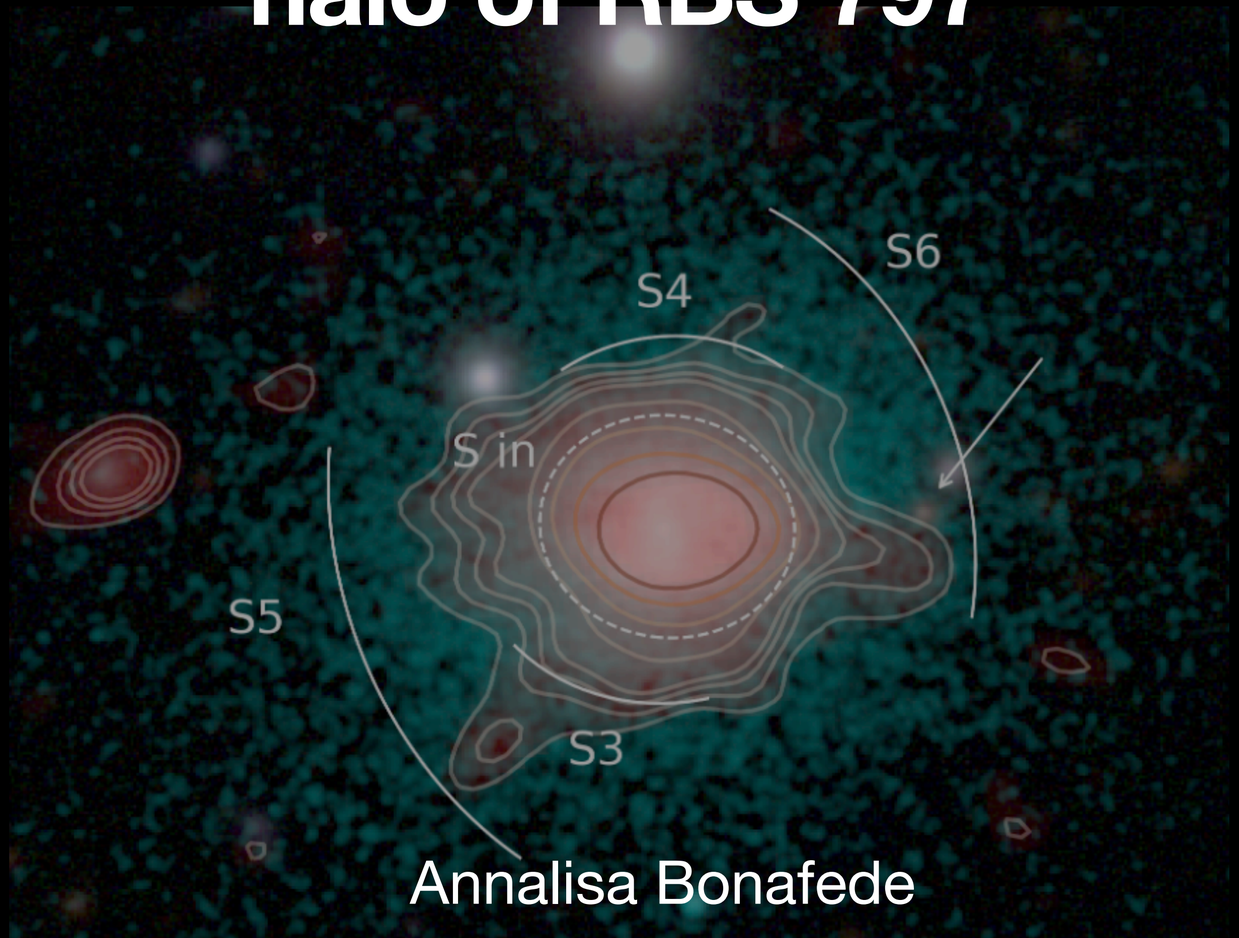
Shock imprints into the radio mini halo of RBS 797



Annalisa Bonafede

with M. Gitti, F. Ubertosi, N. Biava, N. la Bella, G. Lusetti, G. Brunetti M. Brienza, C. J. Riseley, C. Stuardi, A. Botteon, A. Ignesti, R. van Weeren

ERC - Stg16 714245

RBS797

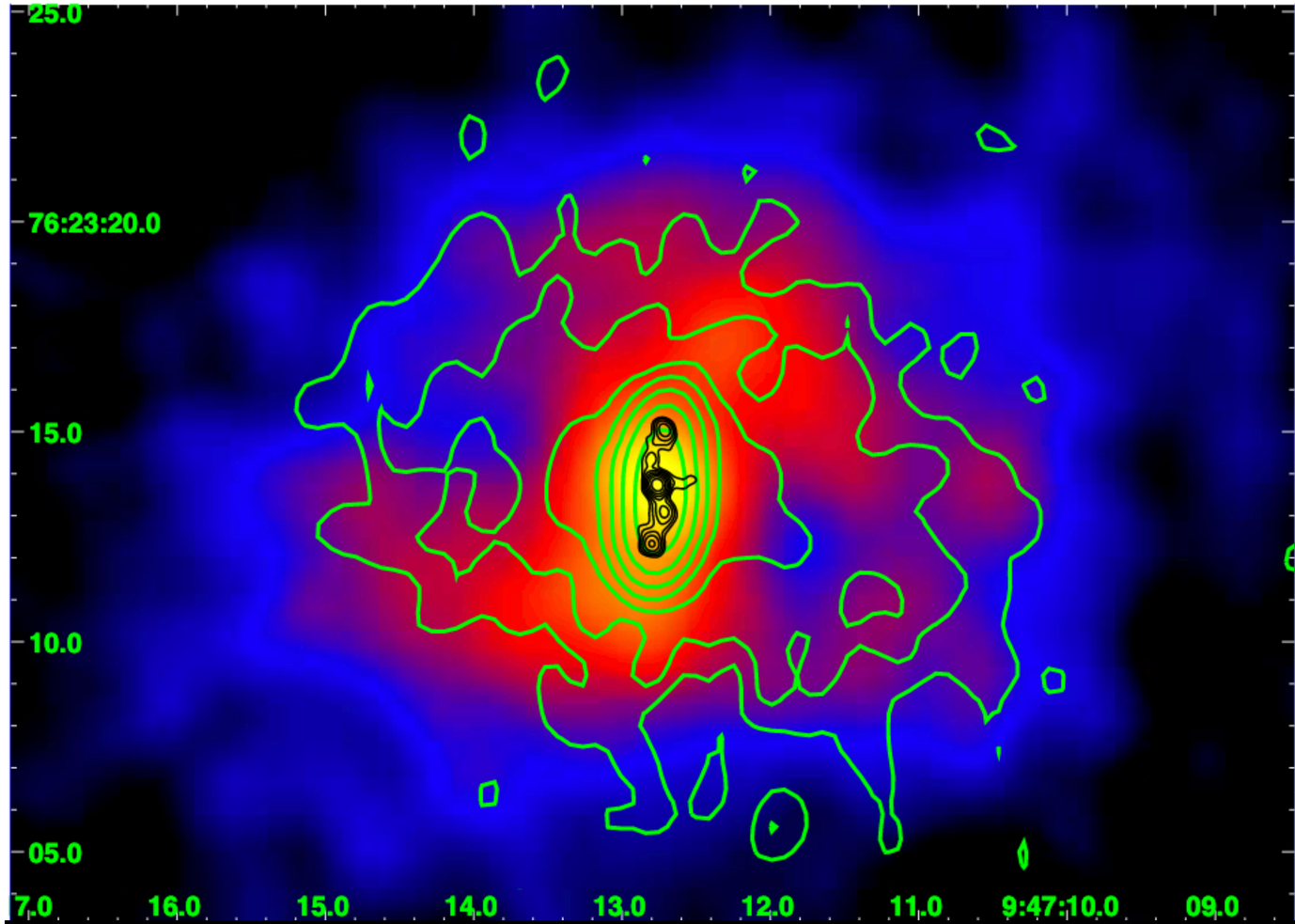
$$M_{500} = (5.6 \pm 0.5) \cdot 10^{14} M_{\odot}$$

z =0.354

cool-core cluster

Central AGN: 2 pairs of jets: NS and EW

challenge: separate AGN and mini halo



Chandra 0.5 - 7 keV in colors

VLA 4.8 GHz (black) beam ~0.3 “

VLA 1.4 GHz (green) beam ~1”

Gitti et al 2006

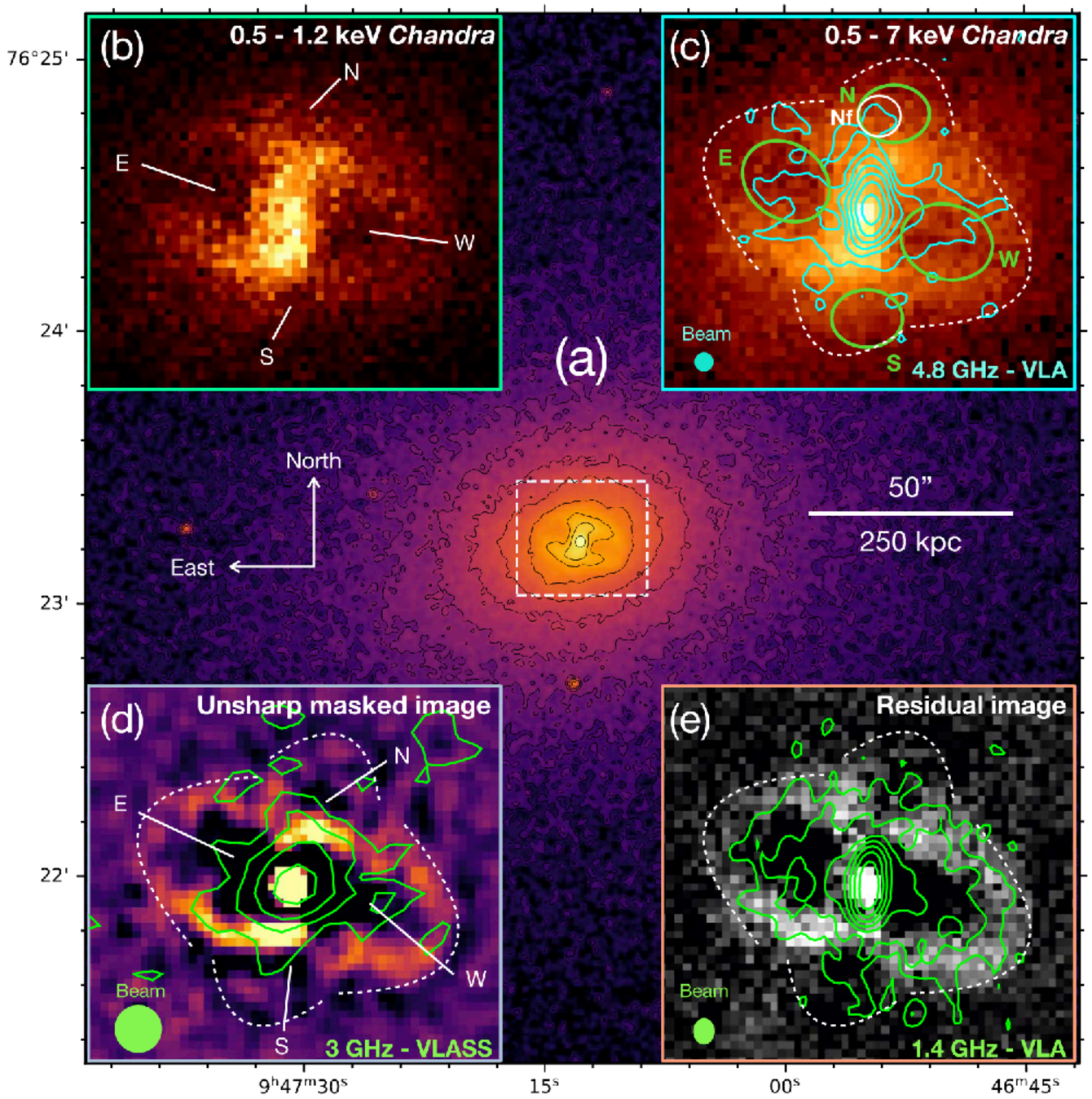
RBS797

Deep Chandra observations (~458 ksec)

2 pairs of cavities

- coeval ($\Delta t < 10\,\mathrm{Myr}$) outbursts

- or rapid re-orientation of the jets



Ubertosi et al (22,23)

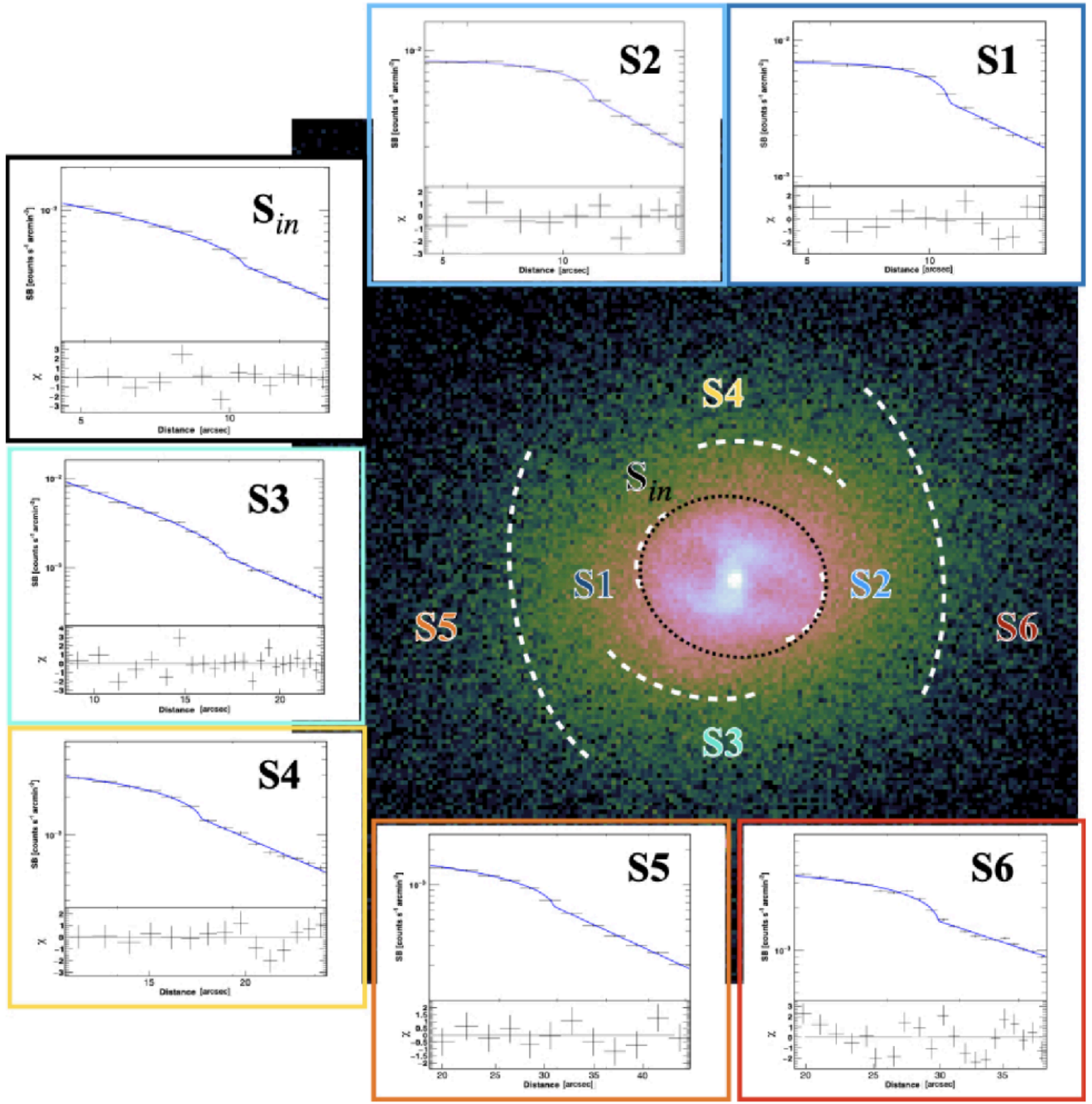
RBS797

Deep Chandra observations (~458 ksec)

3 pairs of shocks

Mach numbers $\mathscr{M} \sim 1.2 - 1.3$

Similar power injected in the ICM ($P \sim 10^{46}$ergs/s every 20-30 Myr)



Ubertosi et al (22,23)

Shocks - diffuse emission interplay?

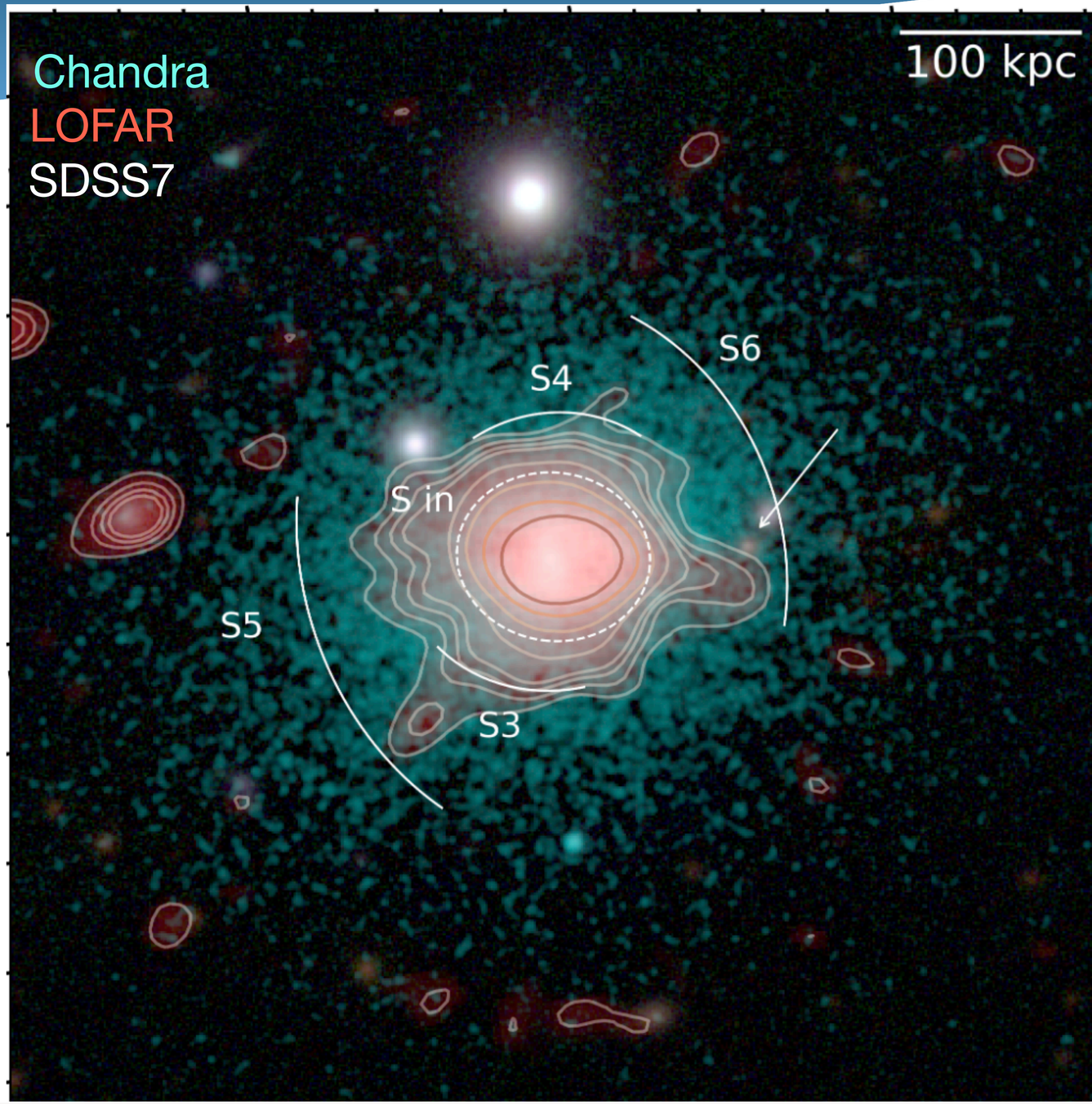
HBA Observations proposed to search for extended emission outside the core (see Nadia Biava's talk on Wednesday)

RBS797

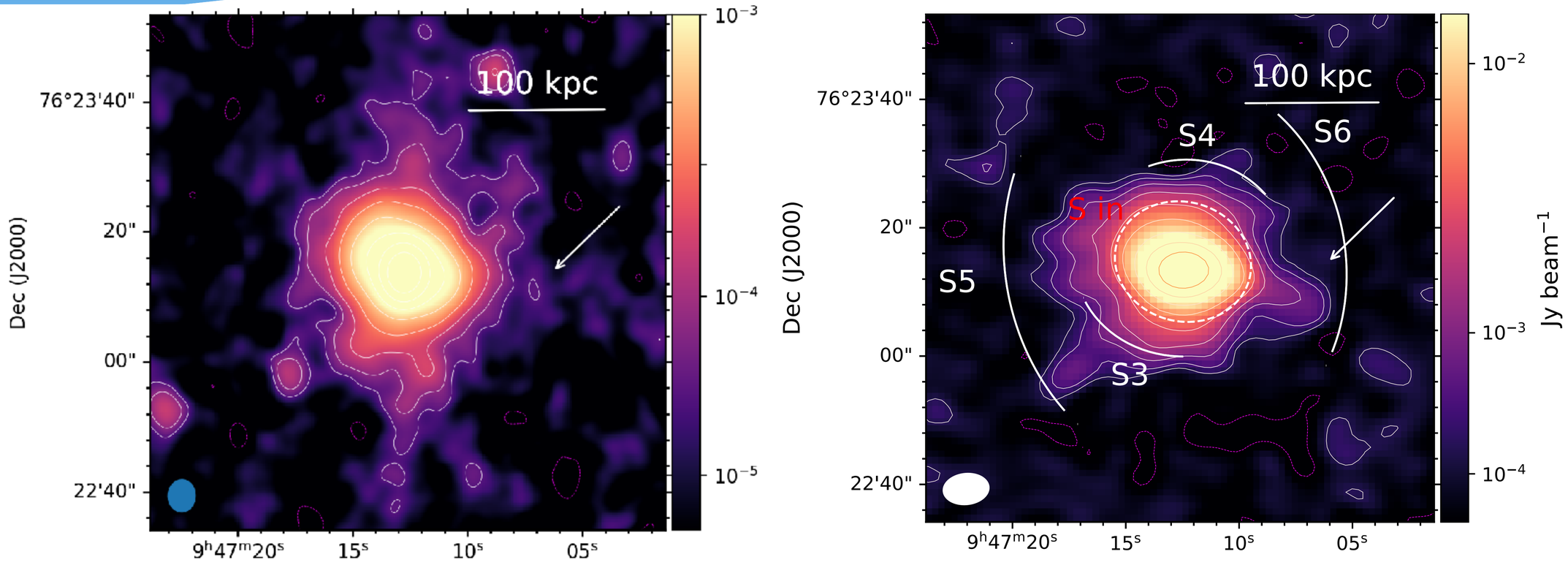
LOFAR HBA (120-168 MHz)

8h on source, same obs setup as LoTSS

Image with Dutch array only (no international stations) res ~5”x7”
rms noise 0.1 mJy/beam

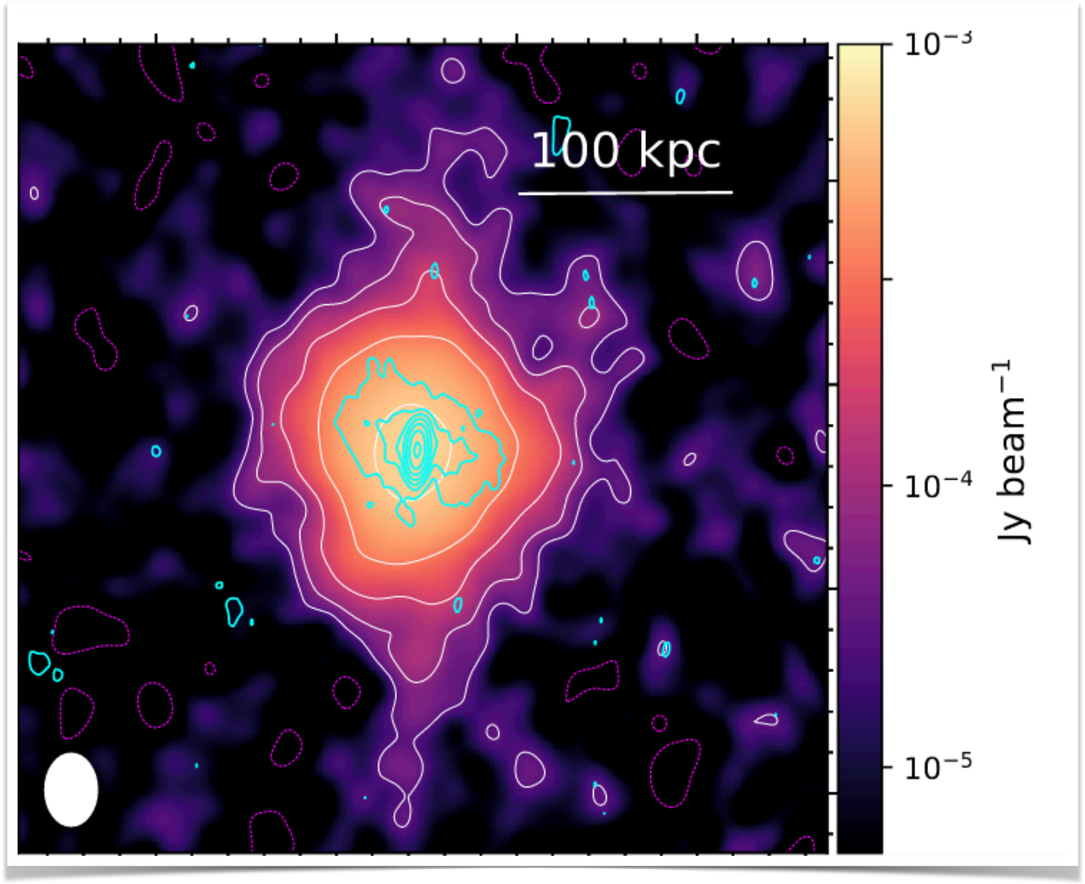


RBS 797: LOFAR vs VLA

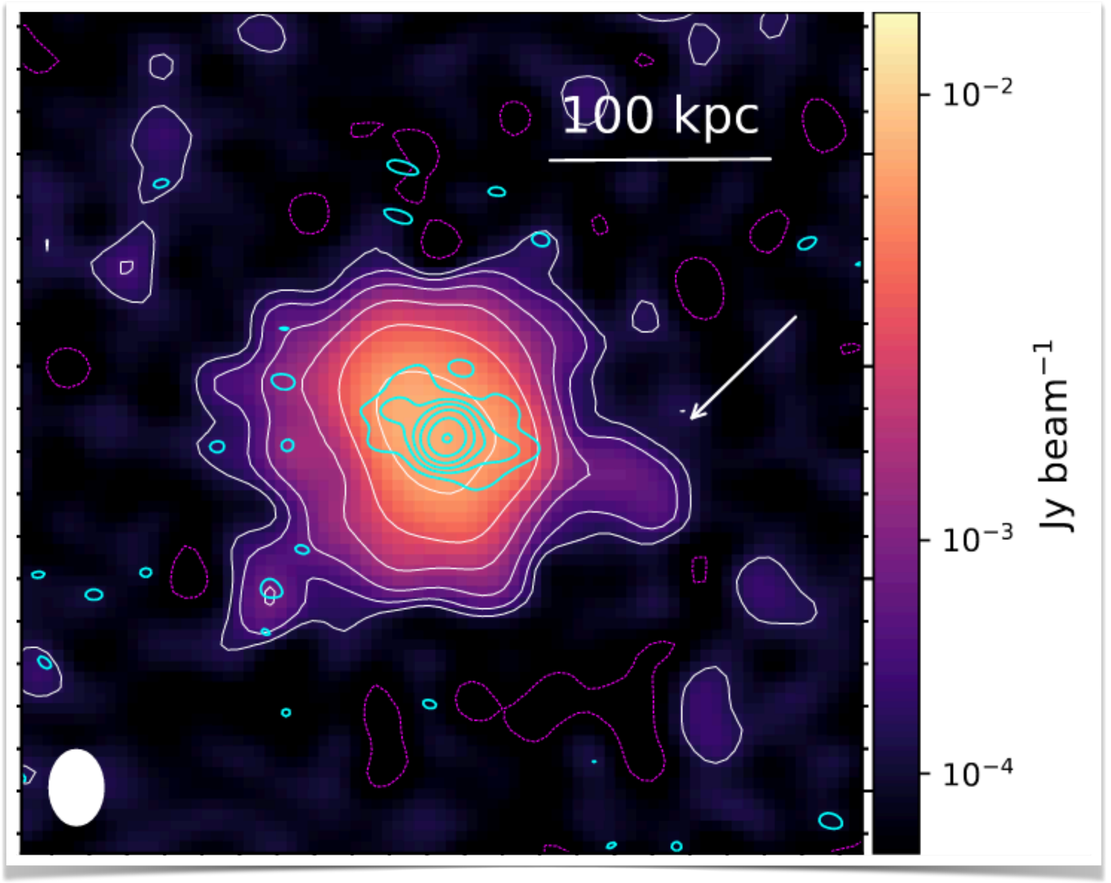


- Different elongation of the mini halo (NS vs EW)
- No more extended emission in LOFAR
- AGN mixed with mini halo emission

AGN and mini halo



VLA - 1.4 GHz array A,B,C combined,
UV subtracted and re-imaged



LOFAR, UV-subtracted

AGN and MINI HALO

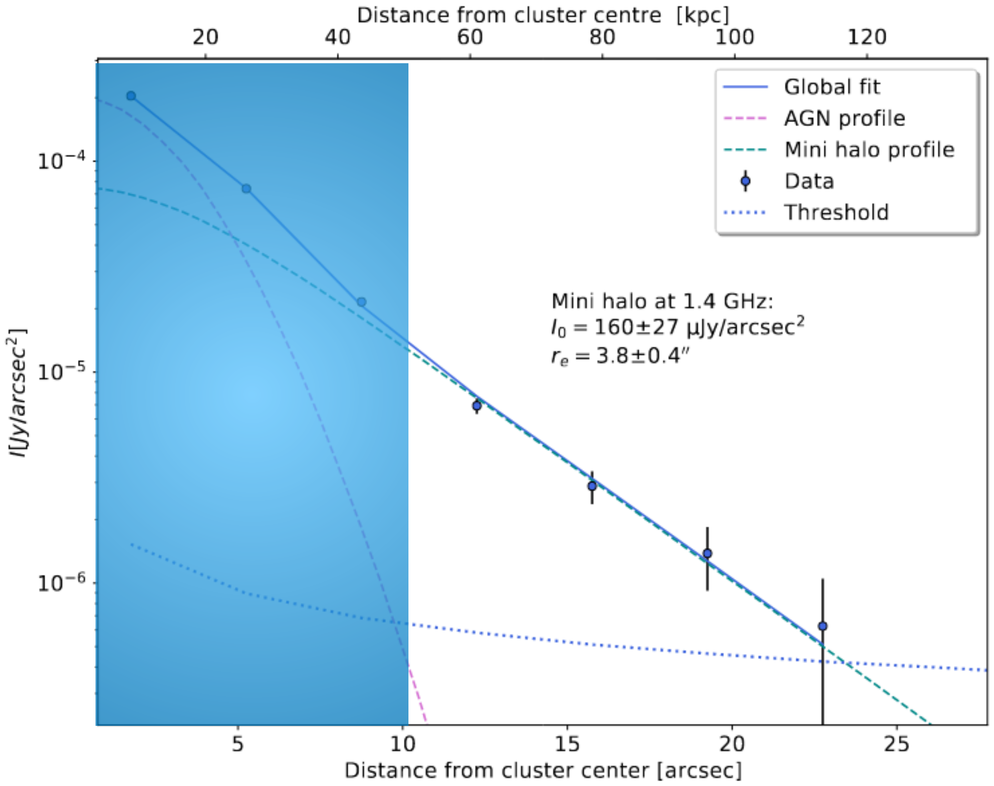
1) Image:
   high and low resolution measurements

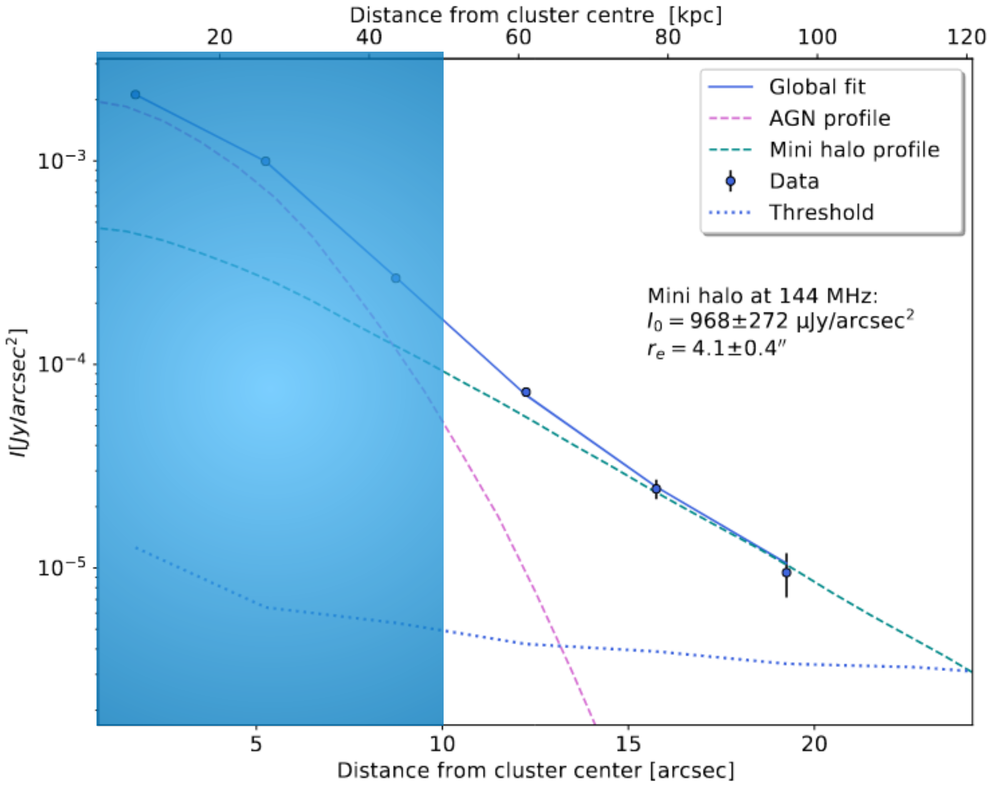
$S_{144\ \mathrm{MHz}}$ mJy	$S_{1.425\ \mathrm{GHz}}$ mJy	α
92±9	8.9±0.4	-1.02±0.05
90±9	8.7±0.4	-1.02±0.05
82±23	11 ± 2	-0.9±0.1
79±8	7.8± 0.4	-1.01 ±0.05

AGN and MINI HALO

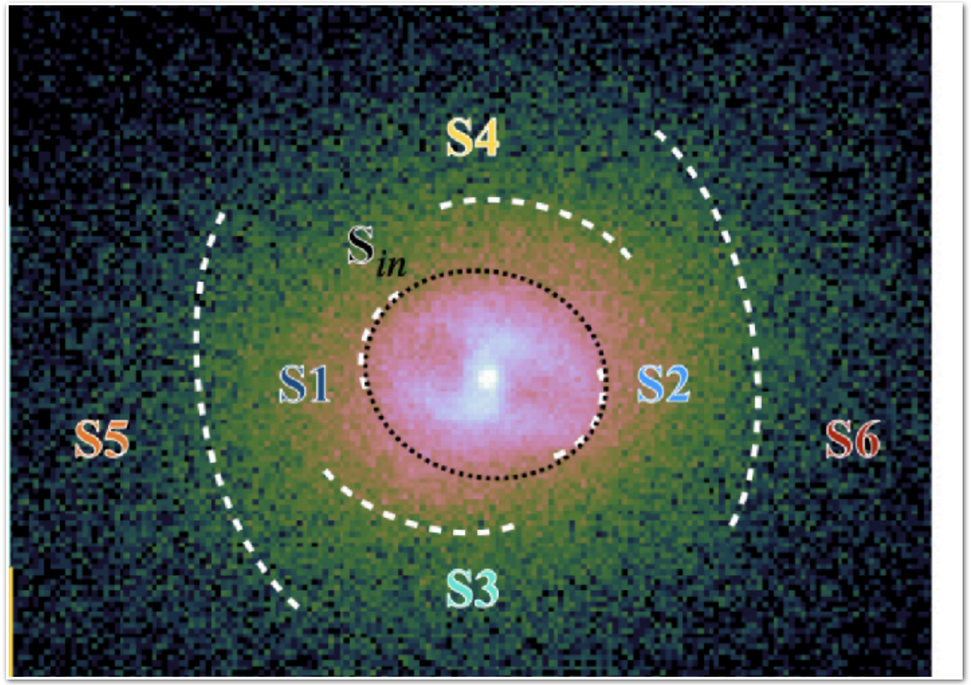
Double fit gives the lowest χ^2 (1.2 ad 0.9 for VLA and LOFAR)

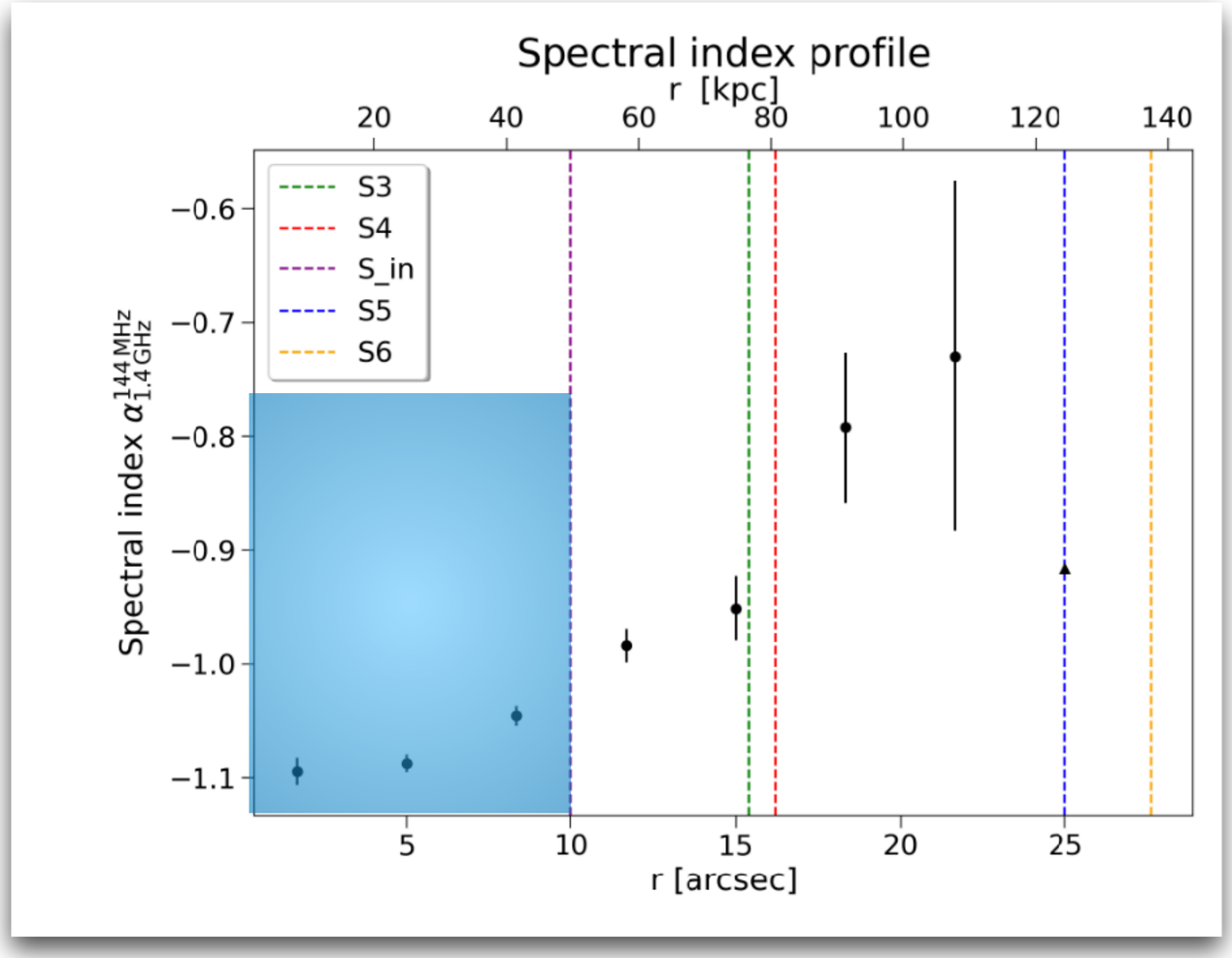
and fit values are slightly in disagreement with previous works





Spectral index trend

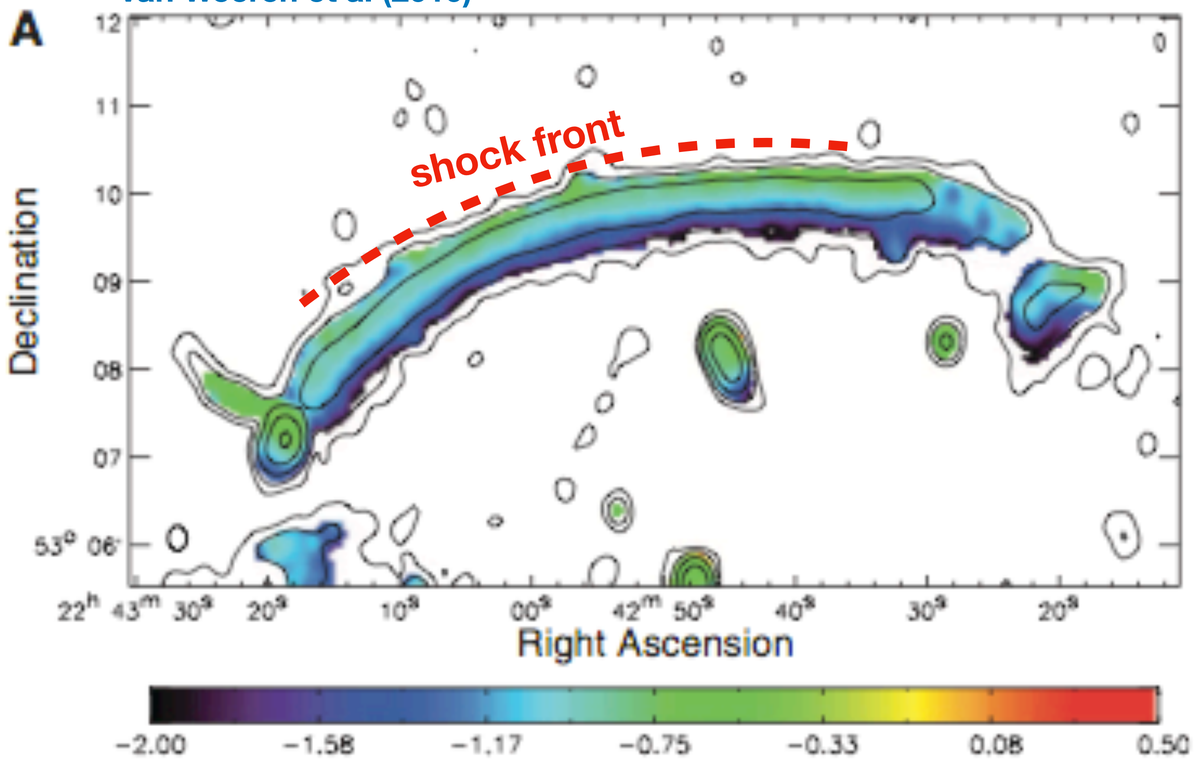




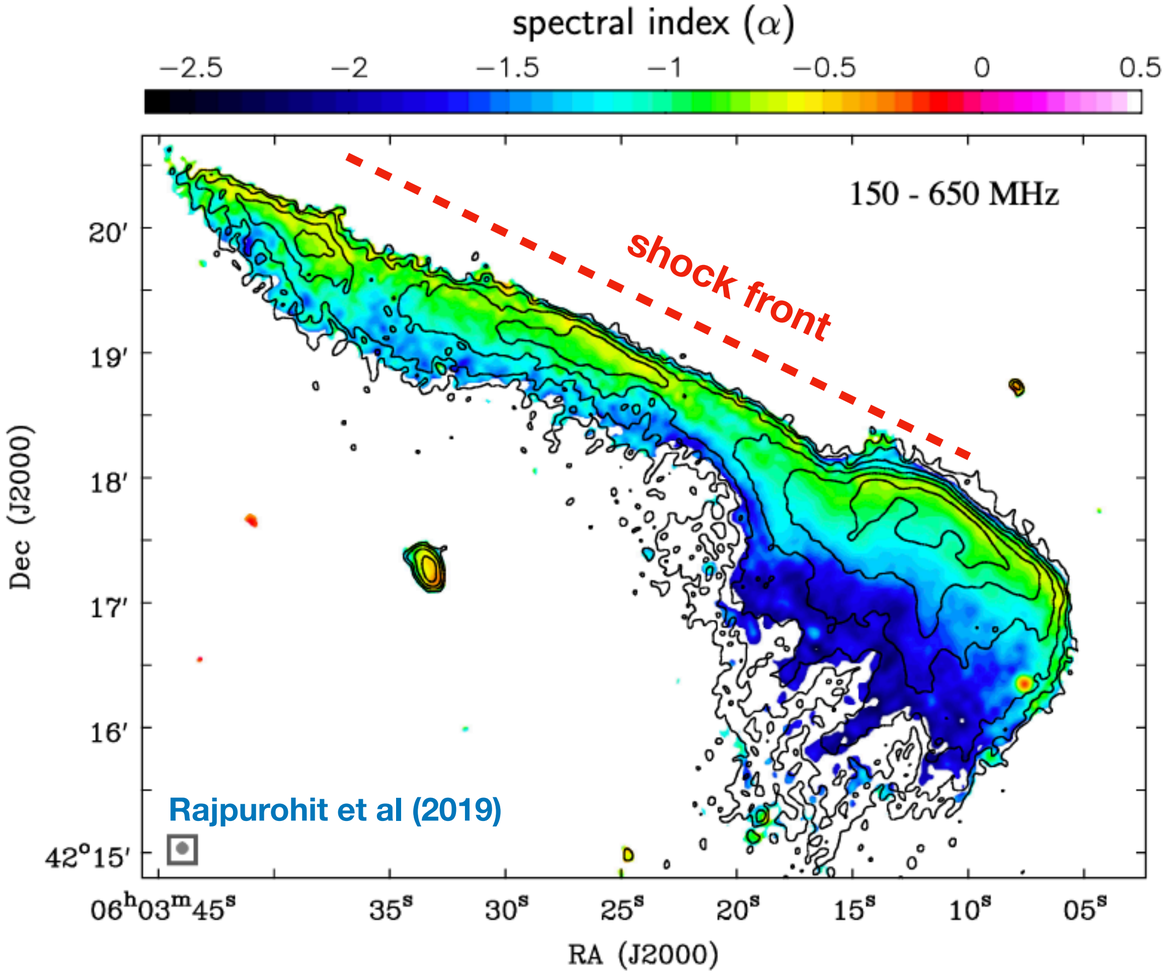
Connection between shocks and radio emission?

1) Shock re-acceleration?

van Weeren et al (2010)



Spectral index α



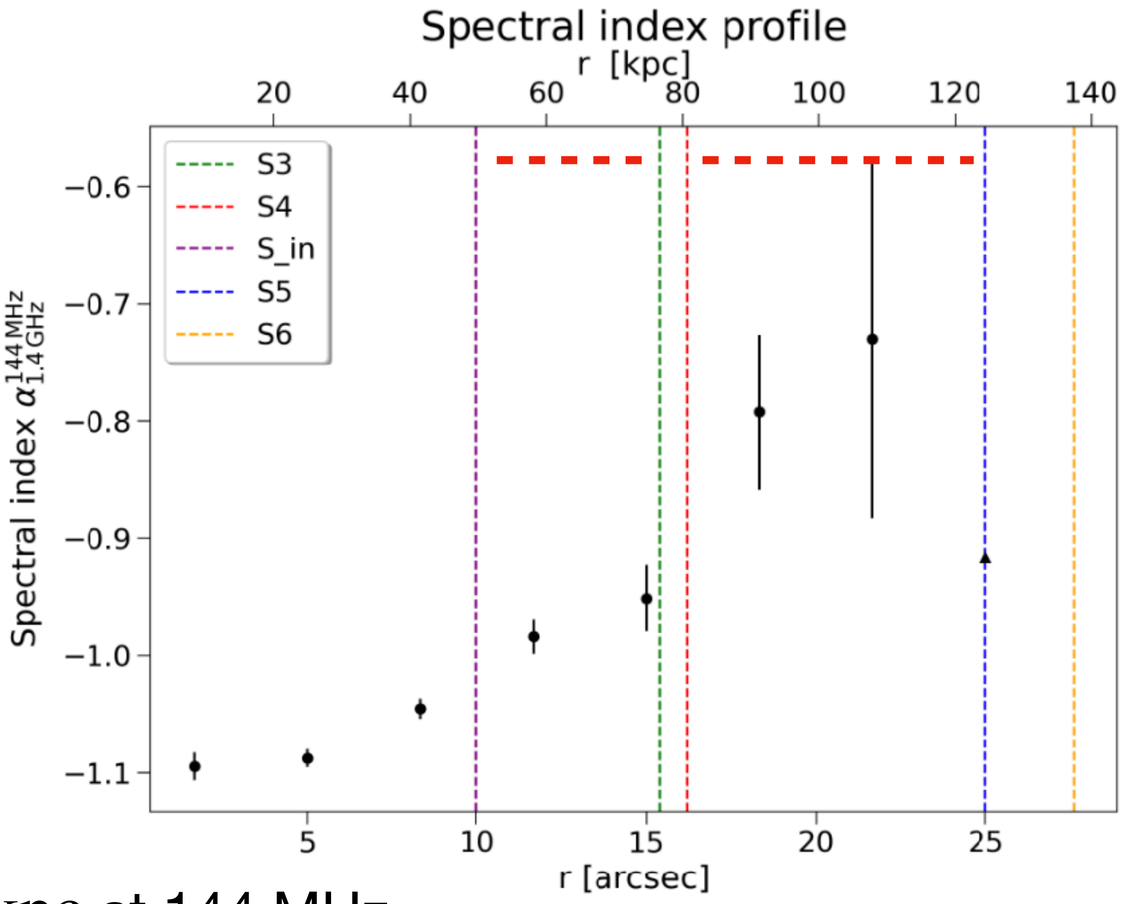
1) Shock re-acceleration?

Kang et al (2012) modelling of seed relativistic electrons re-accelerated by weak shocks

Width of radio emitting regions behind the shock:

$$L_{rad} \approx 765 \cdot \left(\frac{v_d}{10^3\,\mathrm{km/s}}\right) \cdot \left(\frac{B_d^{1/2}}{B_{eff,2}^2}\right) \cdot \left(\frac{\nu}{\mathrm{GHz}}\right)^{-1/2} \mathrm{kpc}$$

Assuming $B(r) = B_0 \left(\frac{n(r)}{n_0}\right)^{2/3}$, $B_0 = 10\mu\mathrm{G}$

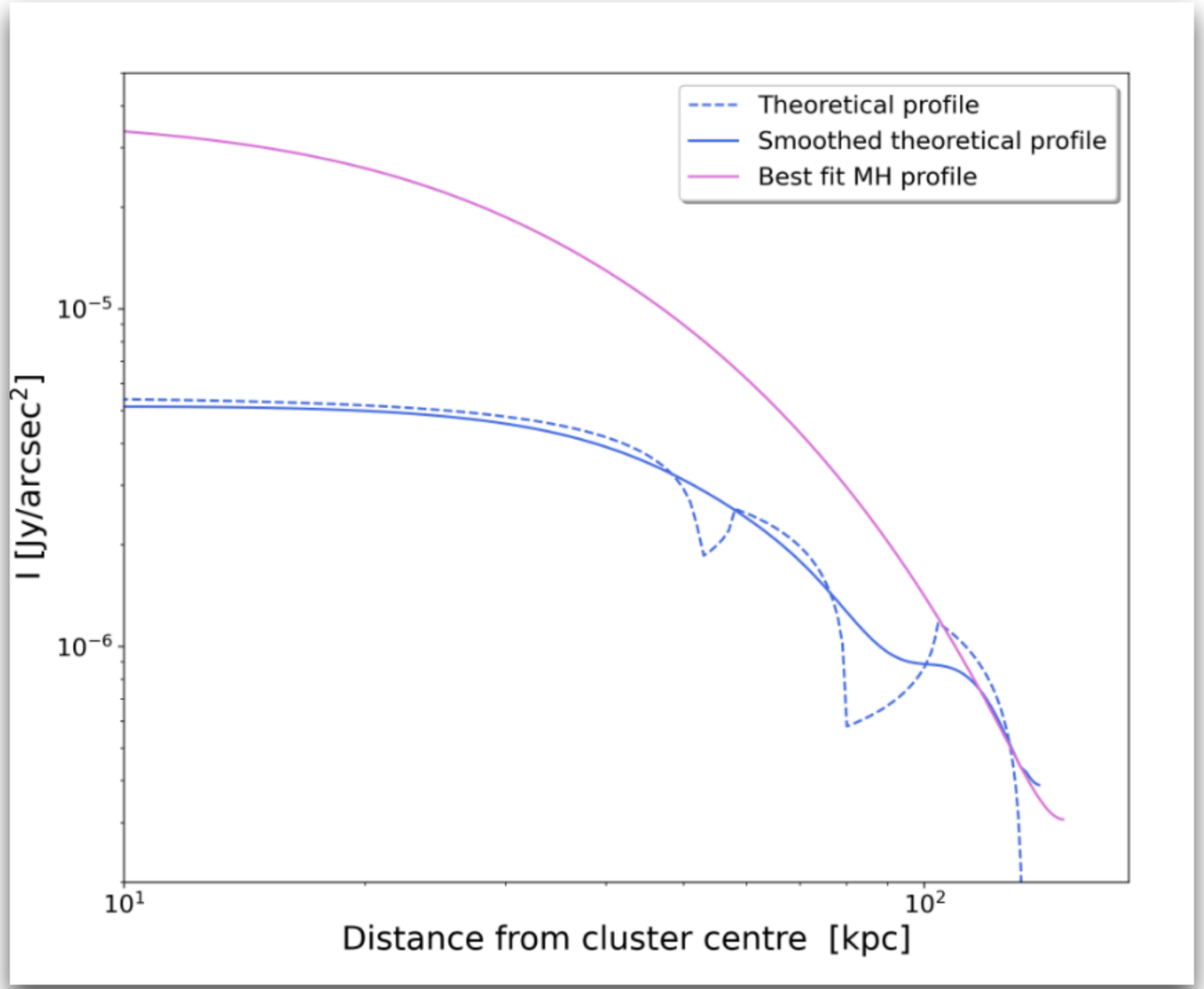


$L_{rad} \sim 16 - 30\,\mathrm{kpc}$ at 1.4 GHz; $L_{rad} \sim 45 - 90\,\mathrm{kpc}$ at 144 MHz

1) Shock re-acceleration?

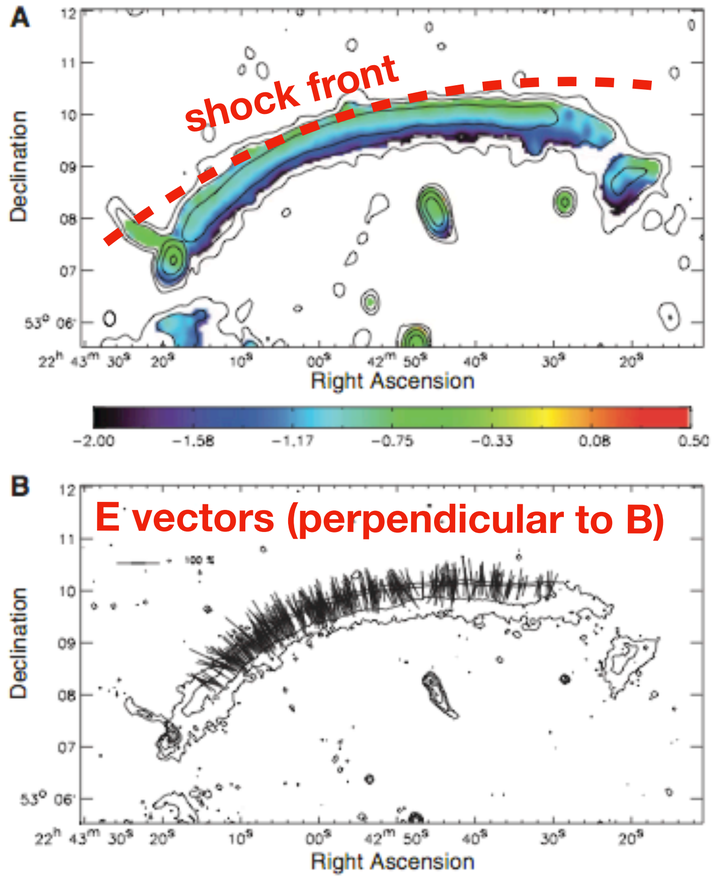
Integrated radio brightness from the superposition of the 3 shocks (normalised at the outer shock)

Assuming seed electrons follow the distribution of the thermal gas



1) Shocks onto pre-existing mini halo?

Shocks injected onto a pre-existing mini halo? Should we observe polarisation?



van Weeren et al (2010)

Depolarisation can be severe in cluster centres

$$P = p_0 e^{-2\sigma_{RM}^2 \lambda^4} e^{2i(\Psi_0 + RM\lambda^2)}.$$

Dispersion of Faraday RM

Assuming $p_0 \sim 25\,\%$ –> $P \sim 7 - 20\,\%$ at 6 GHz for $\sigma_{RM} \sim 300 - 50\,\mathrm{rad/m^2}$

1) Shocks onto pre-existing mini halo?

Draft by Gitti et al (2006)
it didn't make it to the final version

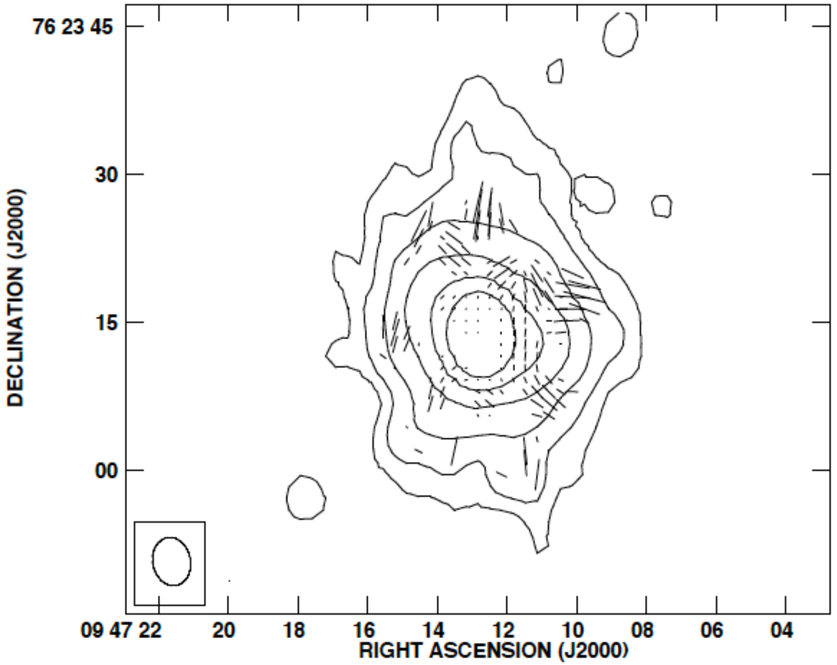


Fig. 2. 1.4 GHz VLA map of RBS797 at a resolution of 4″.9 × 3″.8. The contour levels are −0.08 (dashed), 0.08, 0.15, 0.30, 0.60, 1.20, 2.50 mJy/beam. The r.m.s. noise is 0.03 mJy/beam.

Polarisation map from VLA data (Gitti et al 2006) mini halo + AGN

"*polarisation at 10-15 % level in a region at 10-15 arcsec from the cluster centre*"

Marginal detection once the central AGN is subtracted and C array data are included

…but promising!

2) Turbulent re-acceleration in a high magnetic field?

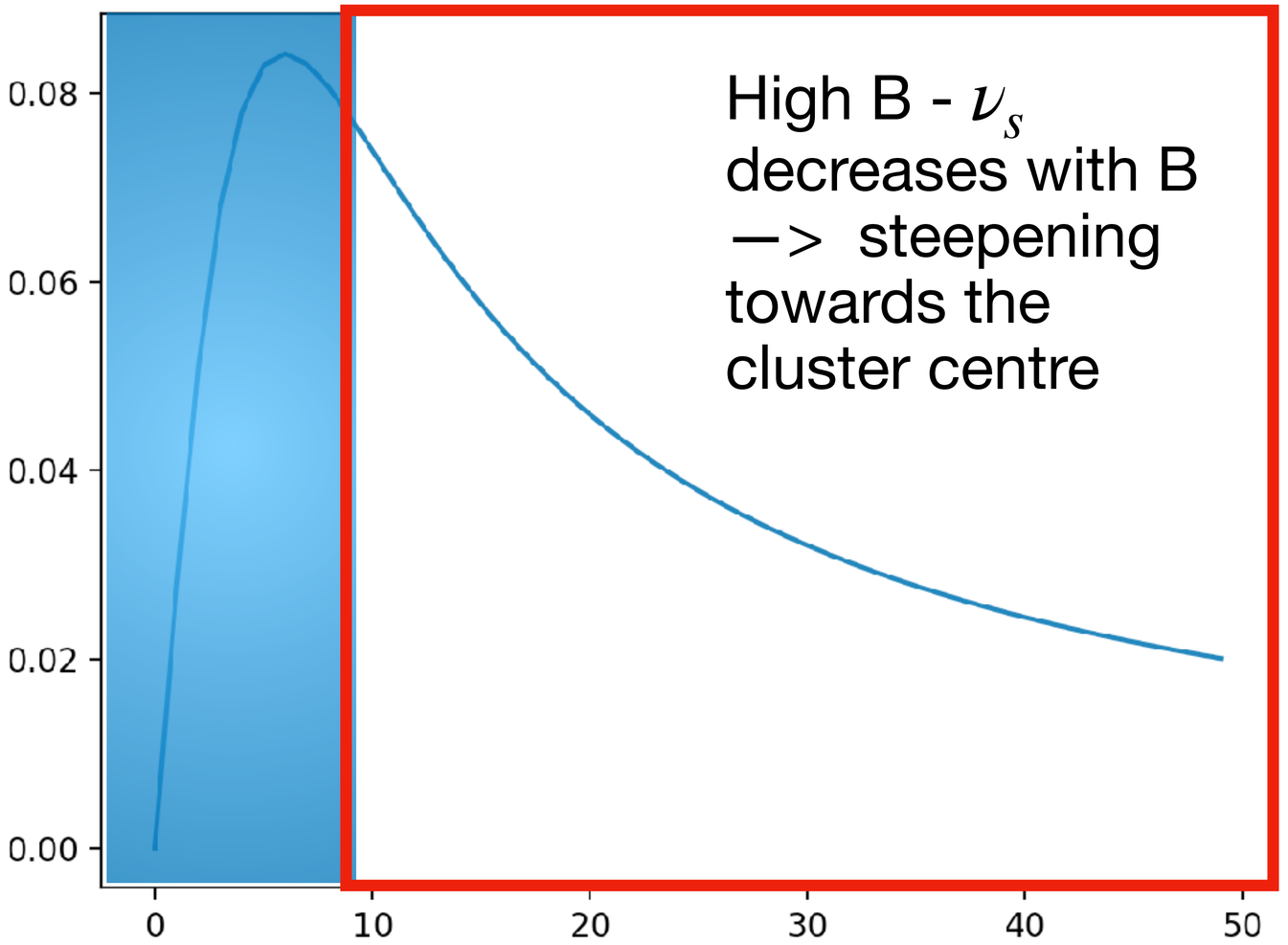
Assuming homogeneous condition and constant acceleration time

$$\nu_s \propto \frac{B}{(B^2 + B_{CBR}^2)^2}$$

To have a flattening up to 22”

$$\text{—> } B_0 > 15\ \mu\text{G}$$

—> steepening expected at larger radii



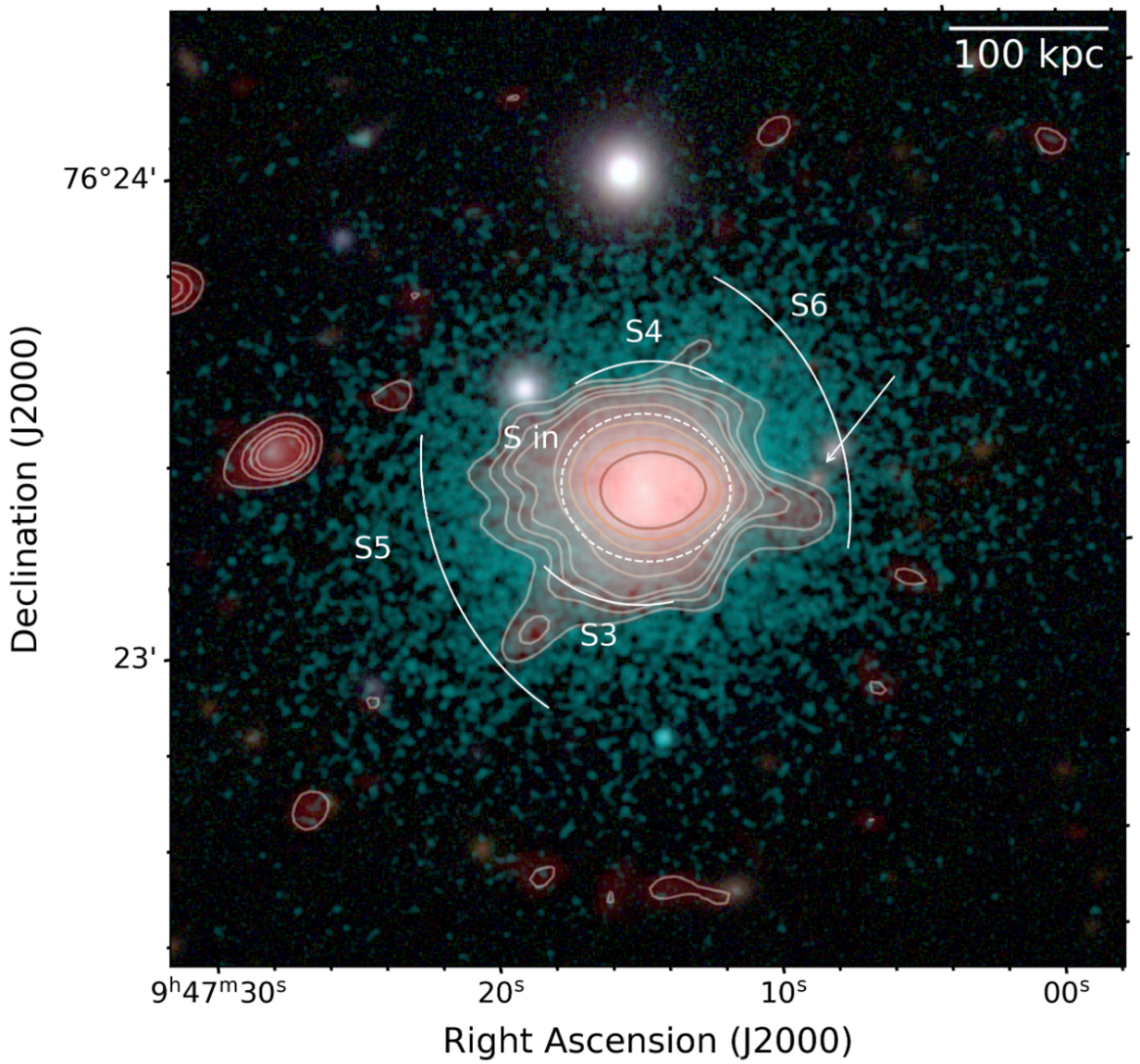
Summary

The mini halo in RBS 797

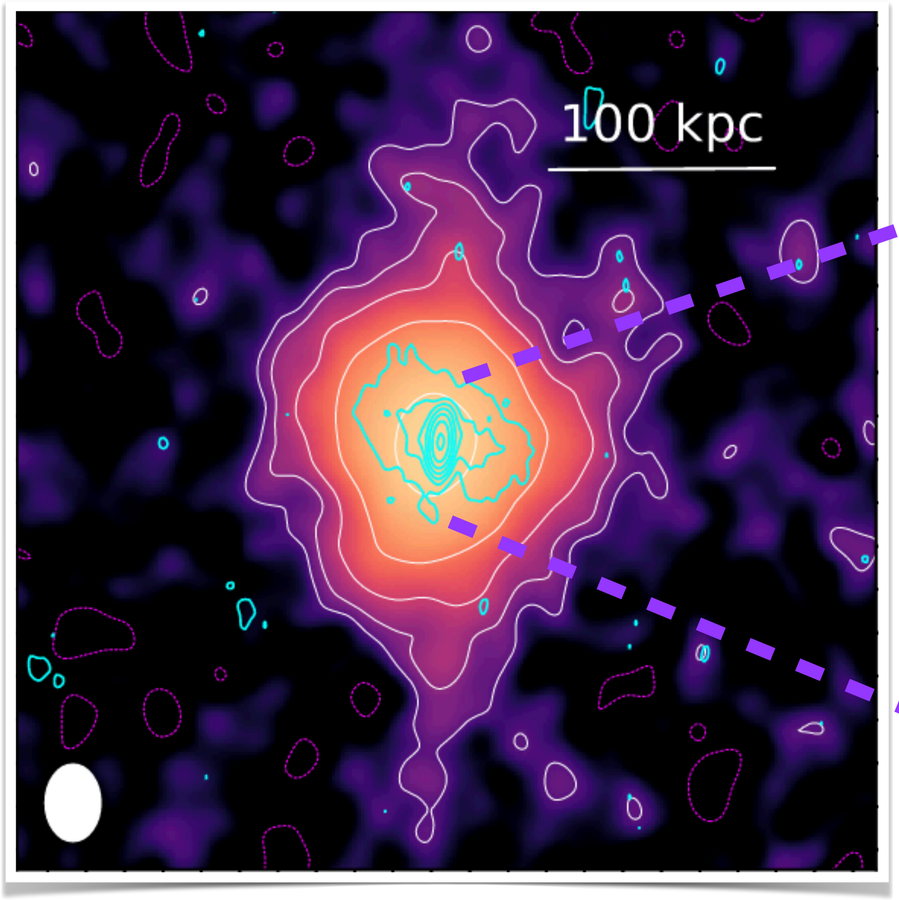
- 3 pairs of shocks
- flattening of the spectral index

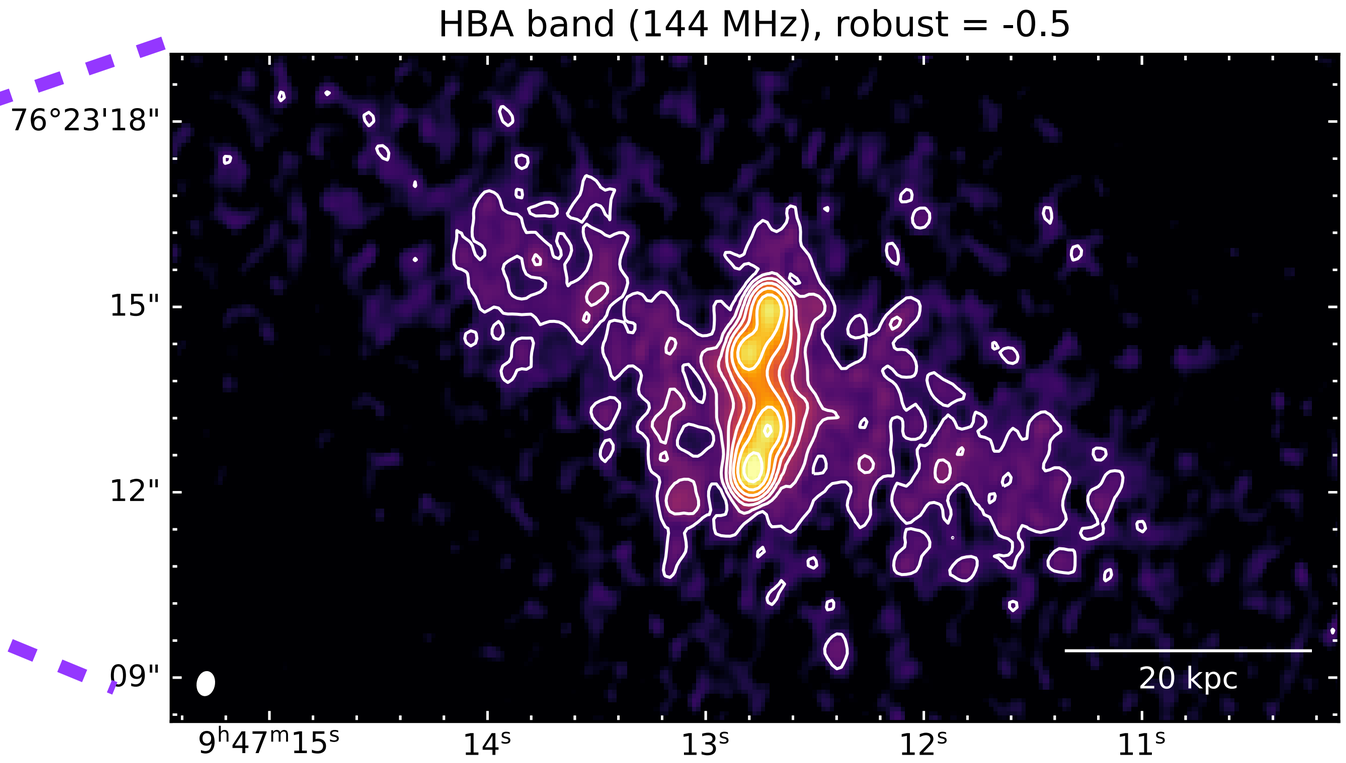
—> Shocks leaving imprints on the mini halo or turbulence re-acceleration in a high B? **Constraints on B needed!**

New polarisation observations obtained at the VLA (PI F Ubertosi)



RBS 797 at 0.3” resolution





F. Ubertosi et al (in preparation)