



ASTRON

Netherlands Institute for Radio Astronomy



Tracing the Life – Cycles of AGN using LOFAR

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& the LOFAR commissioning team

YERAC, 18 – 21 October 2012

Pushchino, Russia



In brief...

- The AGN menagerie - is there a method behind the madness?
- AGN life-cycles? What? Why?
- LOFAR and the LF connection + first results.

Radio galaxies, QSO, BLlac etc...

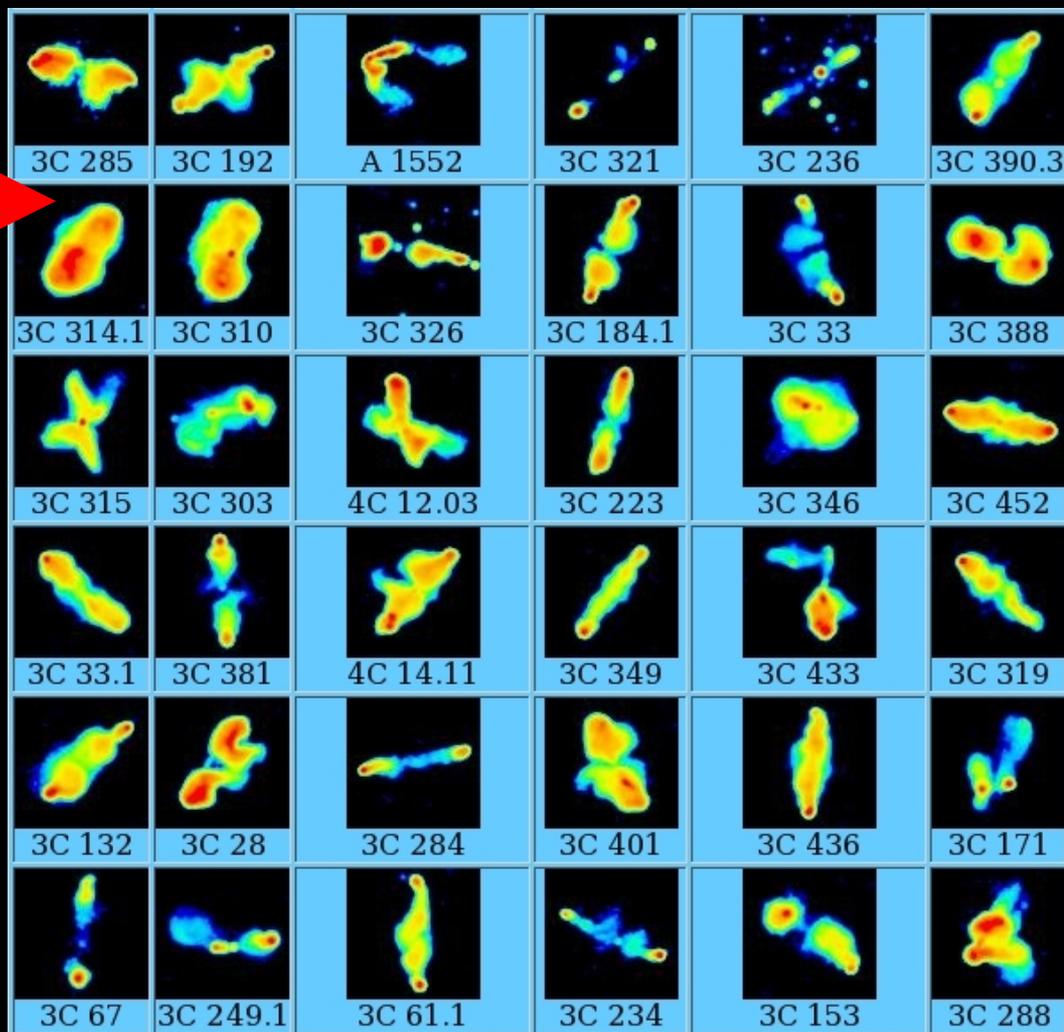
RG`s: large,

FR I - ish

Optical:

Emission
lines spectra

High / low
excitation



or
FR II

Hardcastle: <http://www.jb.man.ac.uk/atlas/icon.html>

Orientation matters, but is unification
overrated?

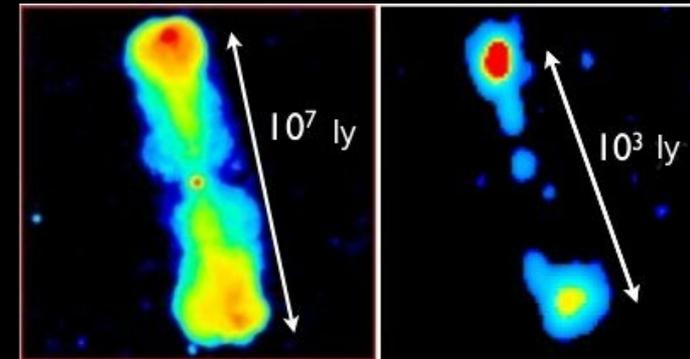
The size also matters

?

Gigahertz – Peaked Spectrum

(GPS) radio sources

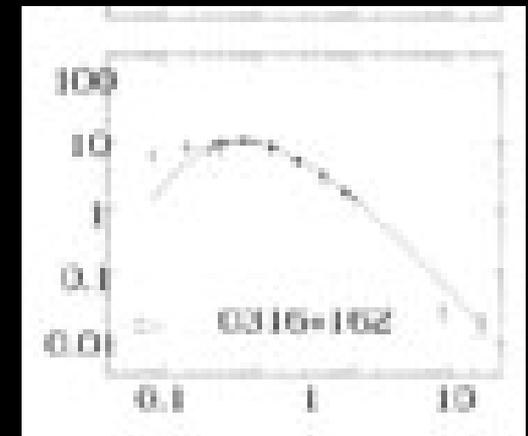
- physical size < 1 kpc
- steep spectra with GHz turnover frequency



3C35 vs. J1335+5844

Compact Steep Spectrum (CSS) radio sources (or Compact Peaked Spectrum sources)

- physical size < 20 kpc
- steep (inverted) spectra, SSA responsible, peak relates to size, lower freq. – larger size.



Both classes can show

FR I / FR II – like morphologies

O’Dea 1999

They are either a young sequence of proper AGNs, a “frustrated” normal AGN population, or...

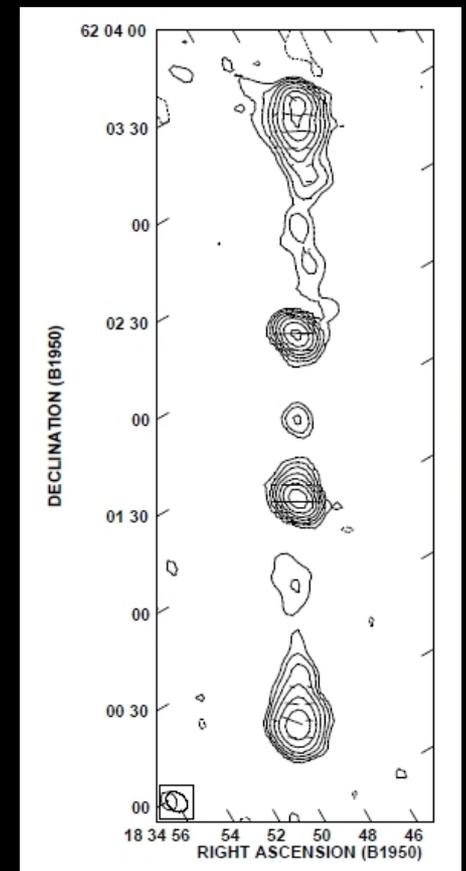
Baby
AGN

Child

“Normal”
Radio loud
galaxy

Restarted and “dead” AGN

- Hint at timescales of activity
“cycling”: $10^7 - 10^8$ yrs?
- Double - doubles: still active.
- Relics: fading away, steep spectra, partially replenished.

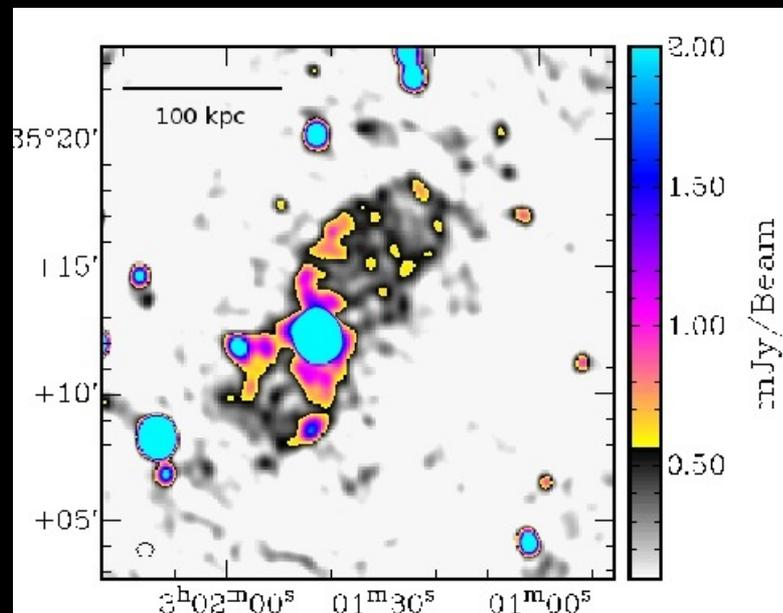
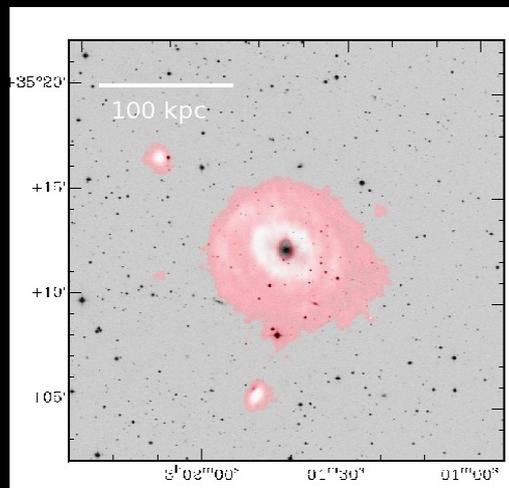
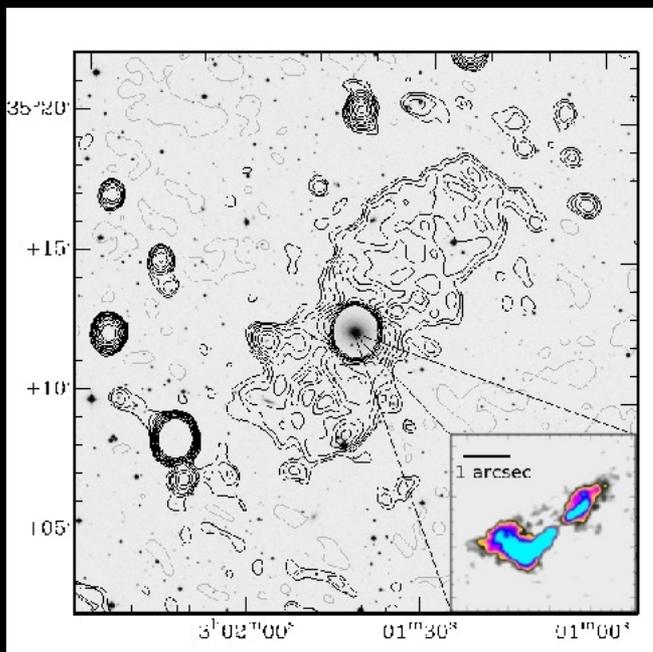


1834+620, 8.4 GHz VLA. Schoenmakers+ 1999

- Dead: No core, no jets, very steep Spectra.

Important for the feedback framework
- multiple cycles means higher net energy output to the ISM / IGM.

Relic or not – B2 0258+35



1.8 Jy CSS
source (inset)

WSRT: 11x12 hrs.
continuum

100 $\mu\text{Jy beam}^{-1}$
rms.

39" x 33" beam

HI disk around
Host galaxy
NGC 1167

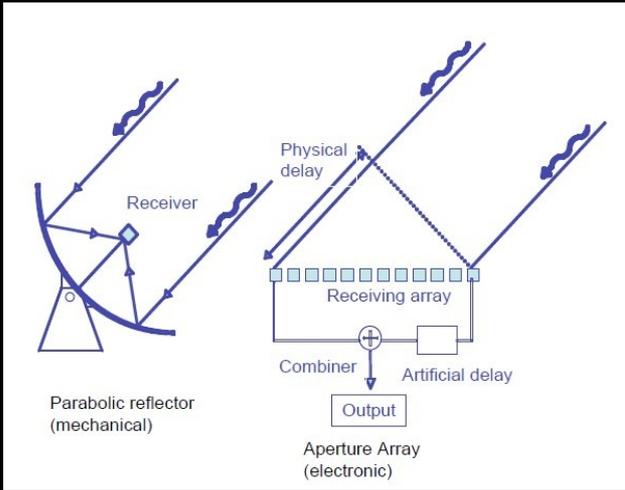
$M_{\text{HI}} = 15 \times 10^9 M_{\text{sun}}$

Diffuse emission
~240 kpc projected
size

Relic? Accretion
source?
Still replenished?

see: Shulevski+ A&A 545 A91, 2012

LOFAR



Cygnus A

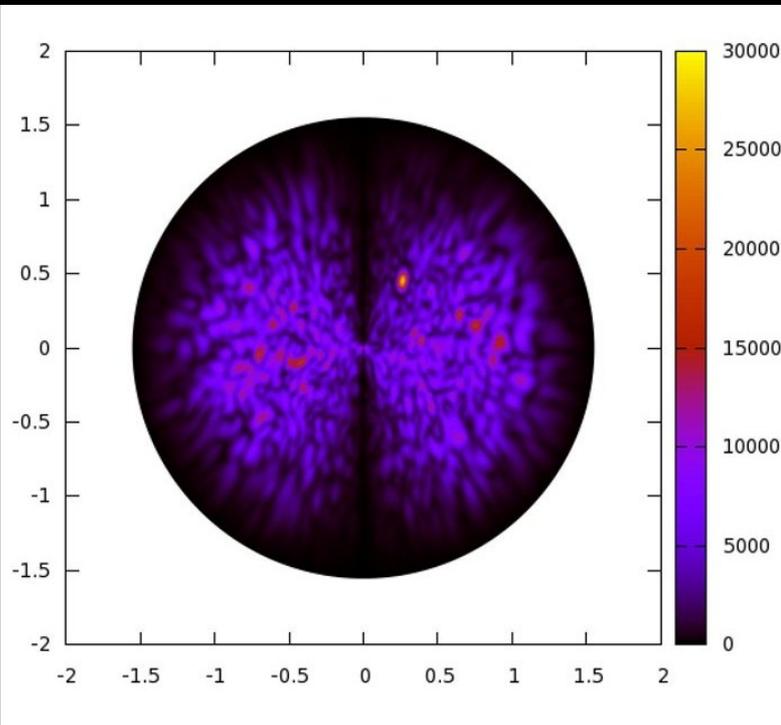
~ 16000 Jy at 74 MHz (LBA)

LOFAR -
Electronic
telescope

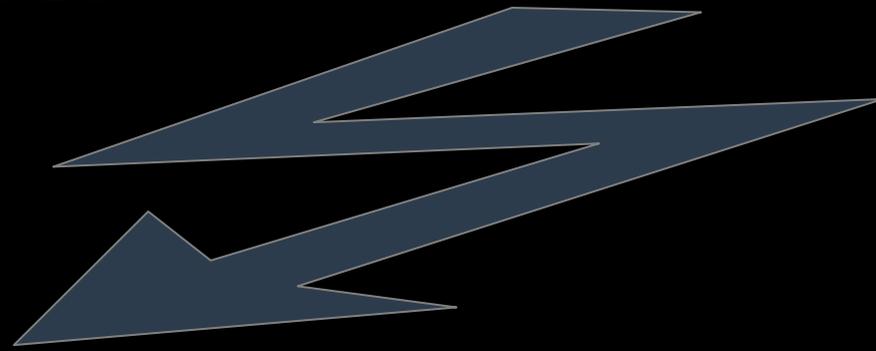


240 MHz (LOFAR HBA)
J. McKean, M. Wise (ASTRON)

LOFAR core station beam, 80 MHz
(analytical model) - note the side-lobes!



Shulevski 2009, MSc. thesis



Cyg A, Cas A, Vir A, Tau A (A - team)
“mix-in” through the sidelobes
with the target visibilities.

We learned how to deal with
these and other issues...

The B2 0258+35 field as LOFAR sees it

- Goal: quantify the recurrence of AGNs (few examples so far).
- Method: Find evidence of past activity - relics, use spectra to constrain ages.
- Determine AGN duty cycles - important - ex. feedback.

- LOFAR LBA - centered at 61 MHz, 6 MHz BW, 6 hr run ~ 25 mJy beam⁻¹ rms noise (5 times thermal), 20" resolution.
- 98 sources detected at a 5 σ detection threshold.
- One new, LOFAR - only source detection, matches to WENSS, NVSS catalogs to ascertain spectral indices.
- One turnover source detected (not B2 0258+35)

A 0407

NVSS J02529+3556

NVSS J030025+352033

Future: better calibration strategy using all LOFAR stations for better resolution (now using only baselines < 20 km)

NEW relic emission seen by LOFAR (red) vs. WSRT at 1.4 GHz (green). DSS2 optical.

Red contours (LOFAR) start at 3 σ .

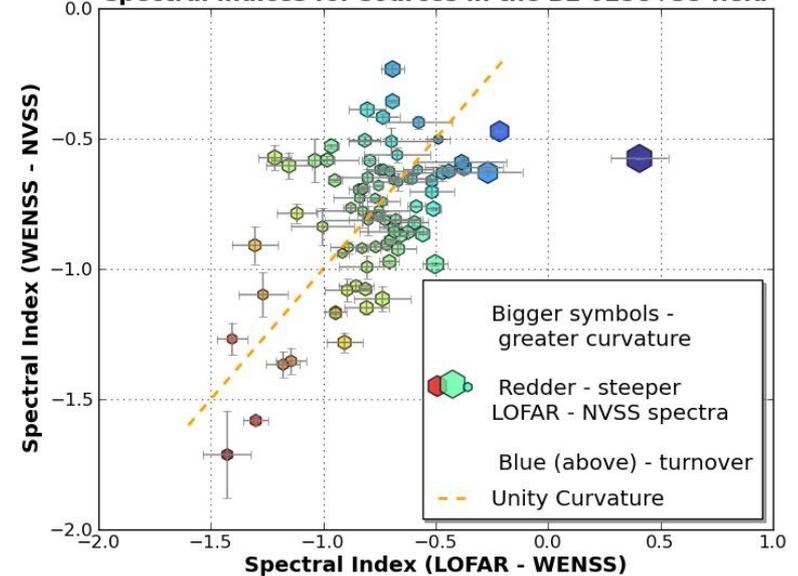
NVSS J0307+3529

More than 12 deg.² sky coverage!

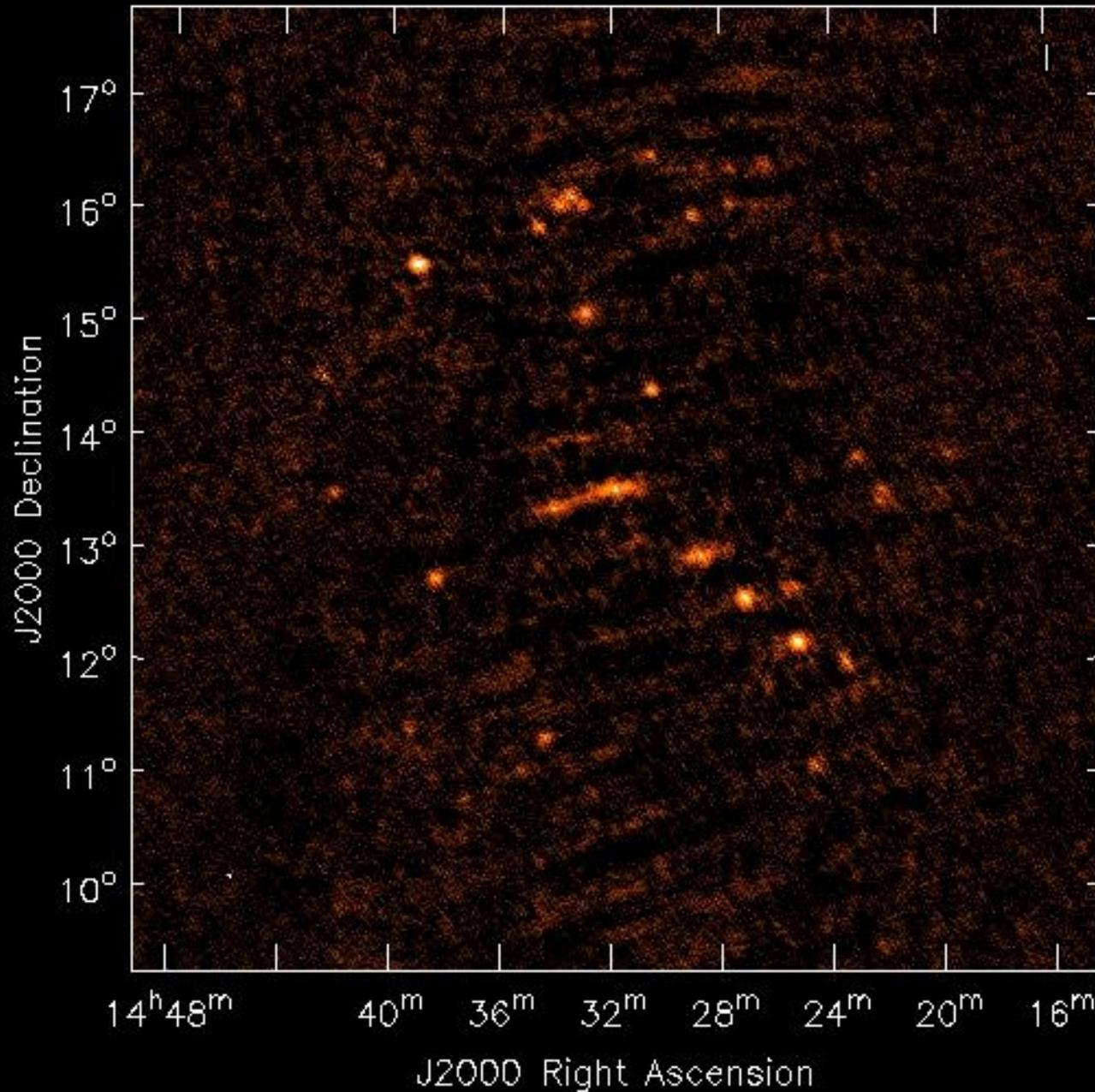
Ultra Steep Spectrum sources listed in De Breuck+ (2000) (red points, lower left) - detected by LOFAR!

Target - B2 0258+35 (relic emission not detected by LOFAR)

Spectral Curvature between LOFAR / WENSS and WENSS / NVSS spectral indices for sources in the B2 0258+35 field



Latest LOFAR images (L60216) . . . MaxBGC



**A2048 & maxBGC
two AGN relics**

25 mJybeam⁻¹

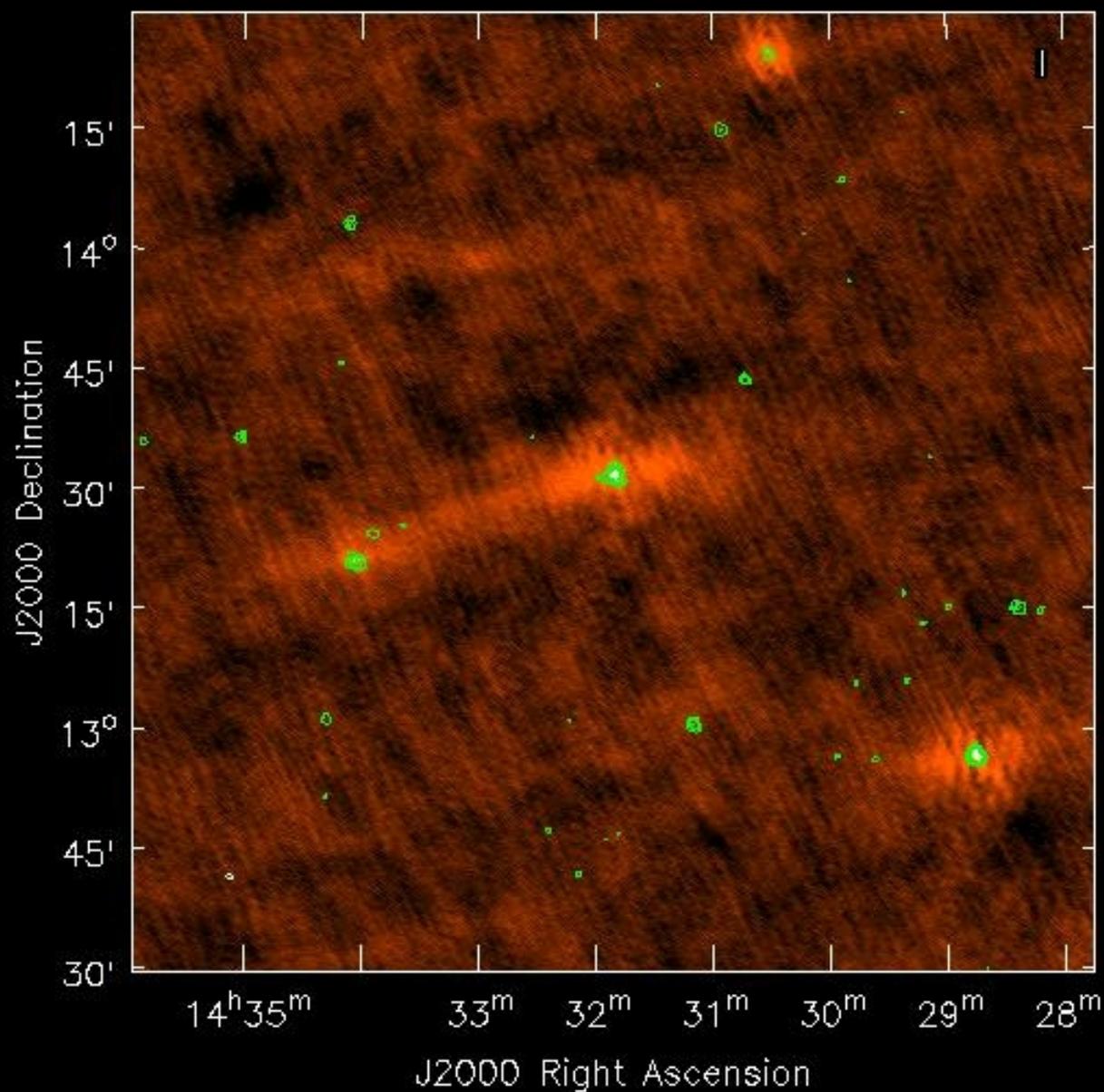
**rms noise,
~30 arcsec
beam⁻¹**

2MHz bandwidth

@ ~ 60 MHz

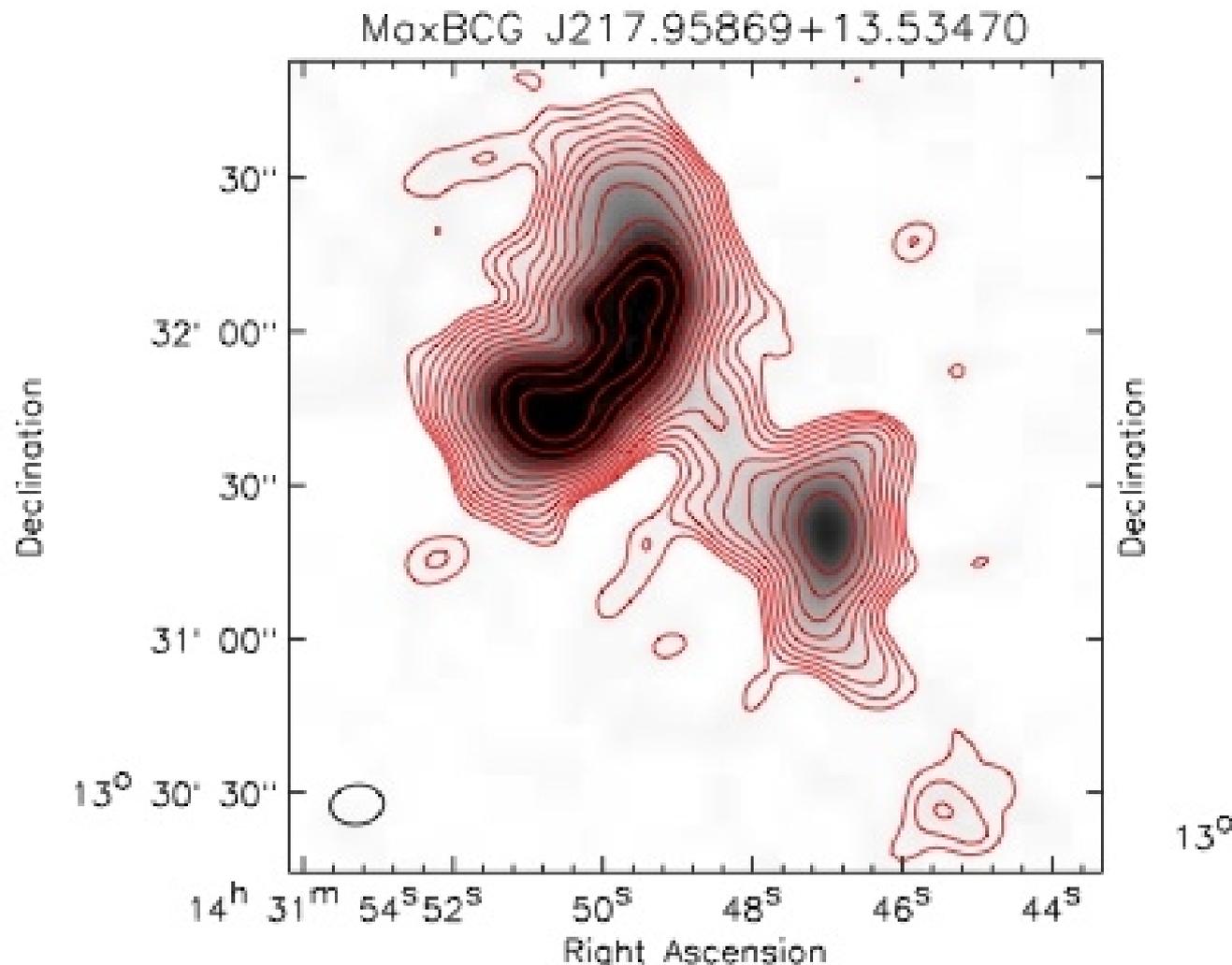
LOFAR LBA

Latest LOFAR images (L60216) ... MaxBCG



MaxBCG closeup

Latest LOFAR images (L60216) . . . MaxBCG



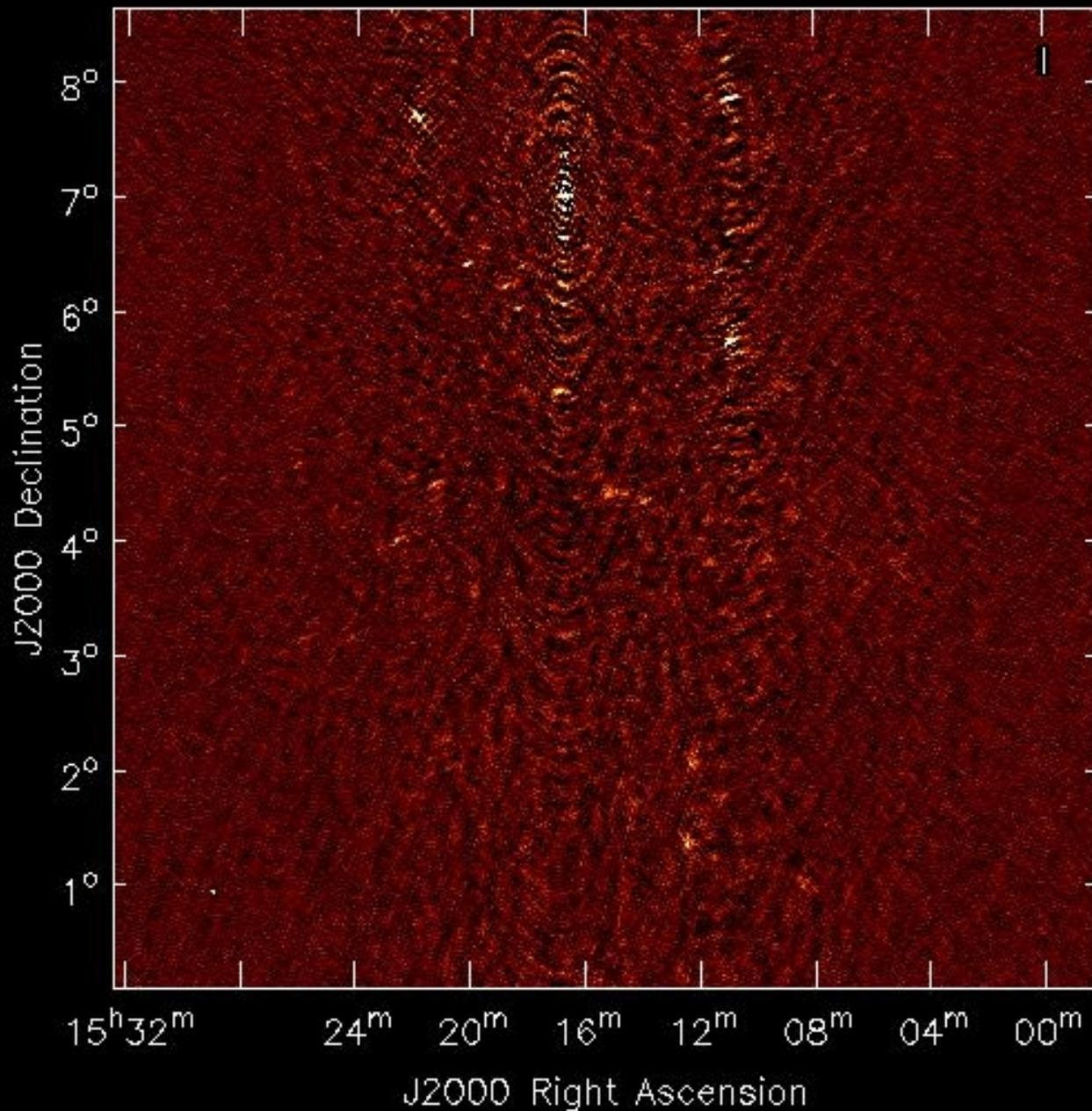
MaxBCG closeup

– comparison
with:

GMRT 325 MHz

Weeren+ A&A
527 (2011)

Latest LOFAR images (L60216) ... A2048



**A2048 & maxBGC
two AGN relics**

75 mJybeam⁻¹

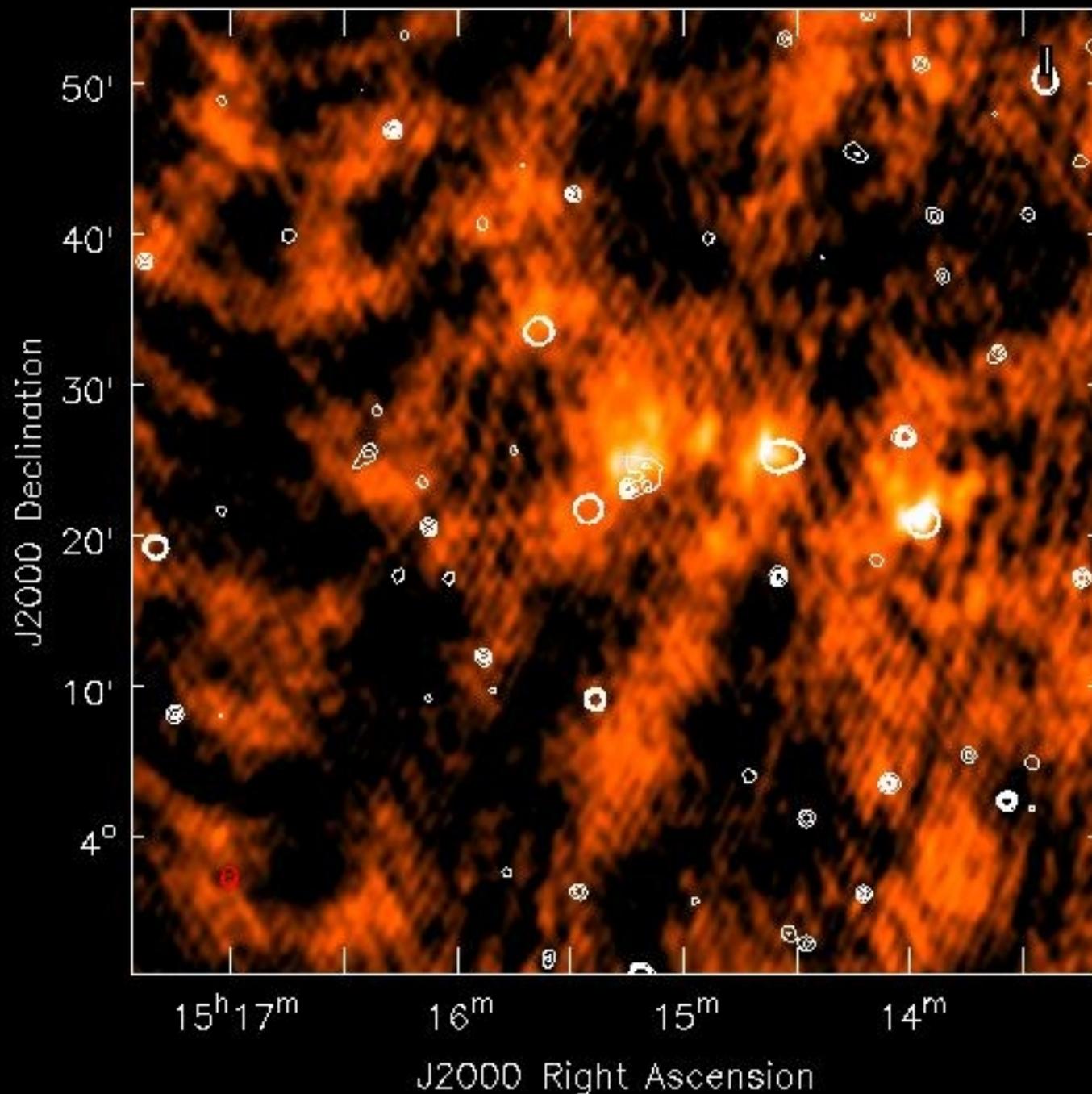
**rms noise,
~70 arcsec
beam⁻¹**

2MHz bandwidth

@ ~ 60 MHz

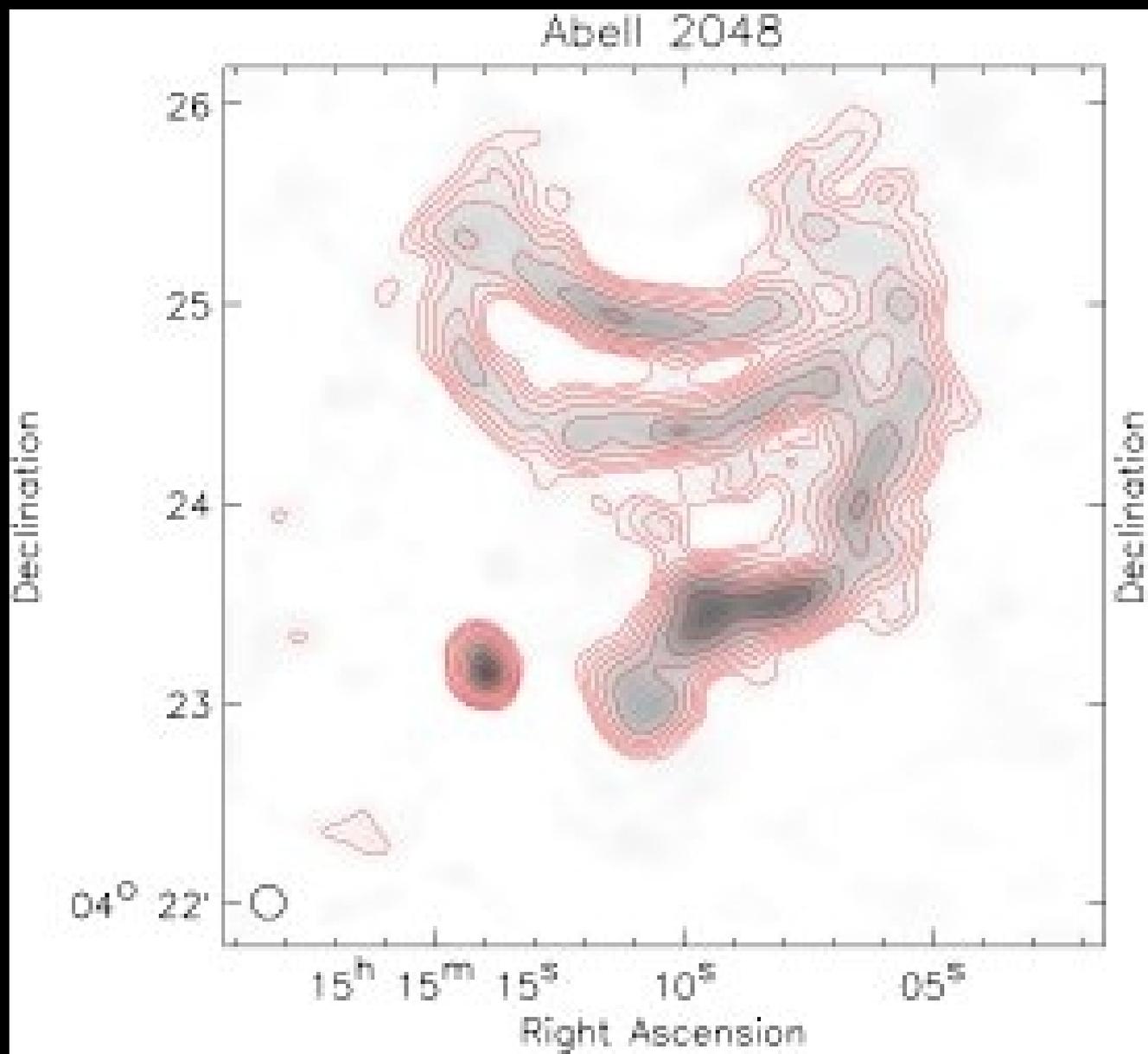
LOFAR LBA

Latest LOFAR images (L60216) . . . A2048



A2048 closeup

Latest LOFAR images (L60216) ... A2048



A2048 closeup

**- comparison
with:**

GMRT 325 MHz

**Weeren+ A&A
527 (2011)**

Conclusions

- Exciting times are ahead as we use LOFAR to investigate steep spectrum sources.
- We will obtain, for the first time, a statistical sample of AGN relics and use it to get a glimpse of how AGN age.

Questions?