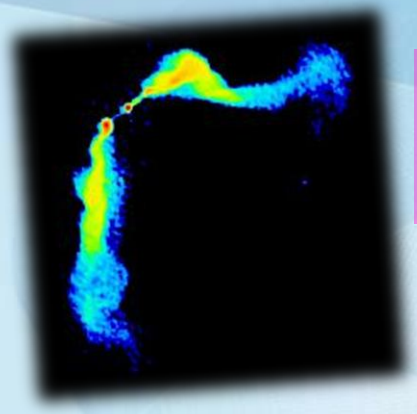
New detections of radio halos in galaxy clusters with low frequency GMRT observations

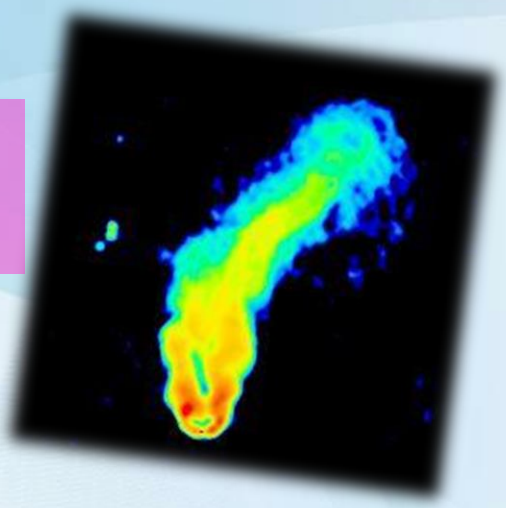
Virginia Cuciti

In collaboration with G. Brunetti, D. Dallacasa, R. van Weeren, A. Bonafede, R. Cassano....

Radio diffuse sources in galaxy clusters



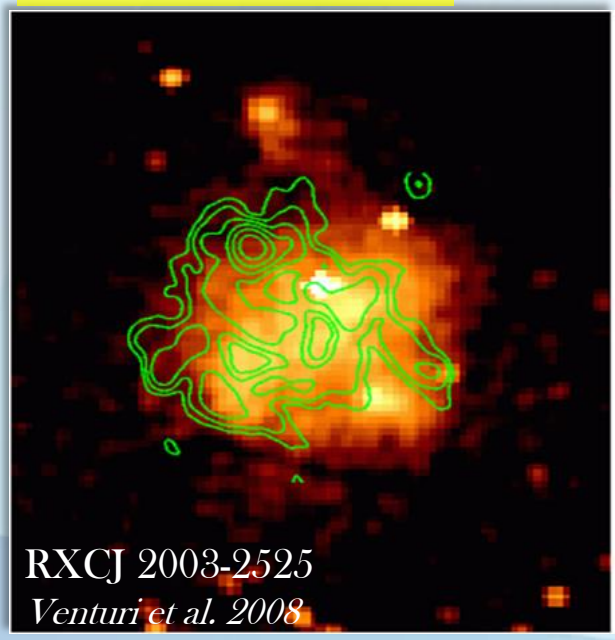
Distorted radio galaxies



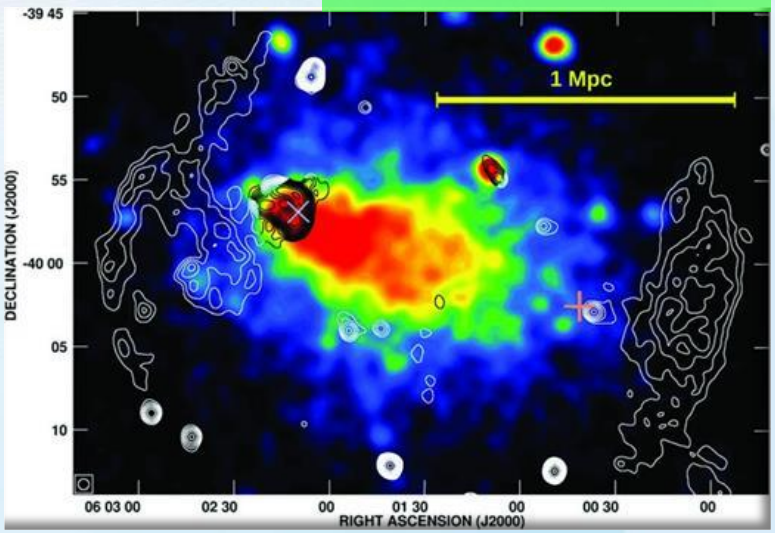
3C465 in A2634 *(Eilek et al. 1984)*

NGC 1265 in Perseus *(O' Dea & Owen ,1986)*

Radio halos



Radio relics



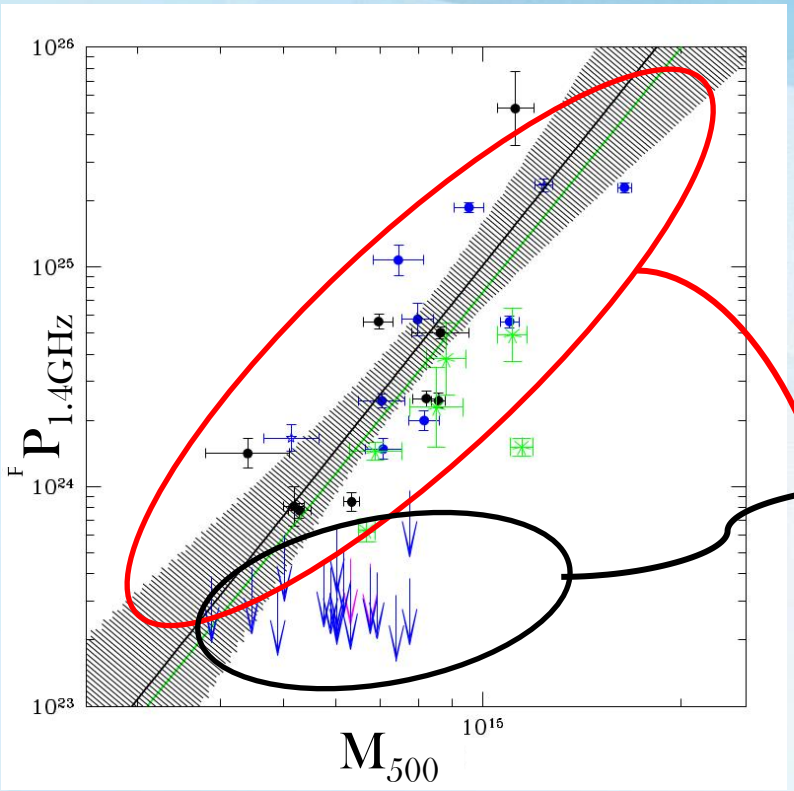
A3376 (*Kale et al. 2012)*

Radio halos: observational results

GMRT Radio Halo Survey (GRHS, *Venturi et al. 2007, 2008, Kale et al. 2013,2015*):

X-ray selected sample of galaxy clusters with:

- $L_X > 5\times10^{44}$ erg/s
- $0.2 < z < 0.4$
- $\delta \geq -30°$



Radio bimodality

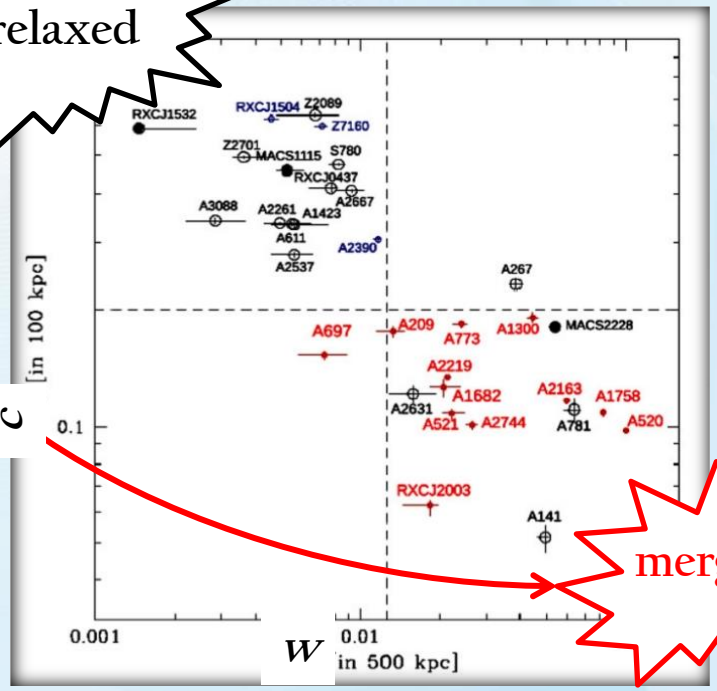
(Cassano et al. 2013)

RH-merger connection

(Cassano et al. 2010)

relaxed

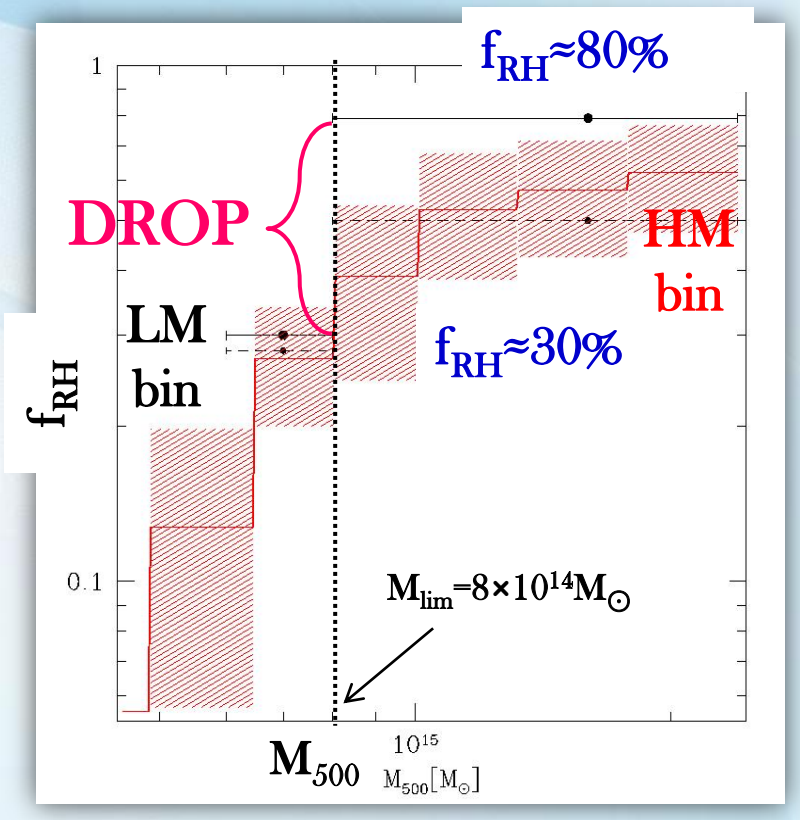
merger



A ‘mass’-selected sample

From the Planck SZ cluster catalogue
(Planck Collaboration 2014):

- $M_{500} \gtrapprox 6\times10^{14} M_{\odot}$
- $0.08<z<0.33$



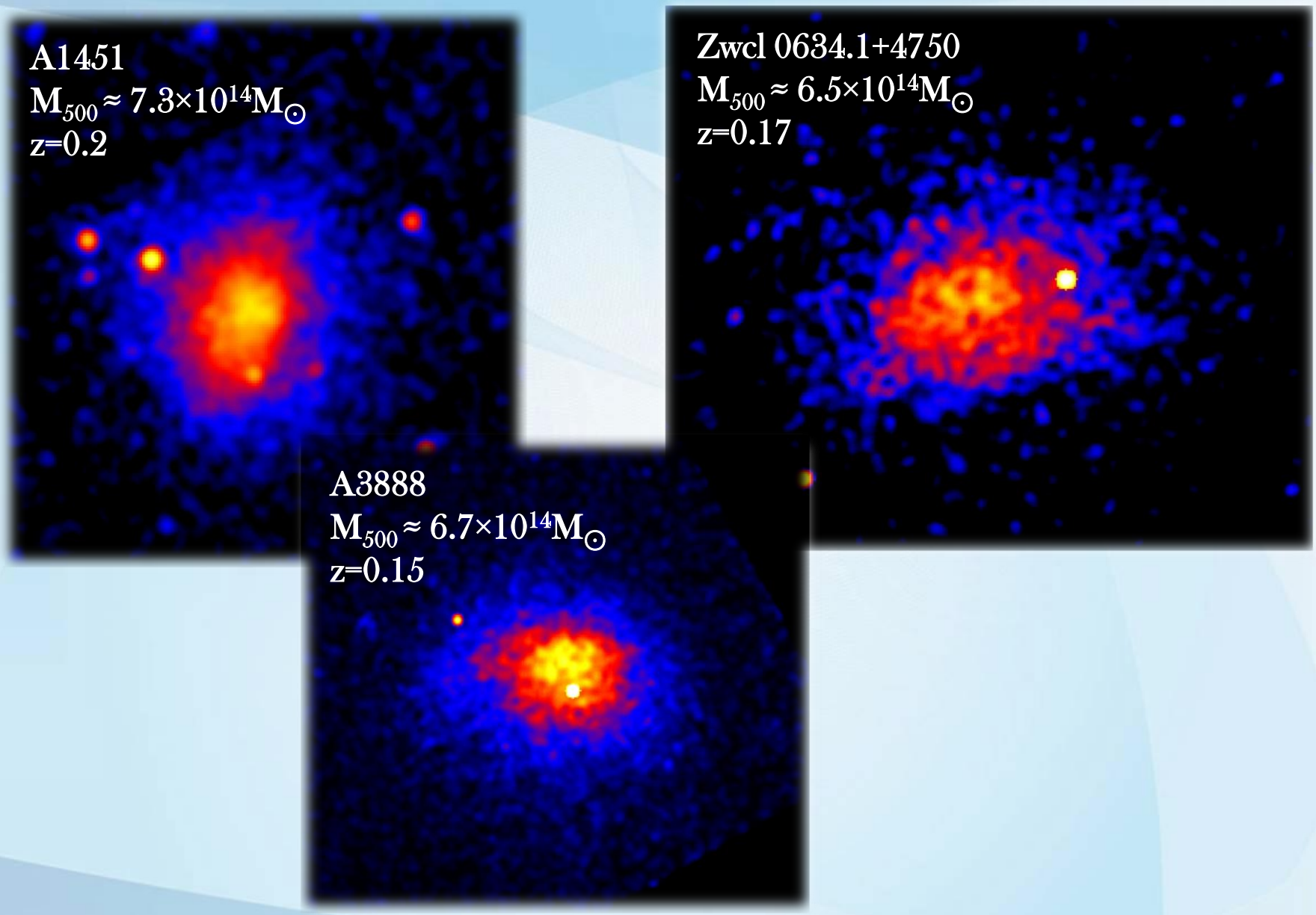
Total of 75 clusters with deep radio observations (GMRT 330/610 MHz and/or JVLA 1.4 GHz)

First result based on a subsample of 57 clusters

Fraction of RHs drops in low mass clusters

(Cuciti et al. 2015)

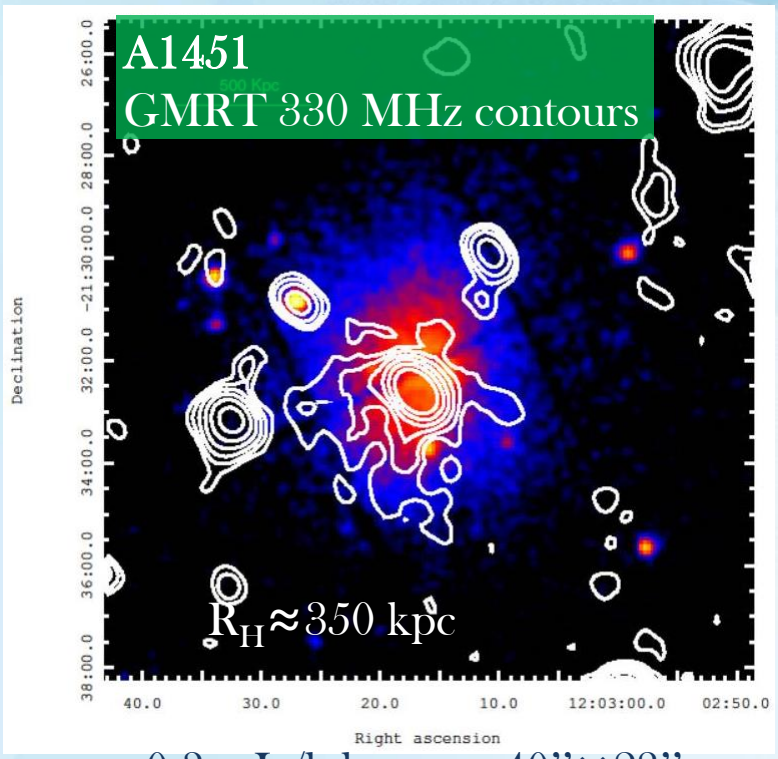
Detection of diffuse radio emission in three clusters



Discovery of radio halos in A1451 and Z0634

(Cuciti et al. submitted)

GMRT 330 MHz and JVLA D array and B array L-band observations

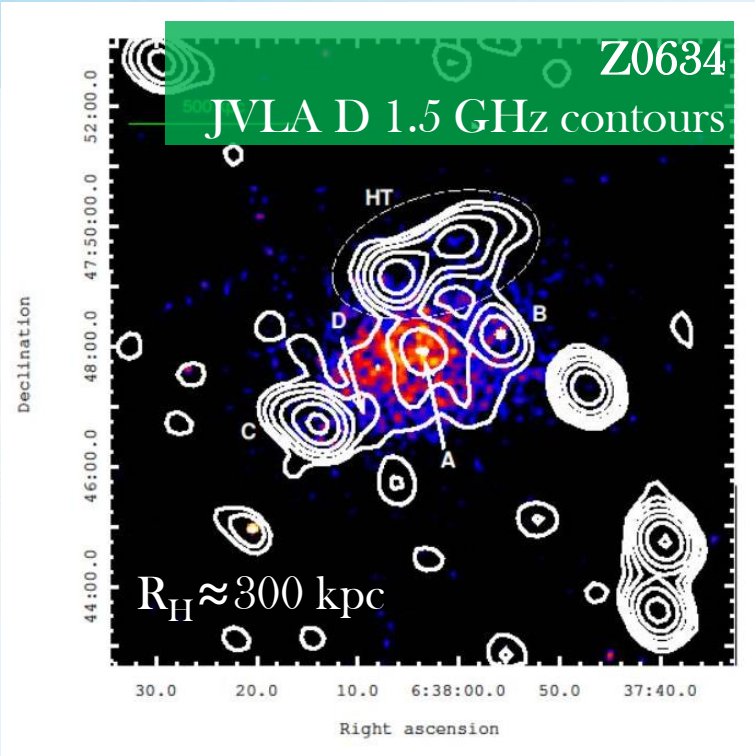


rms ≈0.3 mJy/b beam ≈40”×28”

S_{330MHz}= 32.6±3.8 mJy

$S_{1.5GHz}$= 5.0±0.5 mJy

$\alpha \approx -1.2$



rms ≈ 45 μJy/b beam ≈ 36”×30”

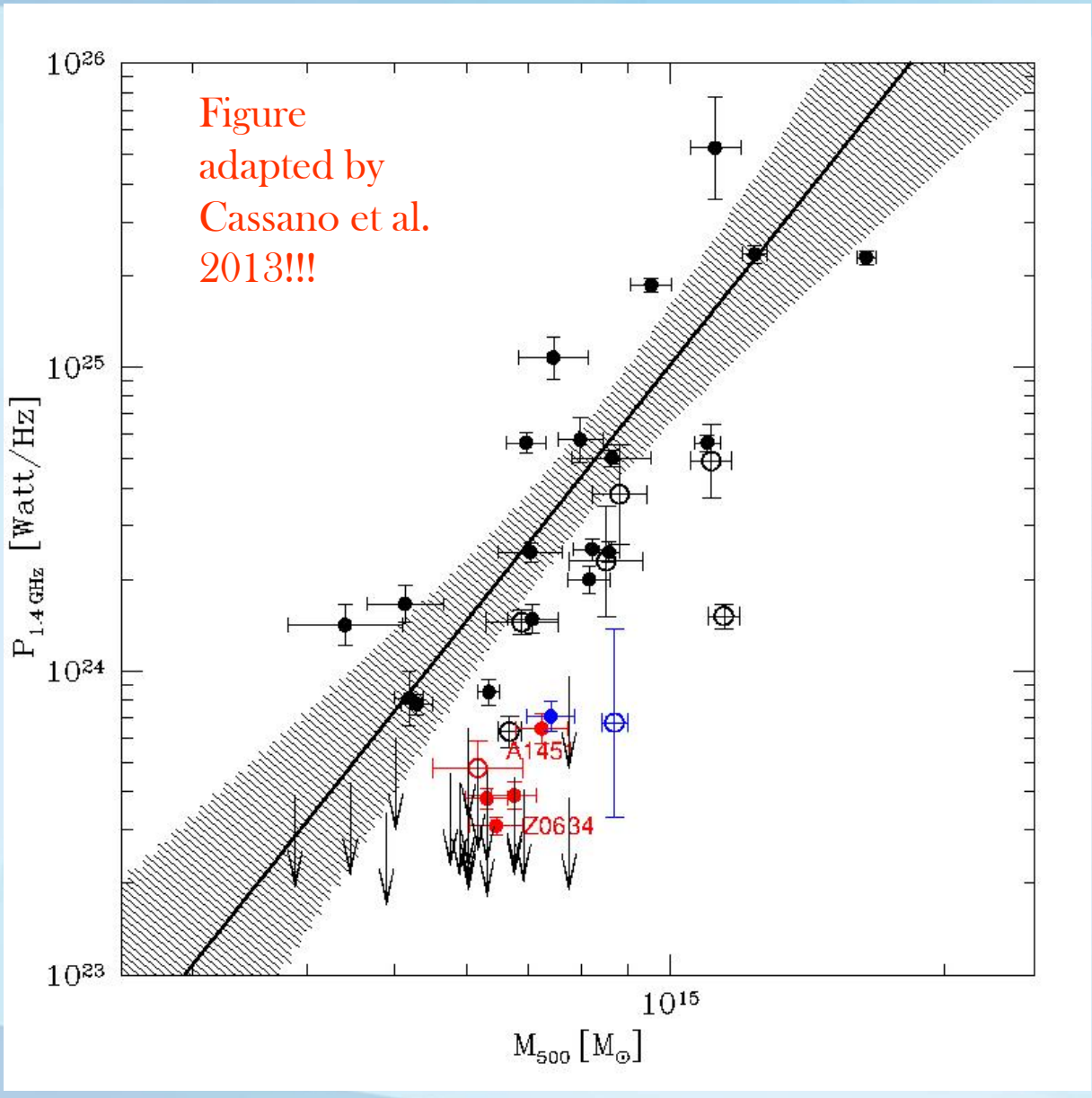
S_{330MHz}= 20.3±2.7 mJy

$S_{1.5GHz}$= 3.3±0.2 mJy

$\alpha \approx -1.1$

Injections $\Longrightarrow \alpha \approx -1$

Underluminous (wrt to $P_{1.4GHz}$-M correlation) radio halos



There are 7 underluminous radio halos in the Cuciti et al. 2015 sample:

A1451

Z0634

A3411 *(van Weeren et al. 2013)*

A2218 *(Giovannini & Feretti 2000)*

RXC J1314.4-2515 *(Venturi et al. 2007;2013)*

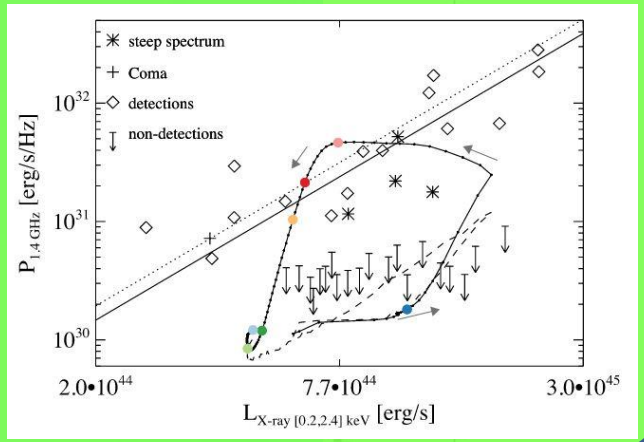
A2261 *(Sommer et al. 2017)*

A2142 *(Farnsworth et al. 2013, Venturi et al. 2017)*

REFERENCE numbers:
Total of 75 clusters
With ~ 30 RHs

Underluminous (wrt to $P_{1.4GHz}$-M correlation) radio halos

I) Evolutionary stage *(Donnert et al. 2013)*



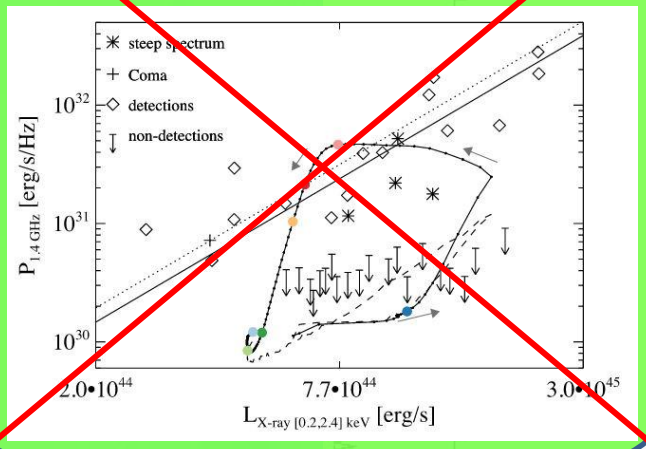
II) USSRH from less energetic merger events or high redshift clusters (e.g. Cassano et al. 2006, Brunetti et al. 2008)

III) Minor mergers where turbulence is dissipated in smaller volumes.

IV) Hadronic origin 'off-state' radio halos (Brunetti & Lazarian 2011, Brown et al. 2011)

What about A1451 and Z0634?

I) Evolutionary stage *(Donnert et al. 2013)*



$\alpha \approx -1$

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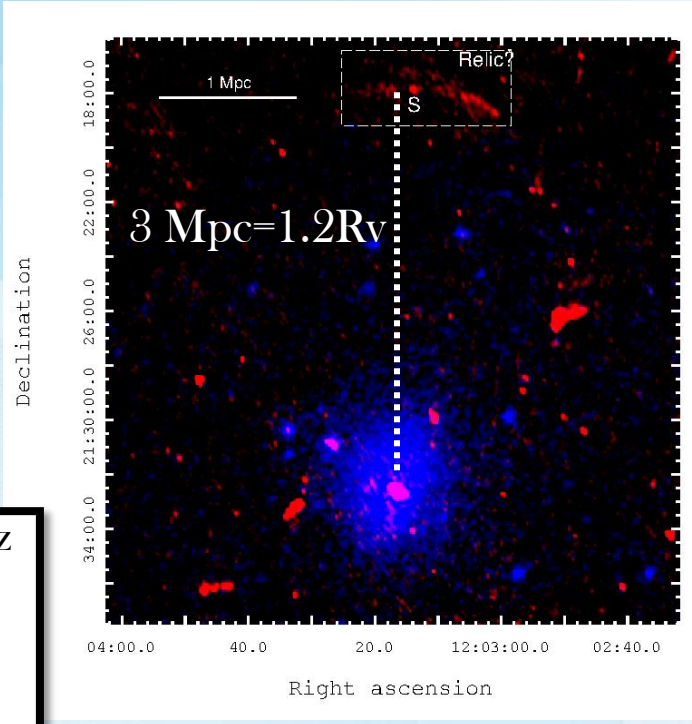
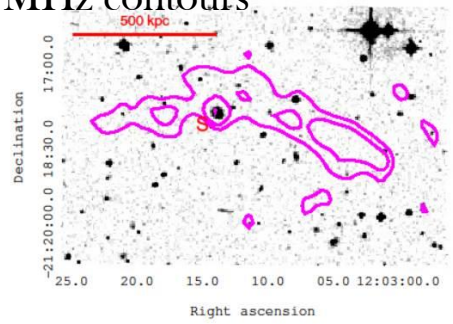
Candidate radio relic in A1451 *(Cuciti et al. submitted)*

Radio power $P_{1.4GHz}=1.1\pm0.6\times10^{24}$W/Hz

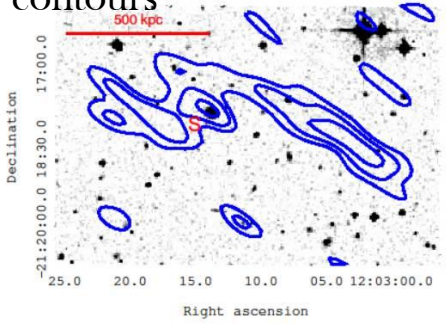
Spectral index $\alpha=1.1\pm0.1$



Optical SDSS+GMRT 330 MHz contours



Optical SDSS+JVLA 1.5 GHz contours

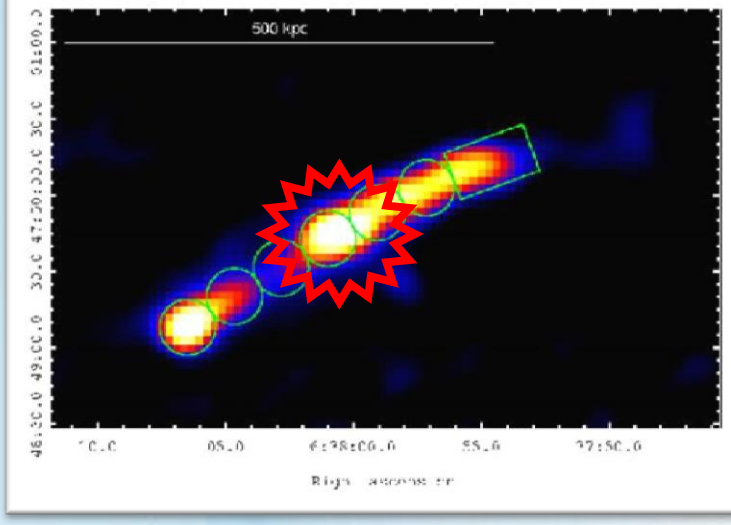


Blue: XMM-Newton. Red: GMRT 330 MHz

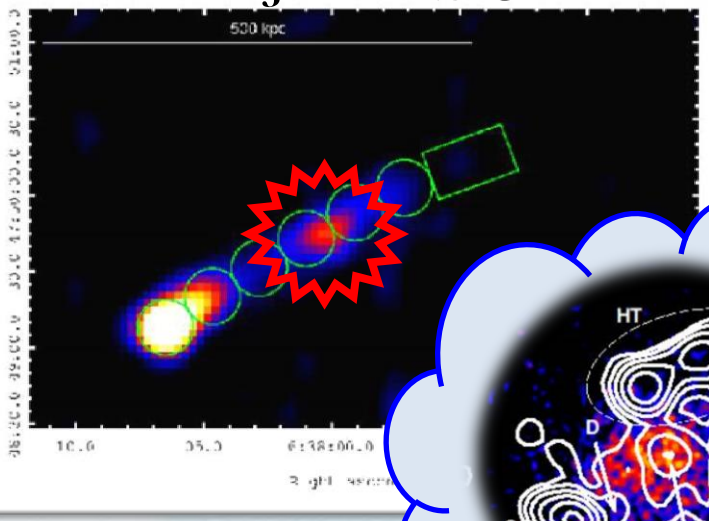
Origin: reaccelerated plasma (AGN) by accretion/distant shock????

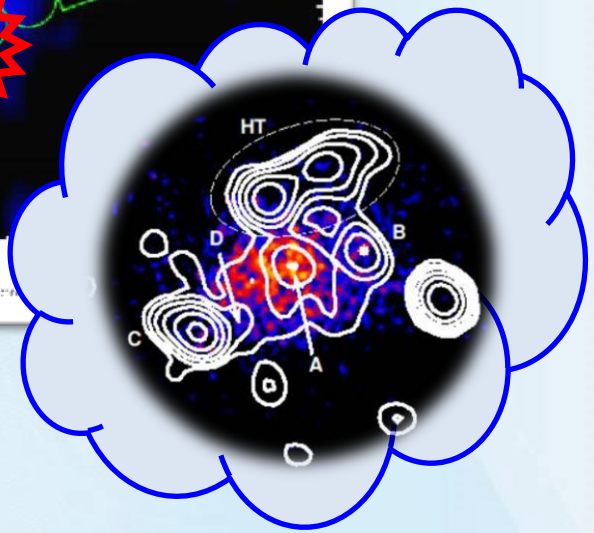
Puzzling head tail radio galaxy in Z0634 *(Cuciti et al. submitted)*

GMRT 330 MHz

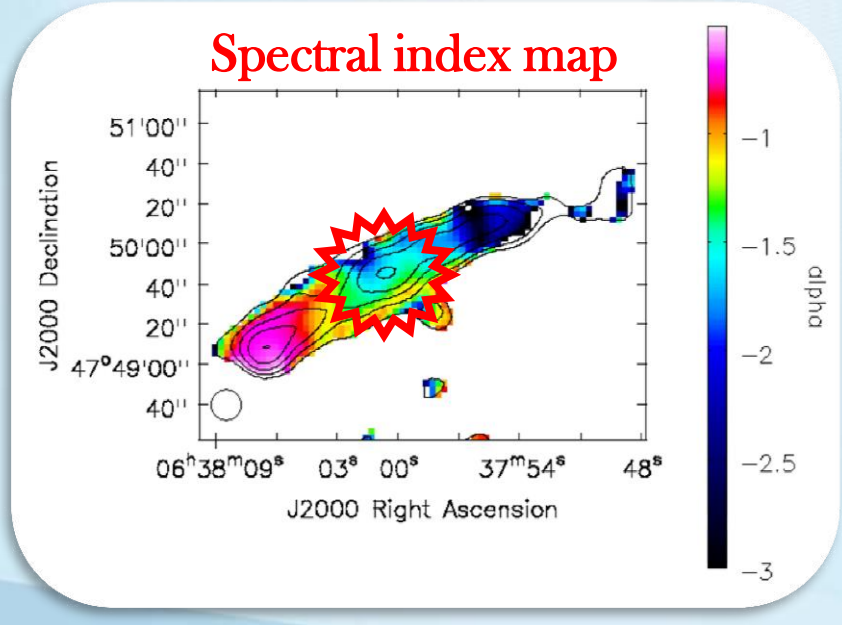


JVLA 1.5 GHz





Spectral index map



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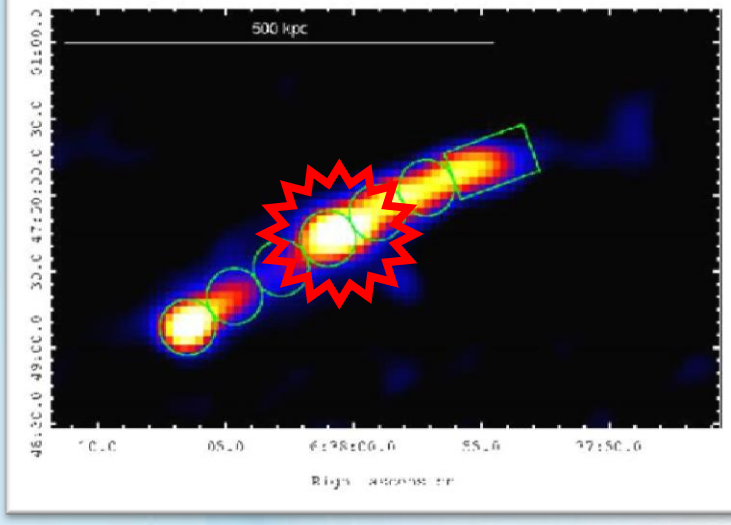
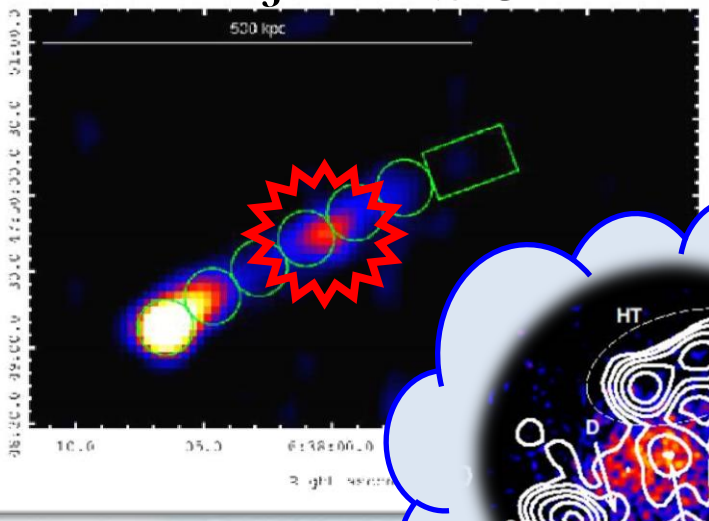
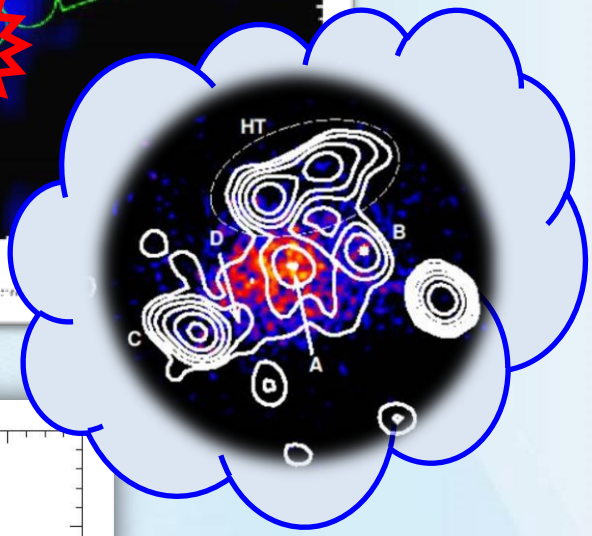
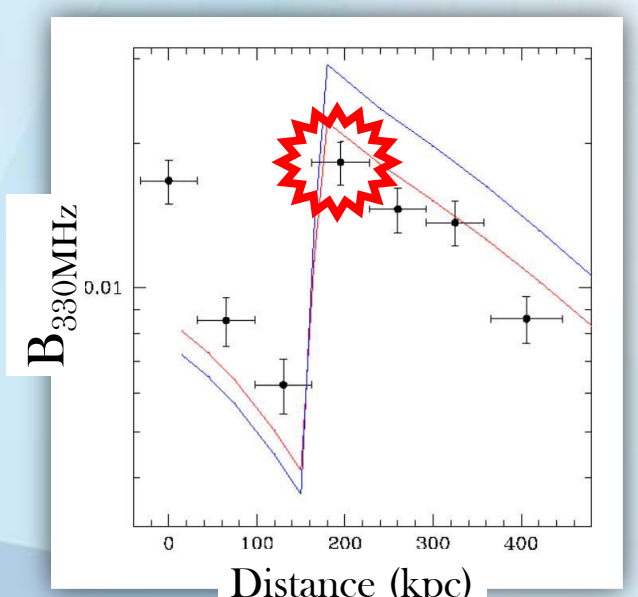
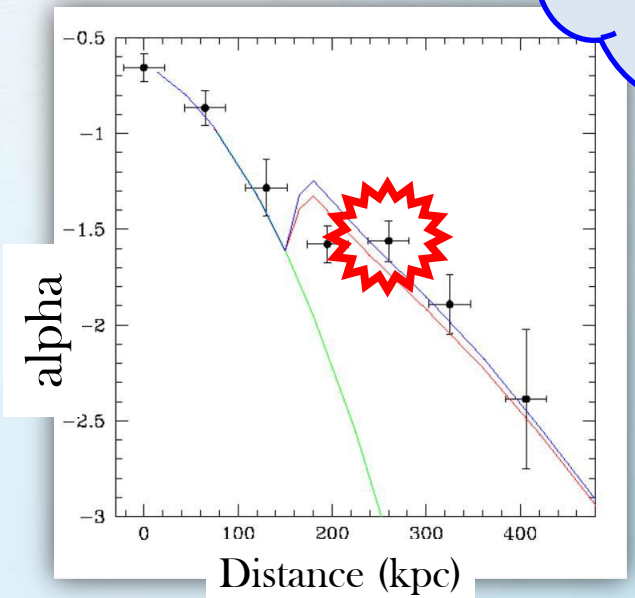


JVLA 1.5 GHz



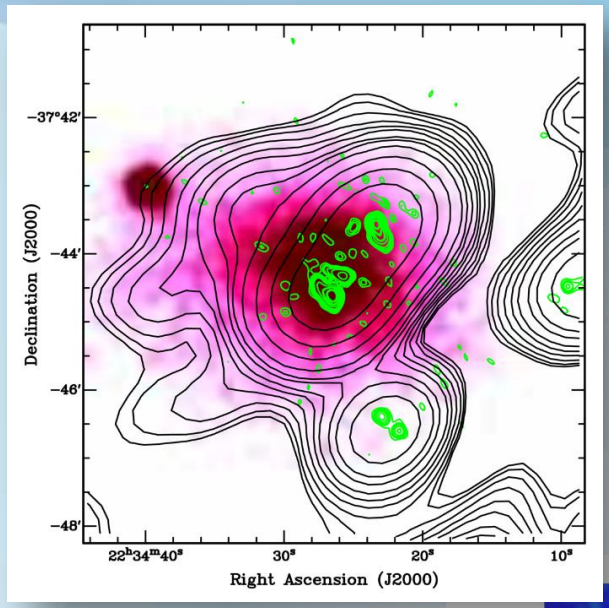




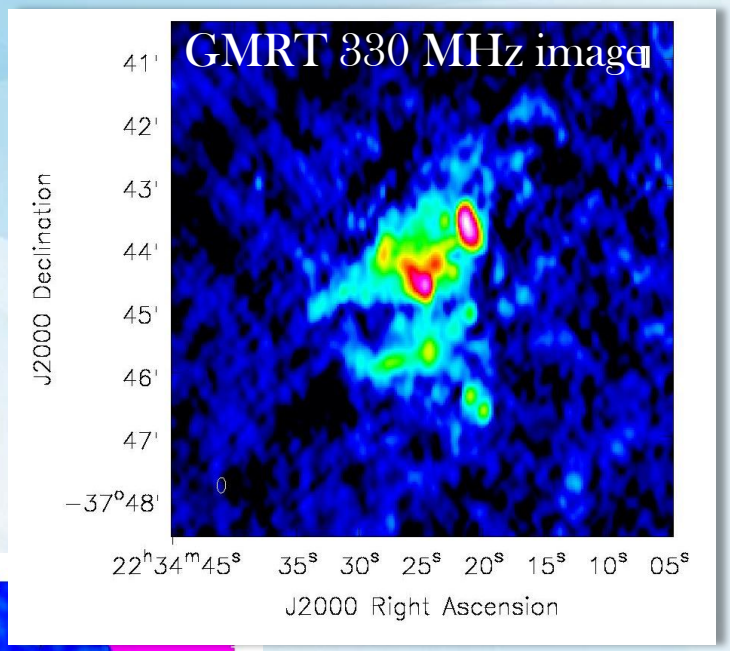


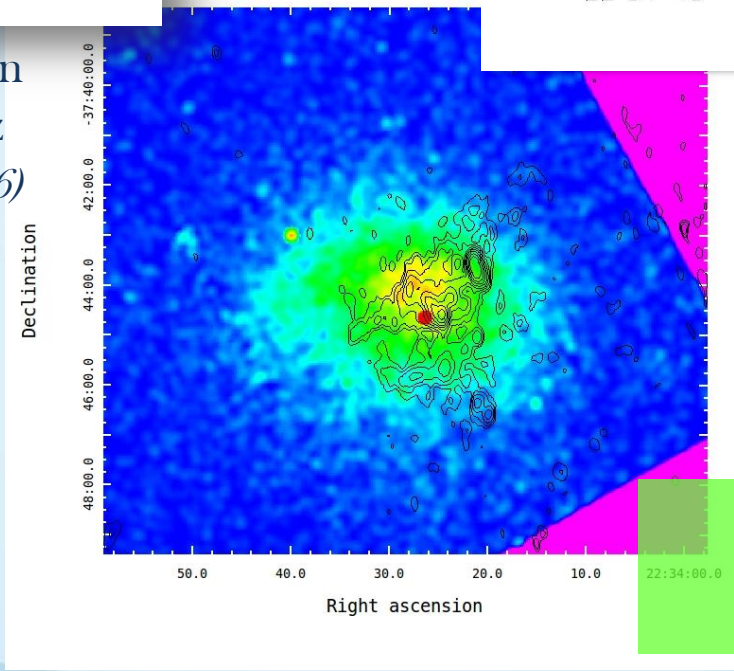
Re-energized plasma from a shock???

The radio halo in A3888 *(Cuciti et al. in prep.)*



Low (black) and high (green resolution ATCA 1.4 GHz contours *(Shakouri et al 2016)*





GMRT 330 MHz contours overlayed on the Chandra X-ray image

Spectral analysis in progress....

Conclusions

- Low frequency observations give crucial constraints on the properties of diffuse emission in clusters of galaxies
- We are building the largest mass-selected sample of galaxy clusters with deep radio observations in the range 330-1400 MHz
- A1451 and Z0634 host radio halos underluminous wrt the classical P-M correlation. The Cuciti et al. 2015 sample contains 7 underluminous radio halos (out of 30 radio halos and 75 clusters). They might constitute an important piece of this complex puzzle.
- We discovered a candidate radio relic in A1451
- We found a puzzling head tail radio galaxy in Z0634
- We confirmed the presence and the morphology of the radio halo in A3888.

Conclusions

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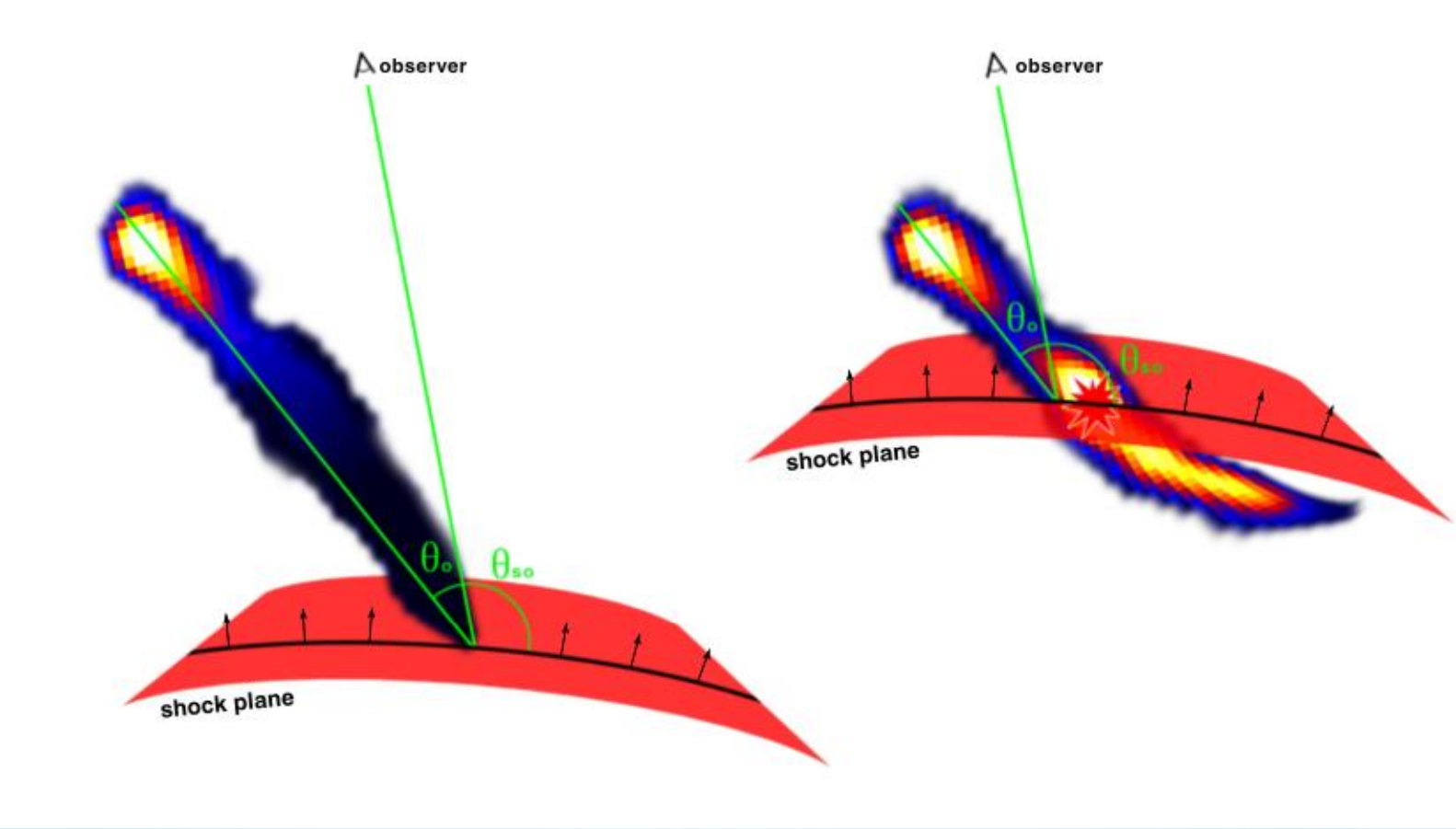
observer
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