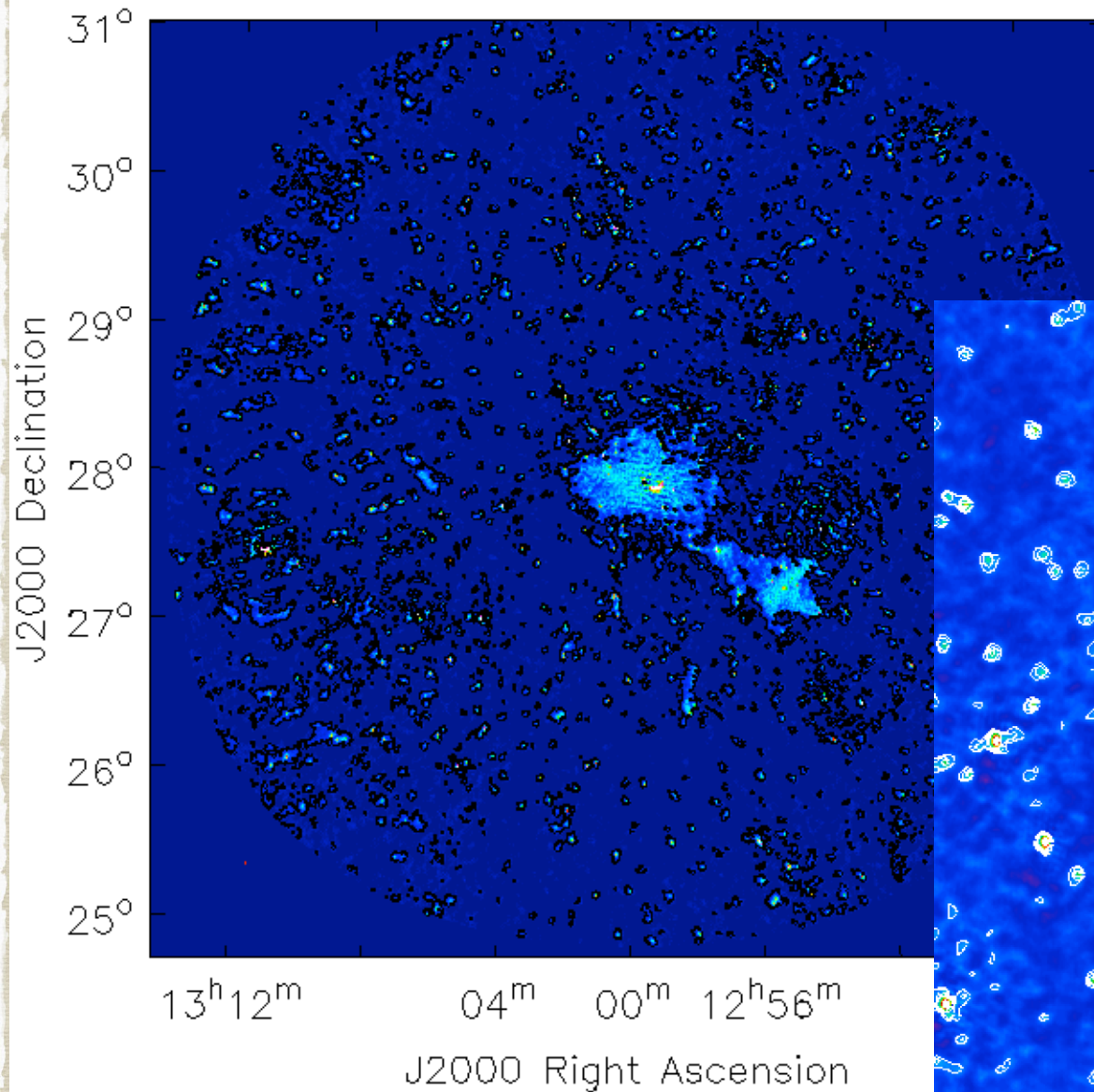
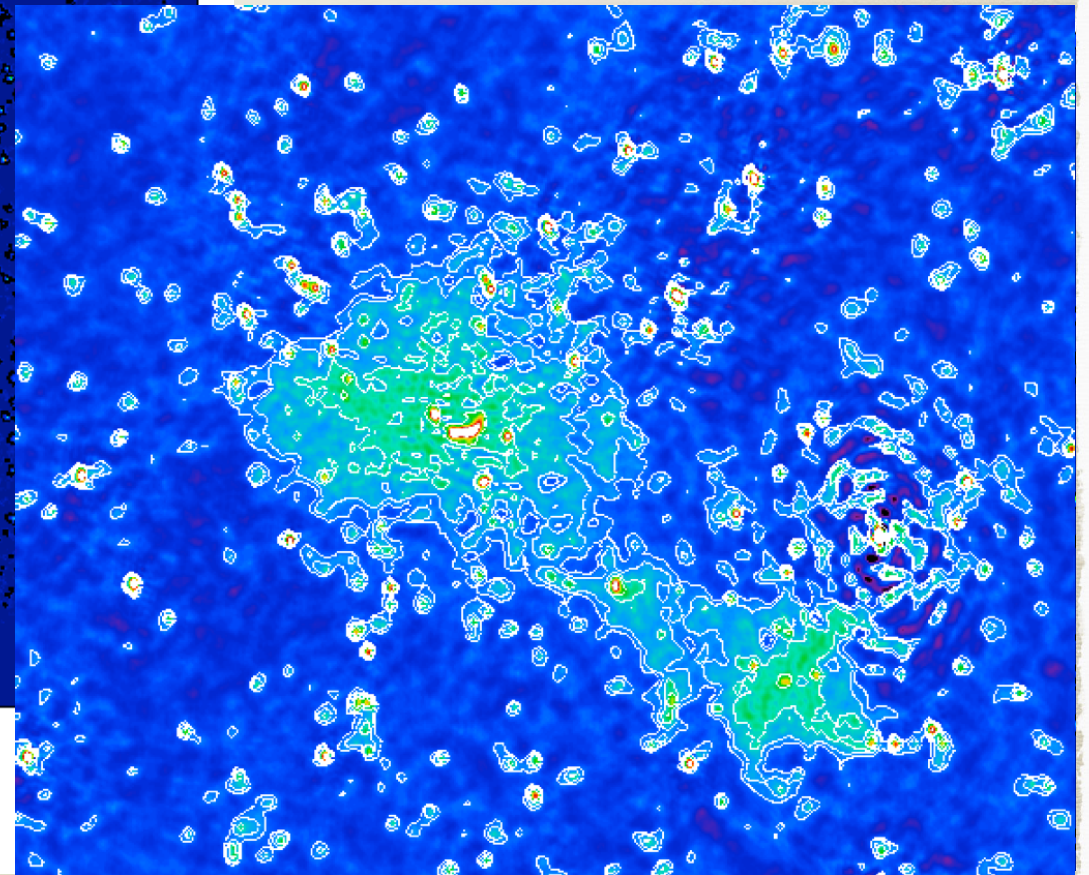


Image at 134 MHz
16 MHz bandwidth
Beam ~ 30''
rms ~ 0.6 mJy/beam
(1/3 of data processed)



Results

Halo E-W ~ 1.07 degrees
1.8 Mpc!

Bridge of emission
connecting Halo and Relic

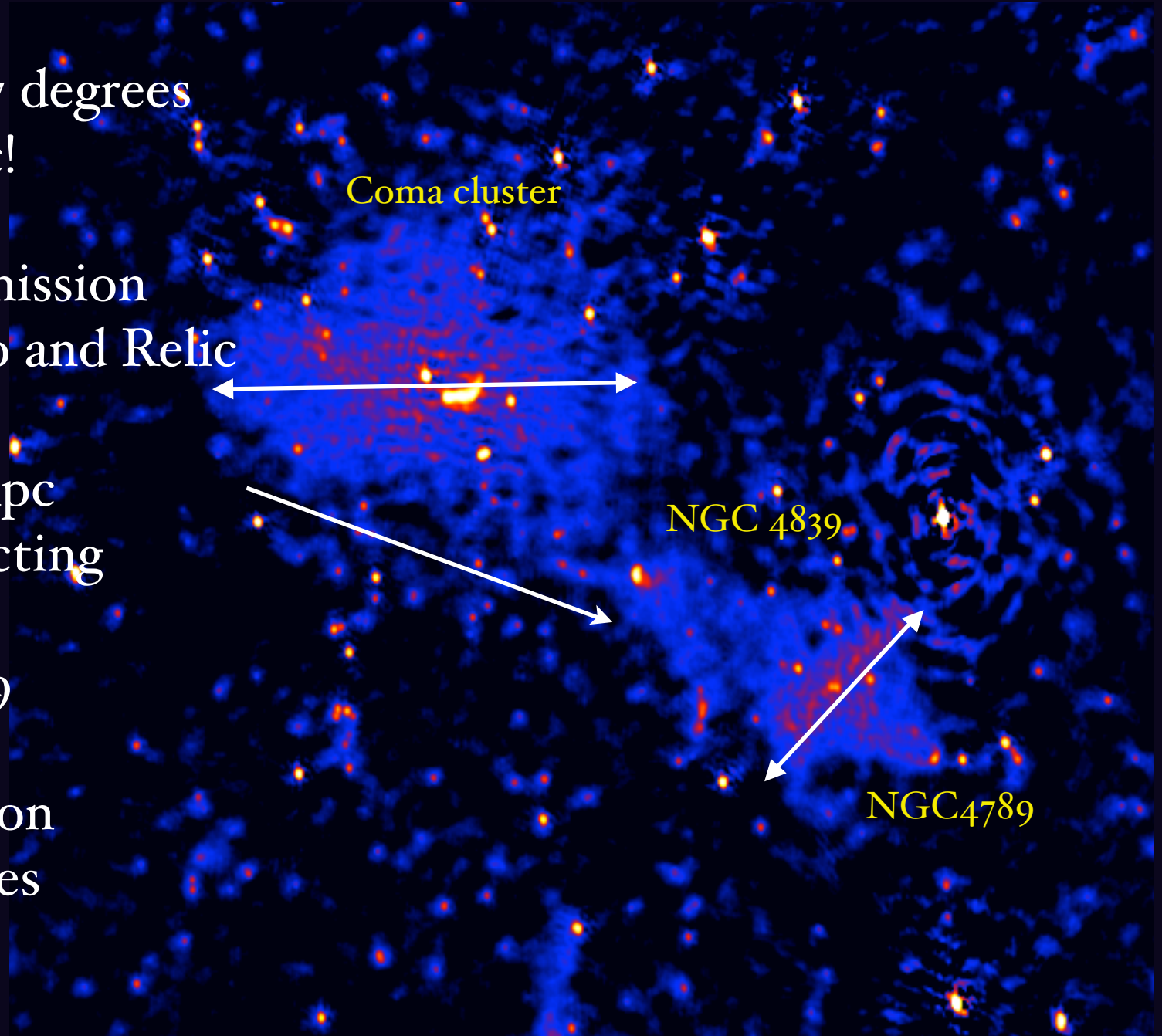
Relic ~ 800 kpc
Bridge connecting
relic and
NGC 4789

Radio emission
over 2 degrees
 ~ 3.3 Mpc

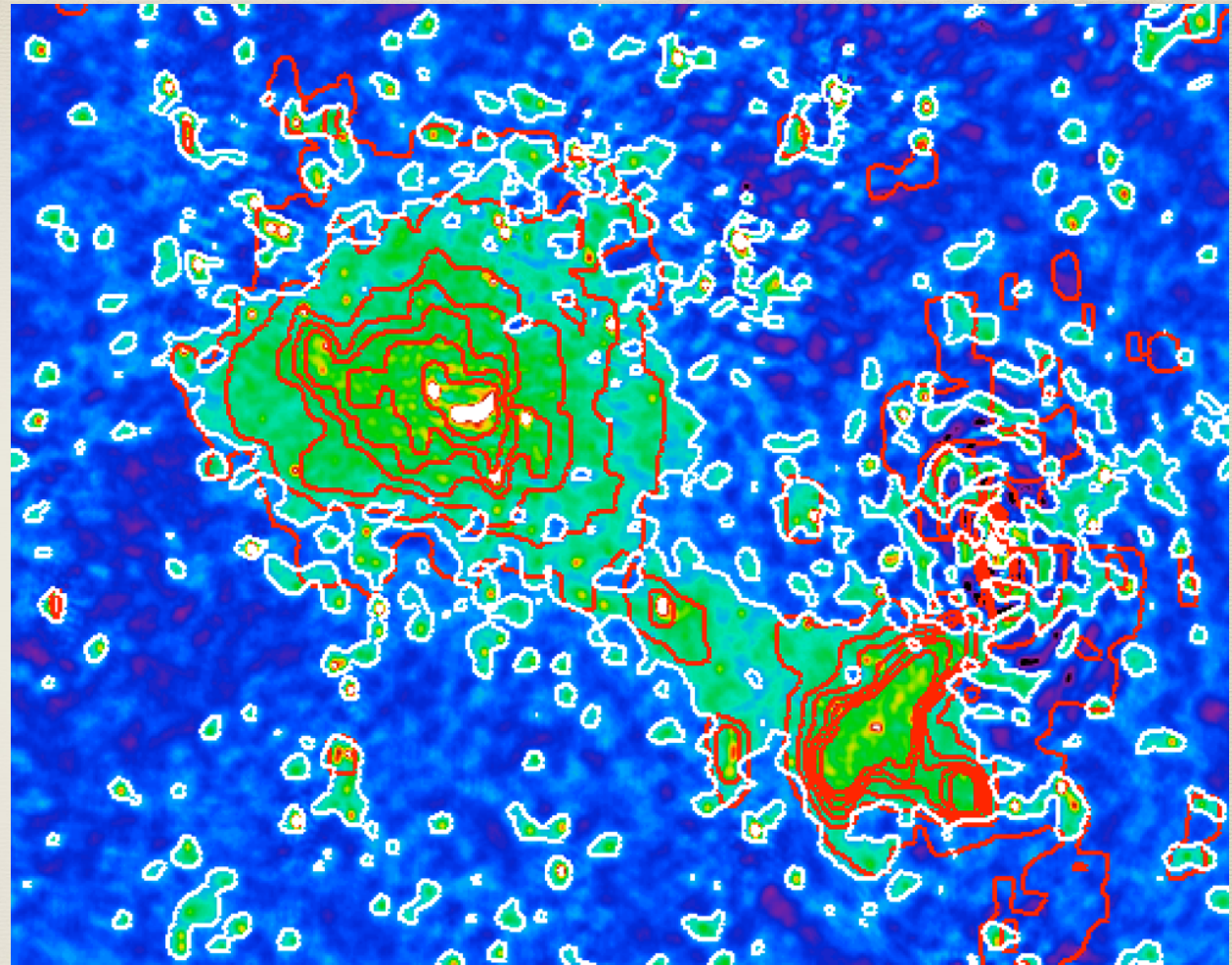
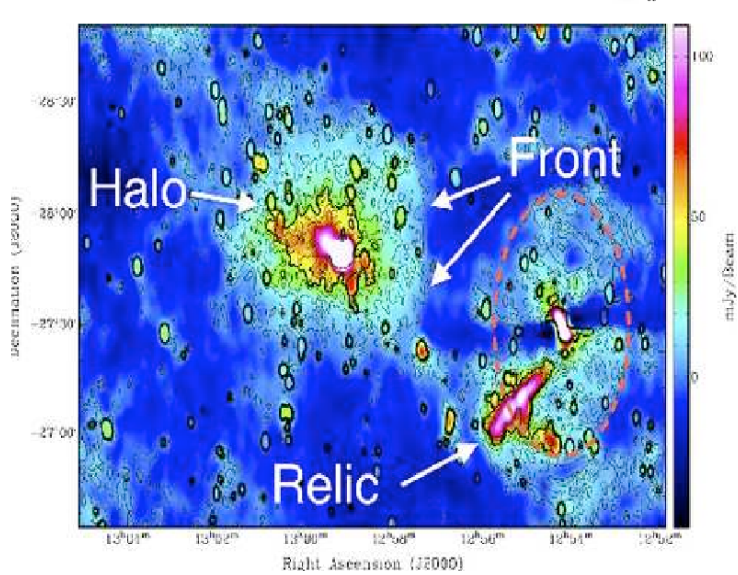
Coma cluster

NGC 4839

NGC 4789



Comparison with 350 MHz map



Colors and white contour:
LOFAR 140 MHz (35'' resolution)

Red contours:
300 MHz by Brown and Rudnick
(1'x2' resolution)

- No sharp front yet
- Halo largest size almost recovered
- Bridge connecting the halo and the relic

Conclusions

- LOFAR observations of galaxy clusters
 - reveal the emission mechanism powering the radio emission
 - new inputs to theoretical models
- Coma HBA: at the level of the best map at 350 MHz
- New emission revealed (bridge)
- Multi-scale imager is running -> reliable fluxes

Announcement



PhD position in Hamburg will be open soon to work on low-frequency observations of galaxy clusters

