Statistical study of radio halos in a mass-selected sample of galaxy clusters

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

Outline

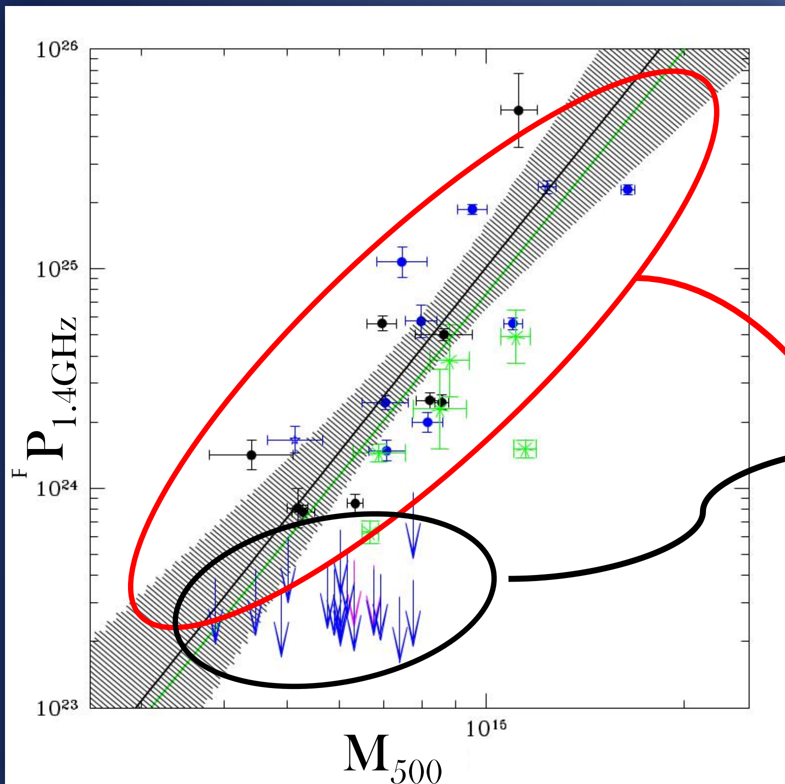
- Previous statistical results on radio halos
- Sample selection and goals
- Early results on the fraction of clusters with radio halos
- Radio data analysis
- Preliminary statistical analysis of the total sample

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
- $0.2<z<0.4$
- $\delta \geq -30^\circ$



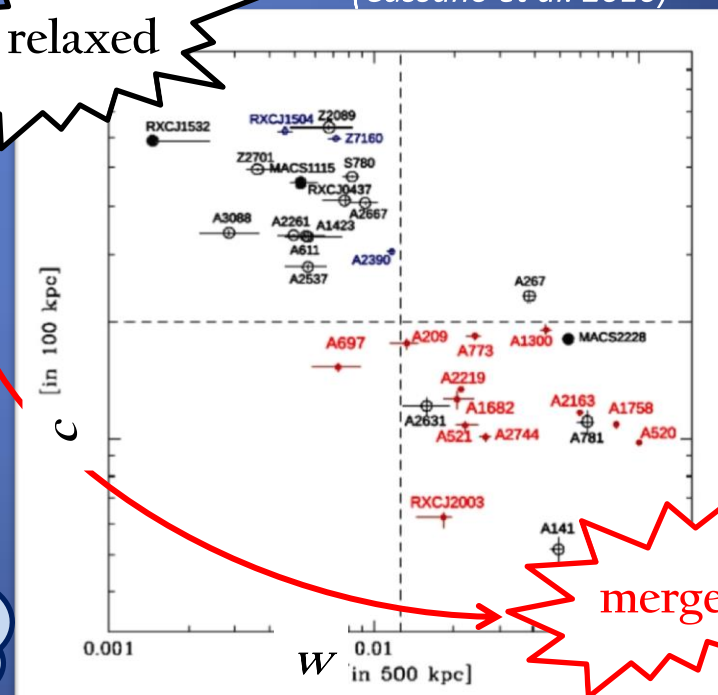
Radio bimodality

on the Mpc scale

(Cassano et al. 2013)

RH-merger connection

(Cassano et al. 2010)



R. Cassano' s talk

A 'mass' selected sample

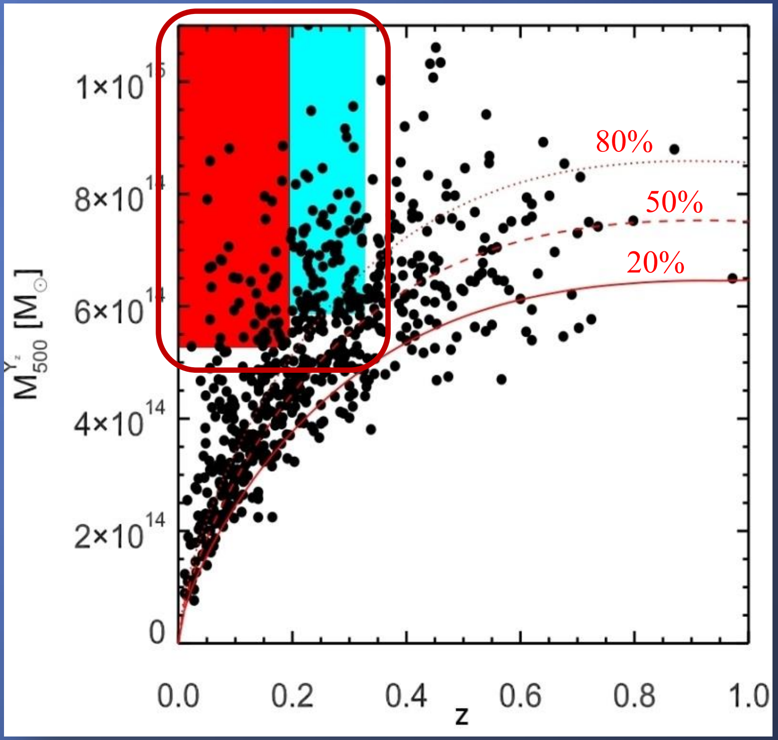
General goal: study the statistical properties of radio halos in the first mass-selected sample of clusters with deep radio observations

From the Planck SZ cluster catalogue

(Planck Collaboration 2014):

- $M_{500} \gtrsim 6 \times 10^{14} M_{\odot}$
- $0.08 < z < 0.33$

Total of 75 clusters
~80% complete in mass
(with GMRT 330/610 MHz and/or JVLA 1.4 GHz observations)



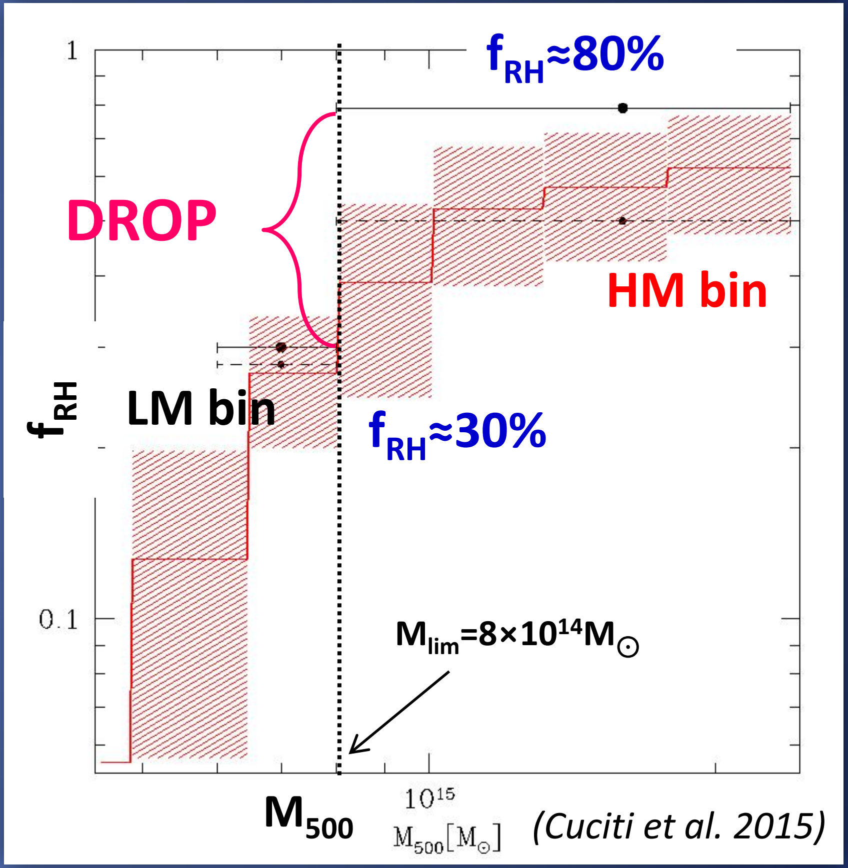
(Planck Collaboration 2014)

Occurrence of radio halos

Early results based on a subsample of 57 clusters with available radio information in the literature (+NVSS reprocessing)

Fraction of RHs drops in low mass clusters

In agreement with expectations from turbulent re-acceleration models



Red line: expected probability of forming 1Mpc scale RHs as a function of cluster mass

Radio data analysis to complete the sample

Early results based on 57 clusters

Total sample = 75 clusters

↕

18 clusters of which we analysed GMRT (330 MHz and/or 610 MHz) and/or JVLA 1.4 GHz observations

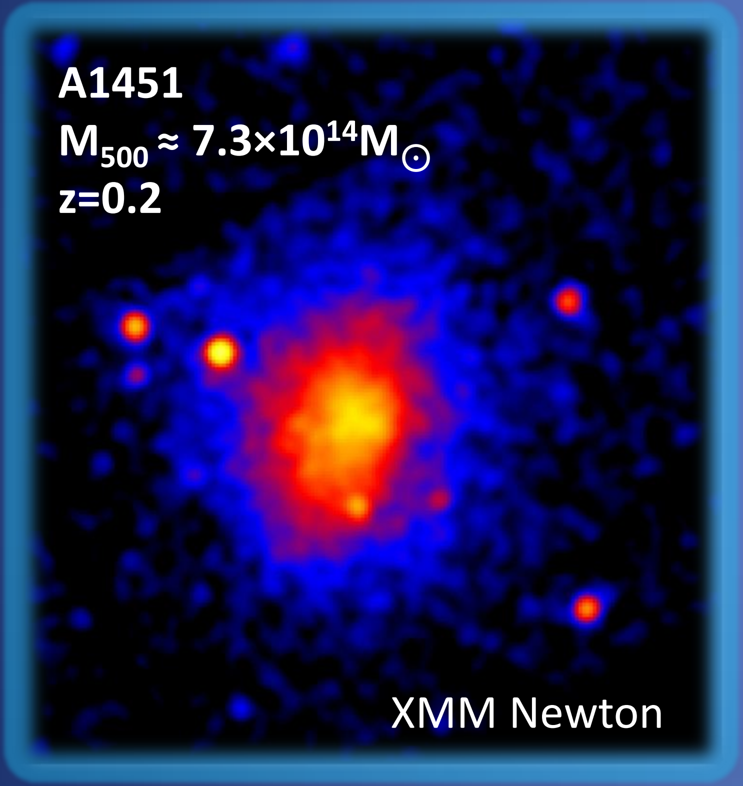
3 new radio halos and **1** relic

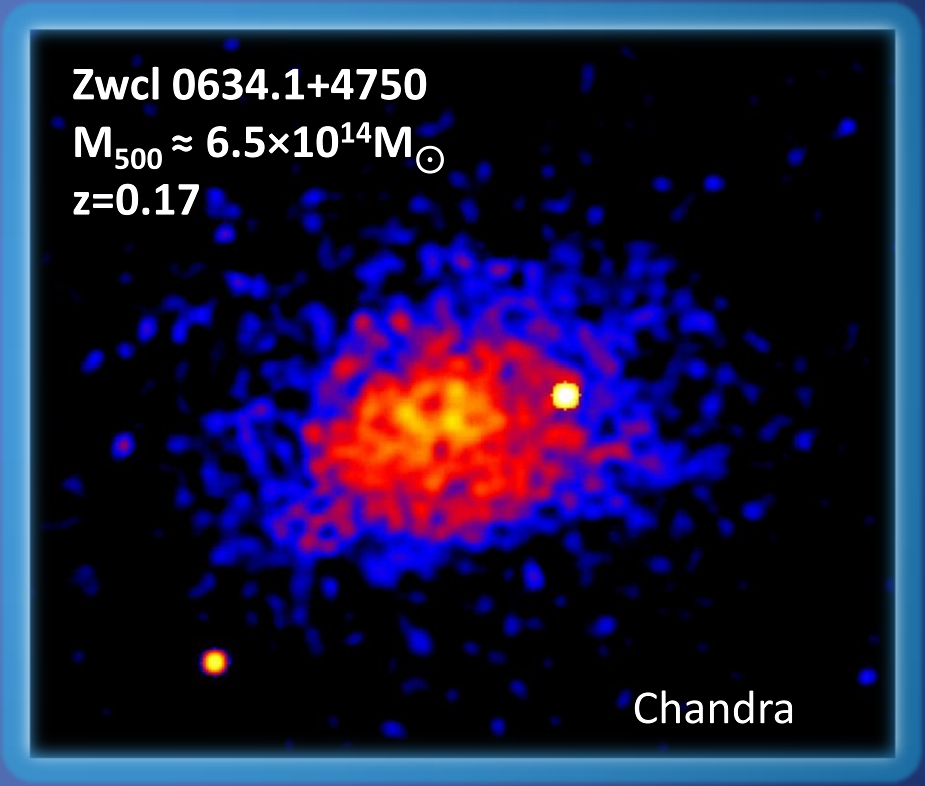
3 candidate radio halos

11 clusters without diffuse emission ⇒ many new upper limits

Discovery of diffuse emission in two merging clusters

Cuciti et al. (2017)





For both clusters we analysed
GMRT 330 MHz and JVLA D and B array 1.5 GHz observations

Discovery of diffuse emission in two merging clusters

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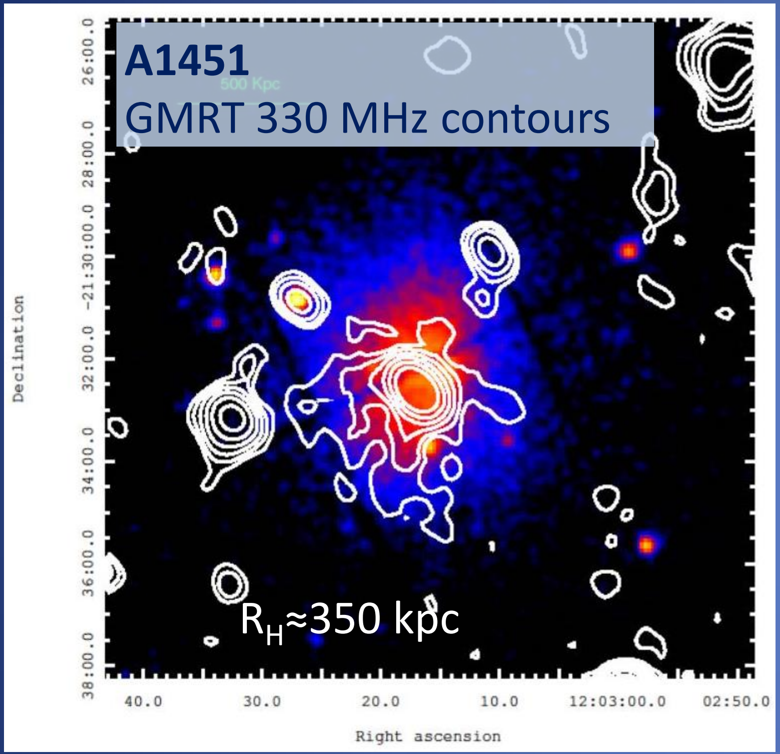
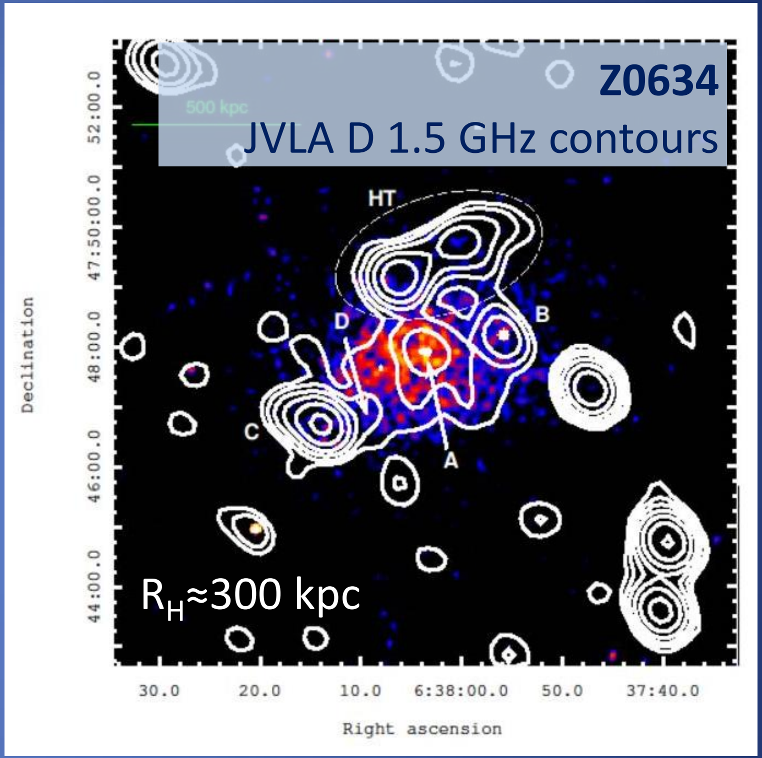


rms ≈0.3 mJy/b beam ≈40''×28''
S_{330MHz}= 32.6±3.8 mJy
$S_{1.5GHz}$= 5.0±0.5 mJy
α≈-1.2



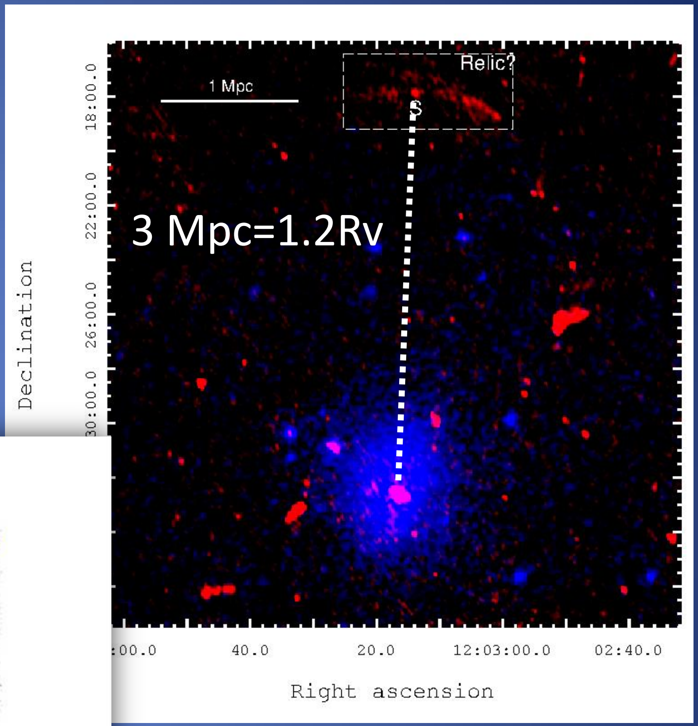
rms ≈ 45 μJy/b beam ≈ 36''×30''
S_{330MHz}= 20.3±2.7 mJy
$S_{1.5GHz}$= 3.3±0.2 mJy
α≈-1.1

Injections $\Longrightarrow$ $\alpha \approx -1$

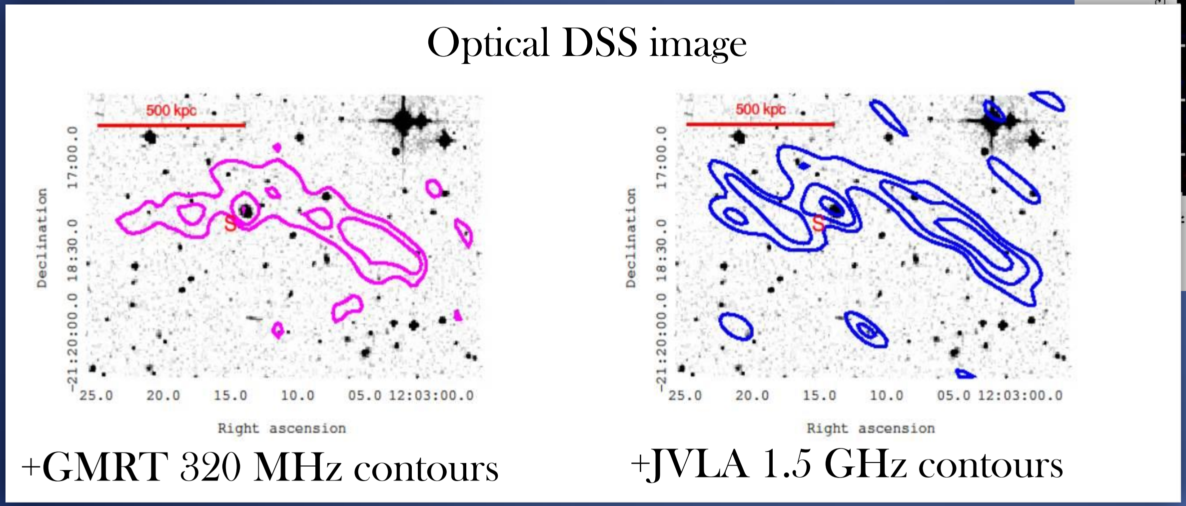
Candidate radio relic in A1451

Radio power $P_{1.4GHz}$=1.1±0.6x10^{24}W/Hz

Spectral index α=1.1±0.1



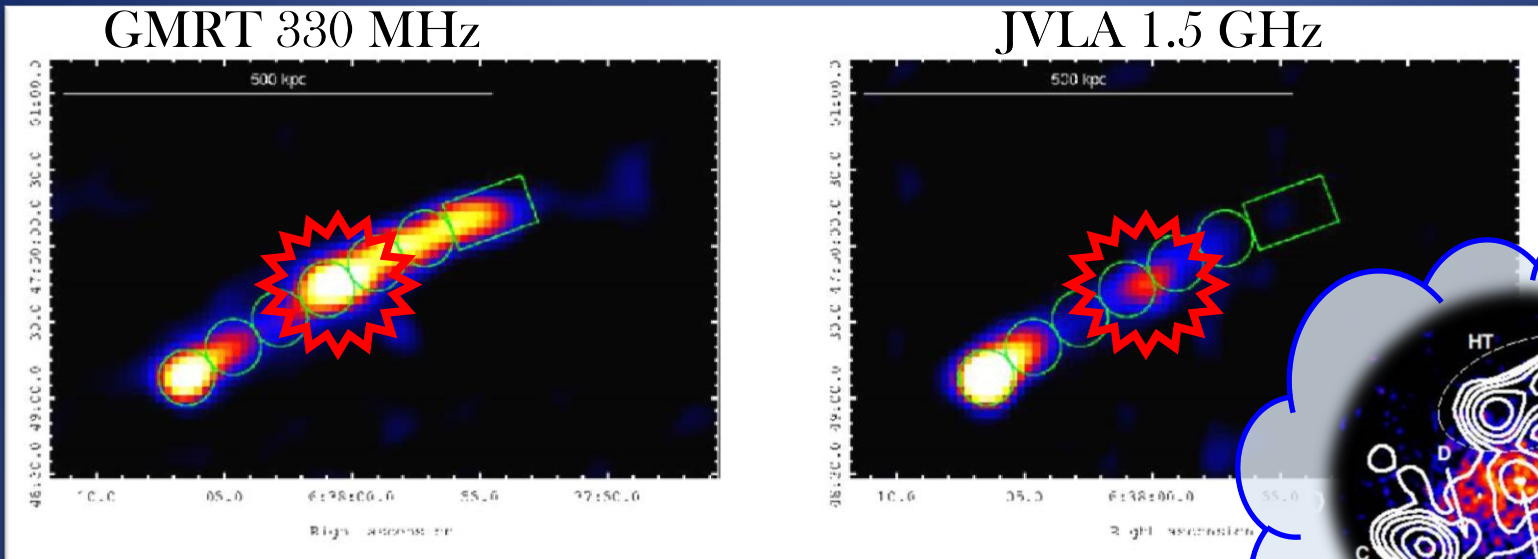
Blue: XMM-Newton.
Red: GMRT 330 MHz

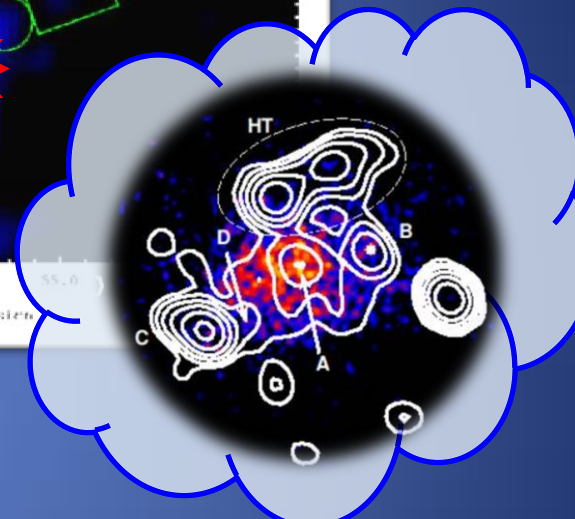


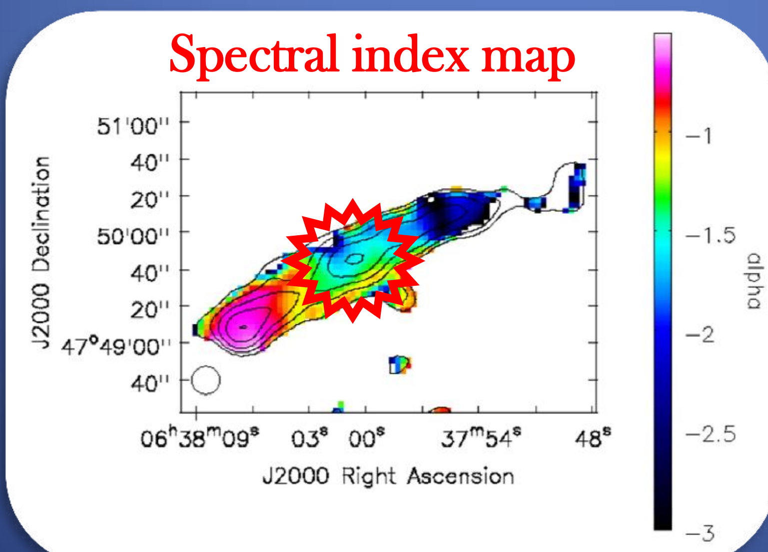
Cuciti et al. (2017)

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

Puzzling head tail radio galaxy in Z0634







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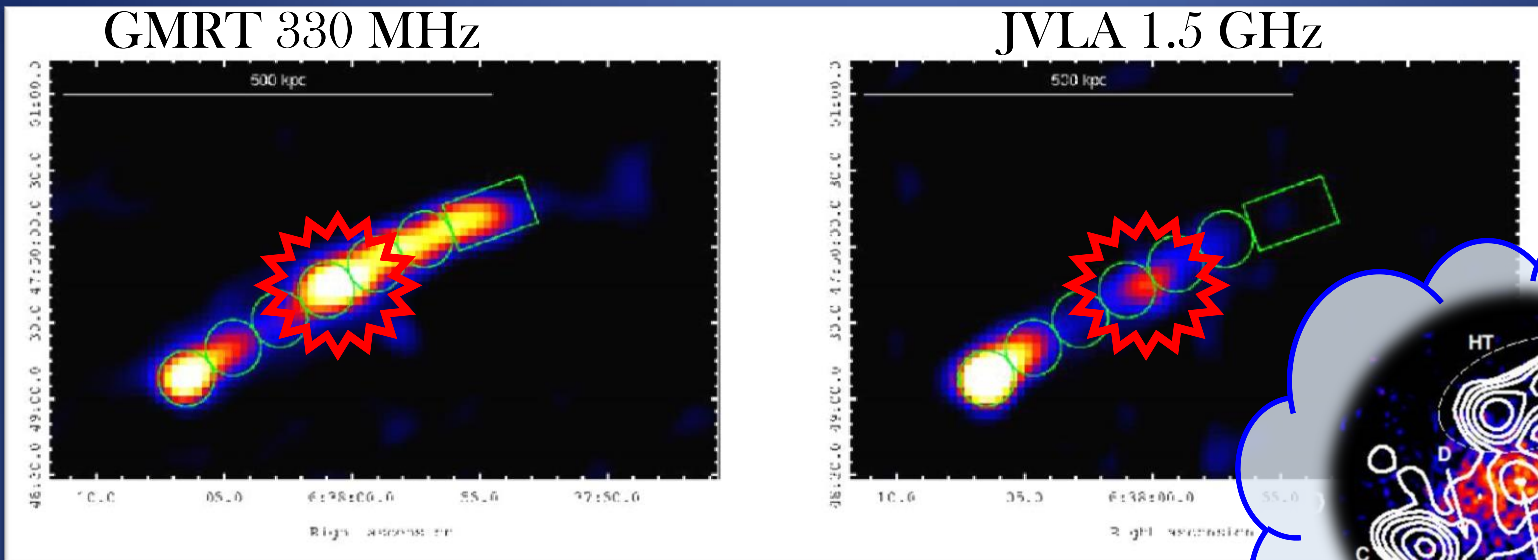
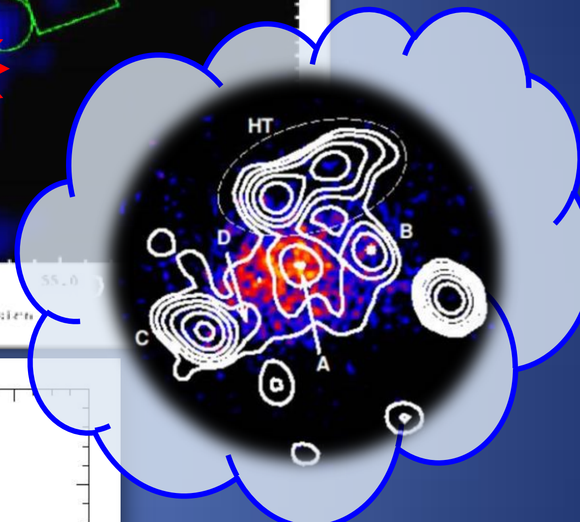
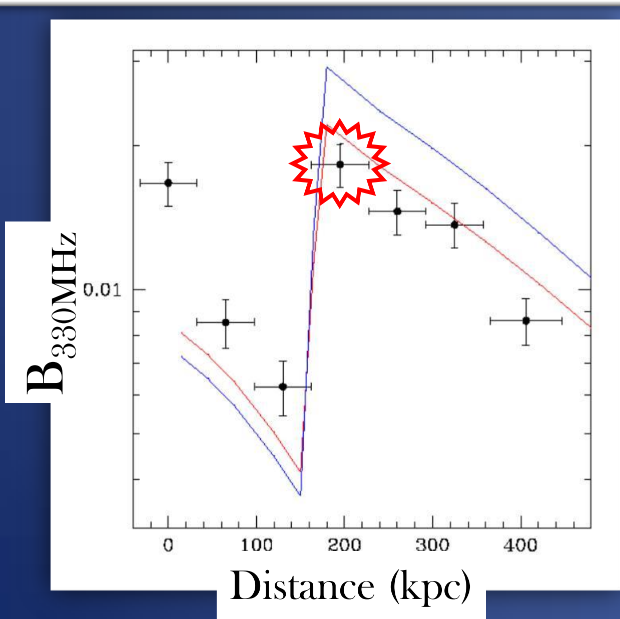
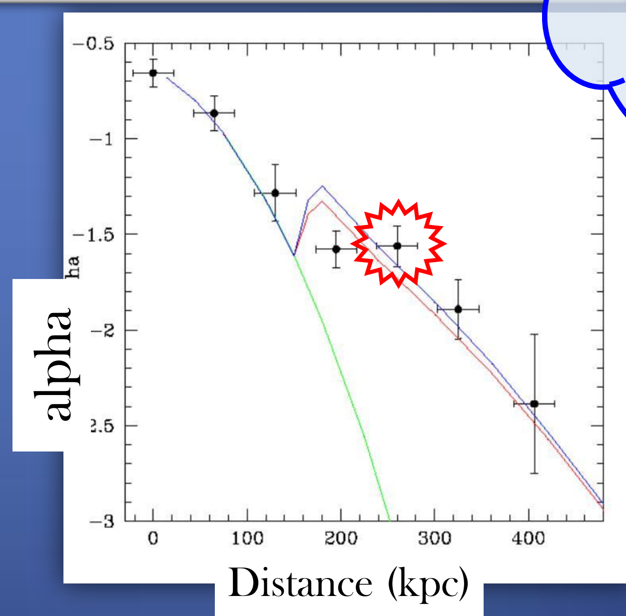






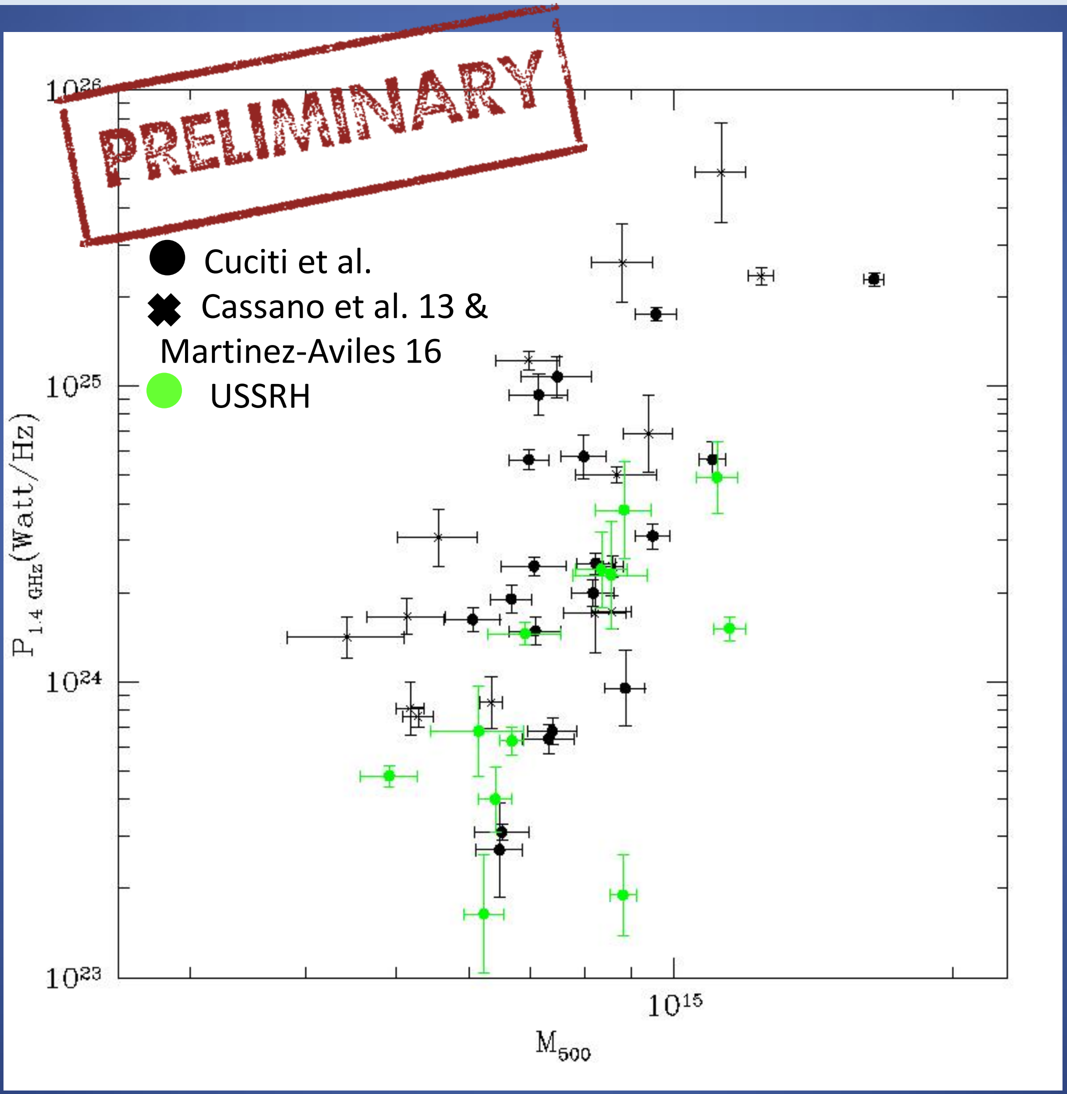


Re-energized plasma from a shock???

e.g. Pfrommer & Jones (2011), De Gasperin et al. (2017)

Statistics of the total sample *(Cuciti et al., in prep.)*

Cuciti et al. sample + Cassano et al. (2013)+ Martinez-Aviles et al. (2016)



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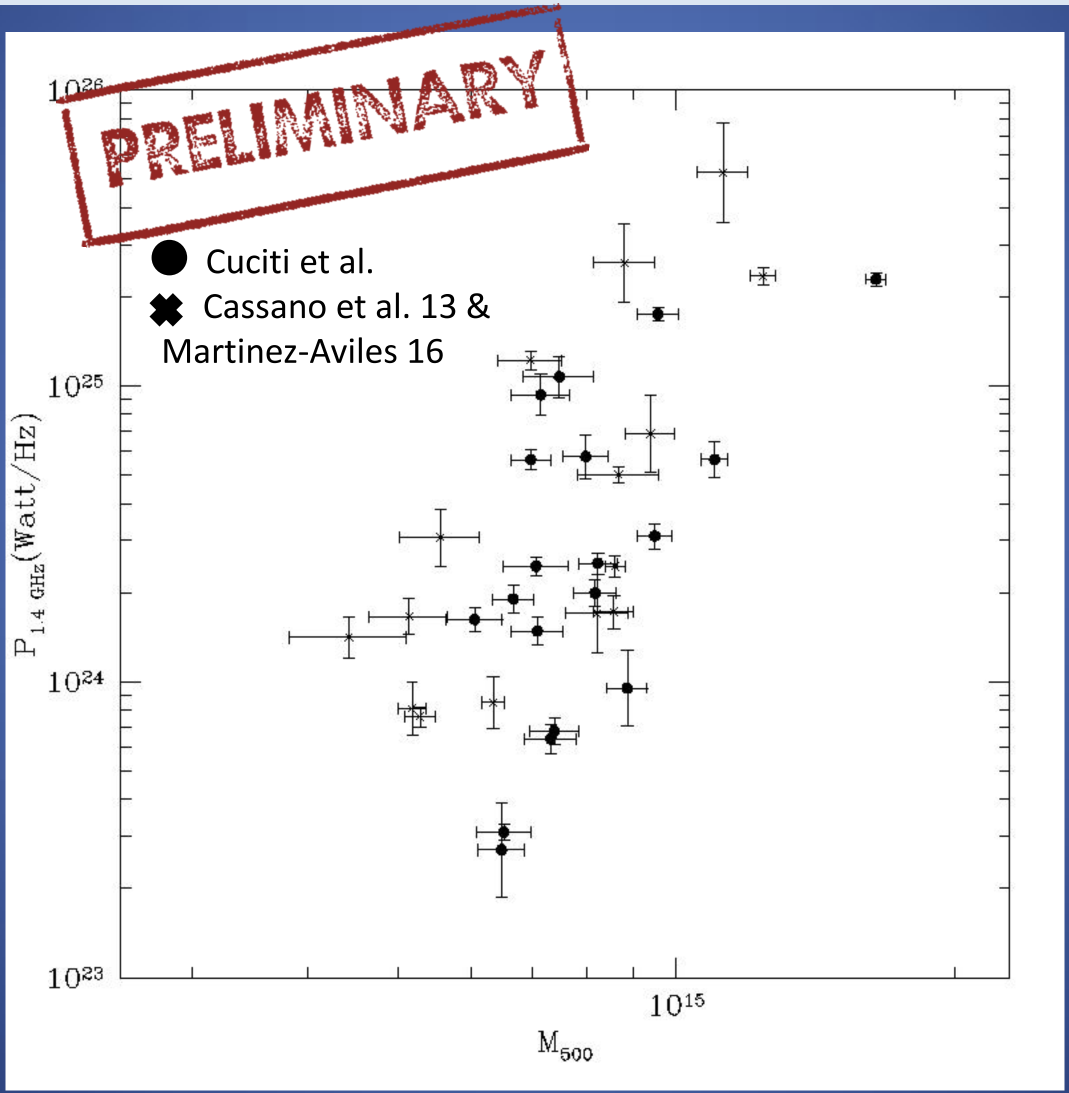

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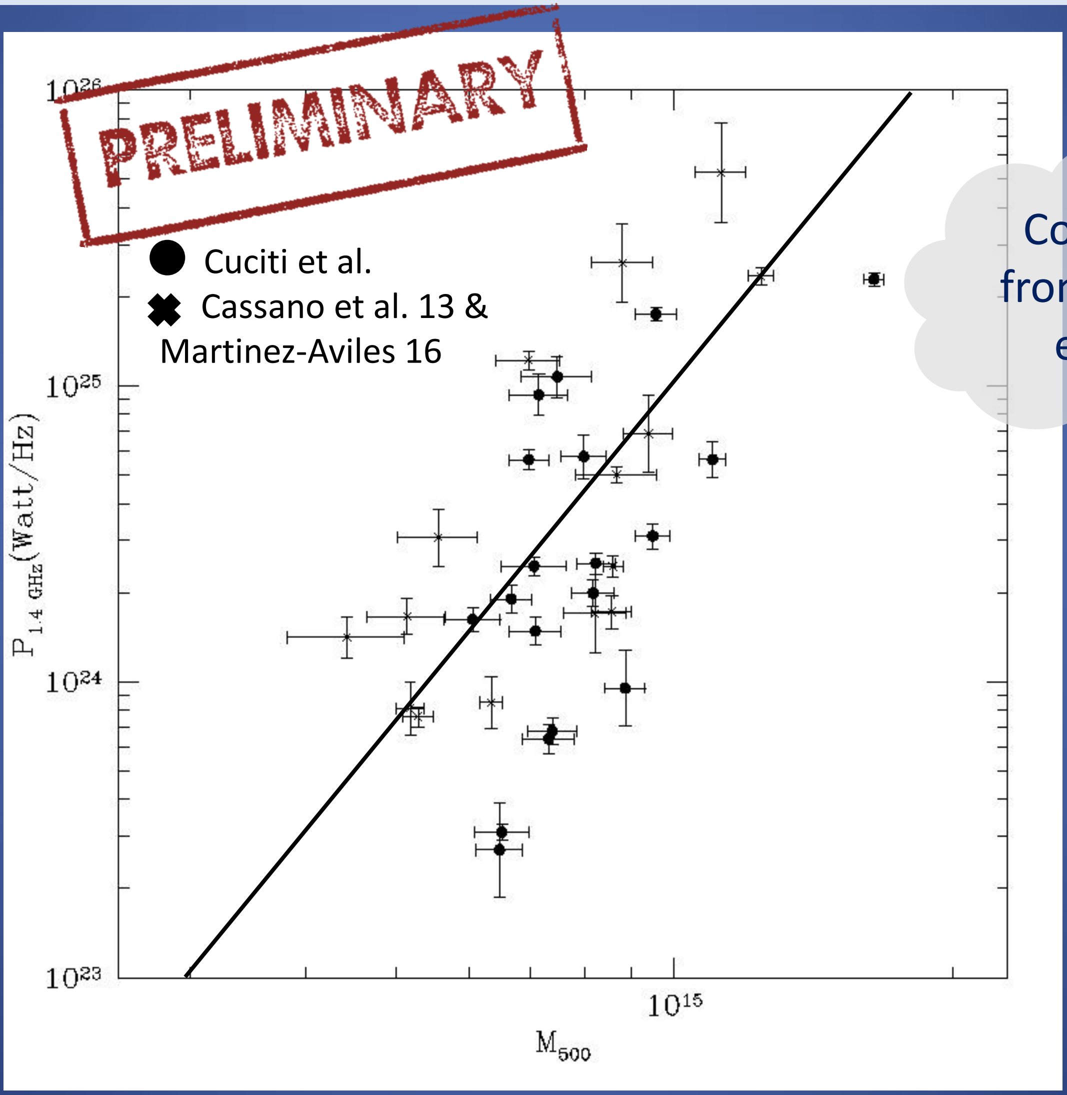

Correlation from Cassano et al. 13

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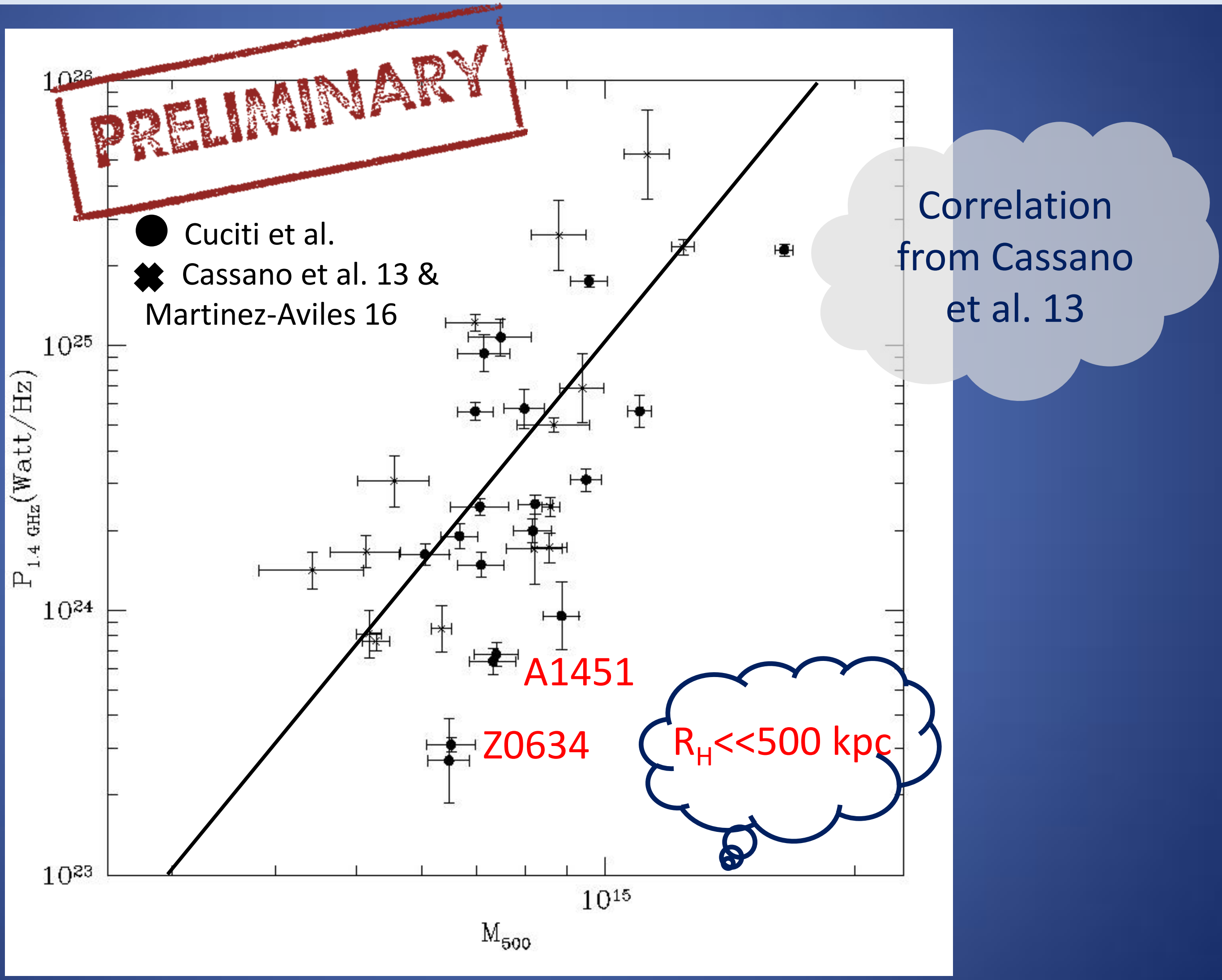

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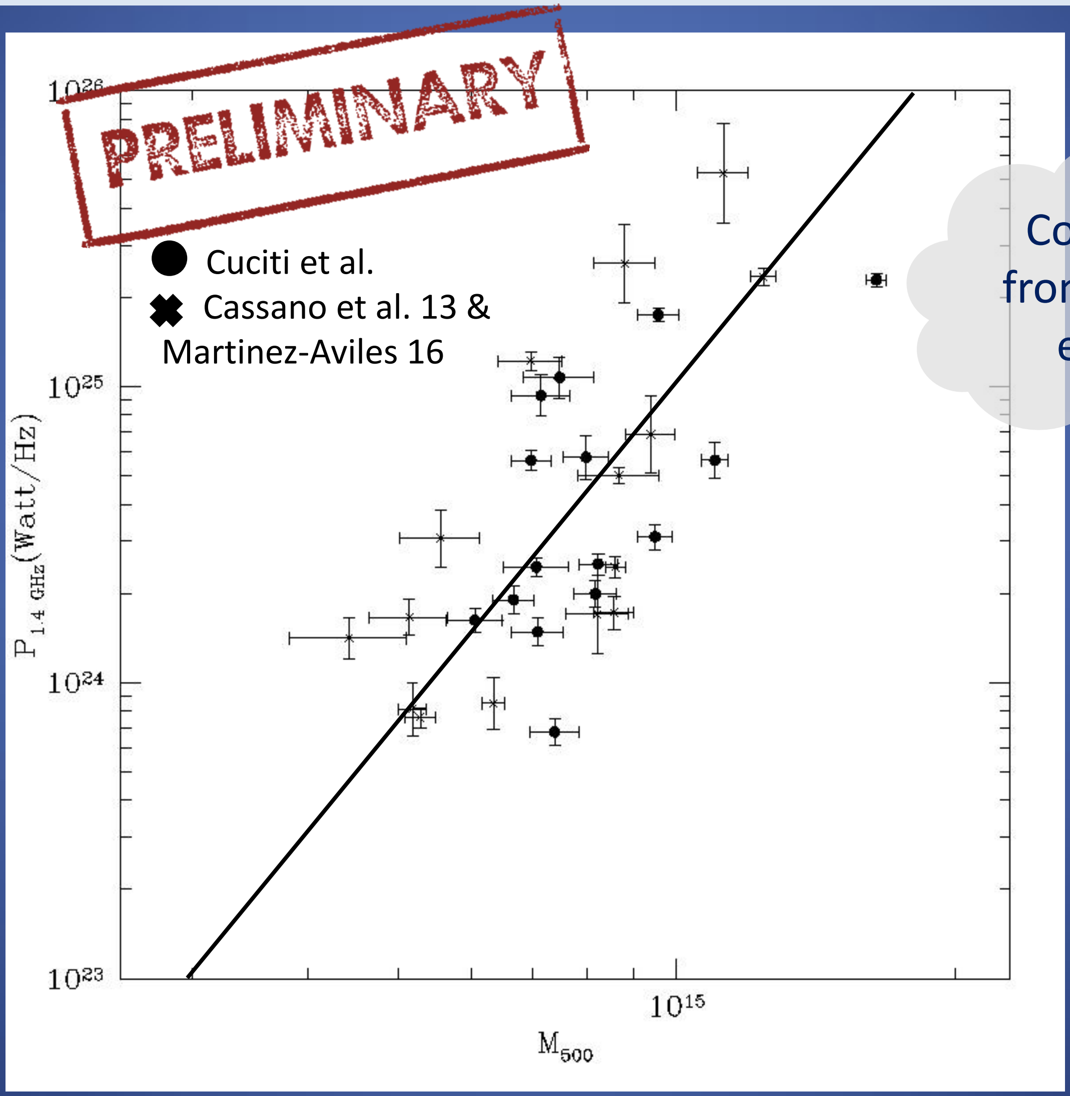

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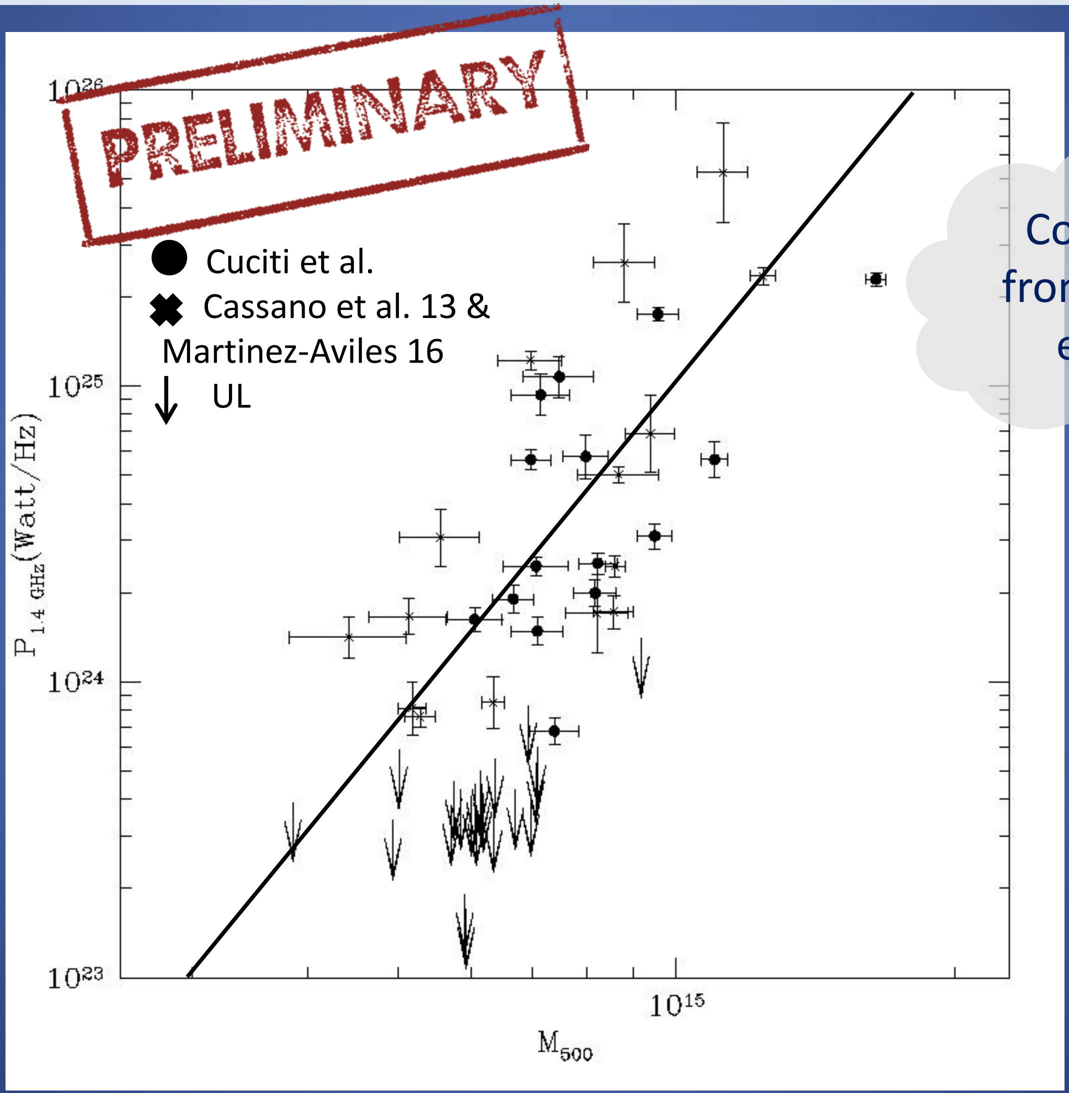

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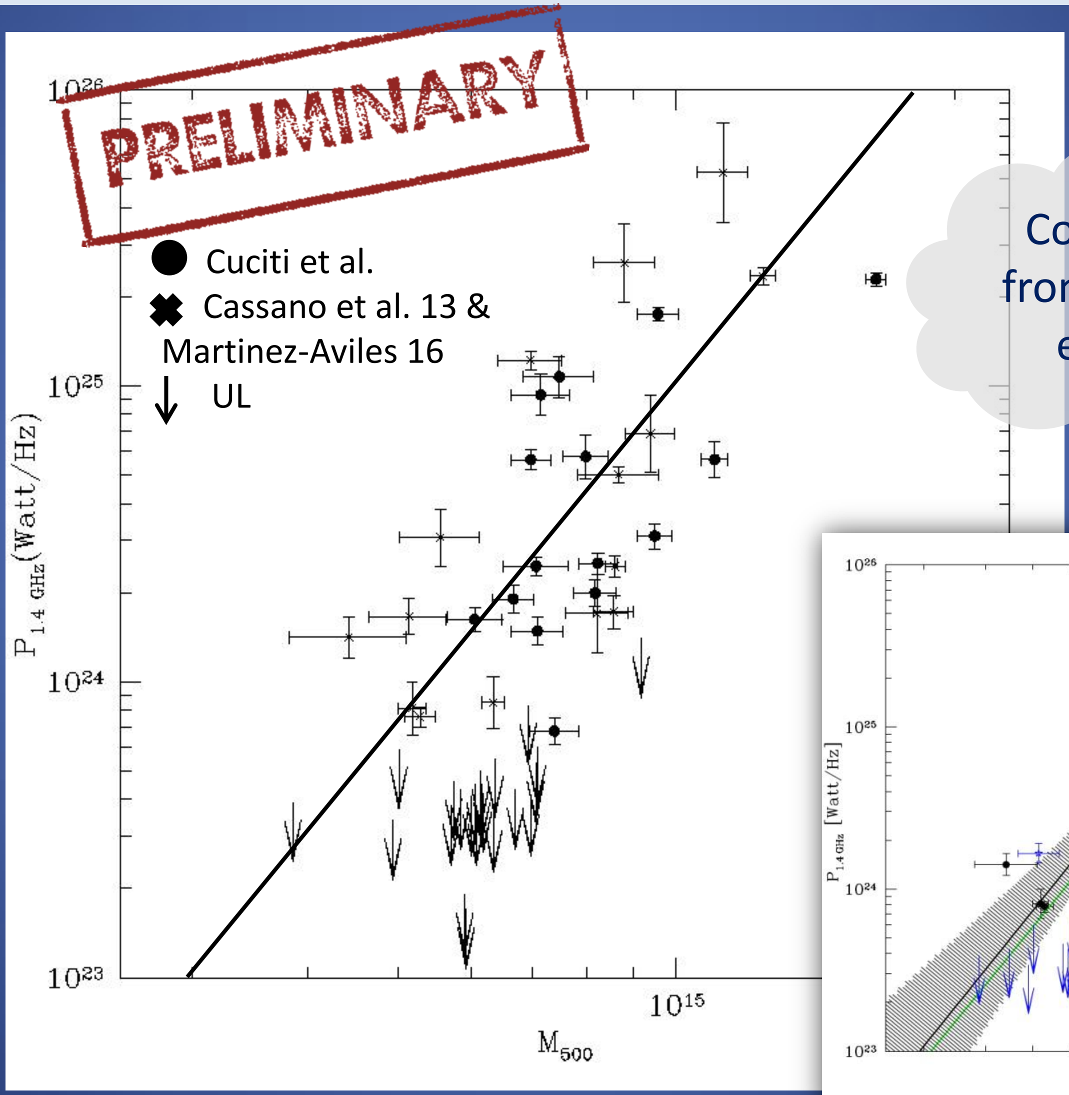

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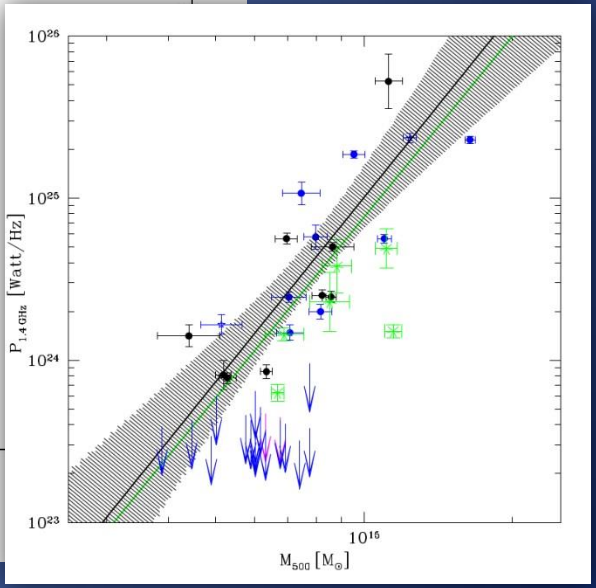

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9 USSRHs or candidate USSRHs

- 2 RHs among 23 relaxed clusters (∼10% of relaxed clusters host a RH)

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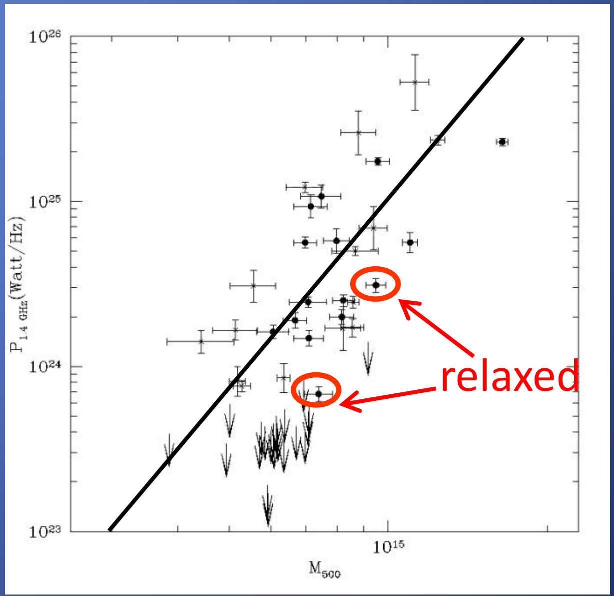

Take home messages

- We have built the largest mass-selected sample of galaxy clusters with deep radio observations available to date
- We are analysing the statistical properties of radio halos in this sample (radio power-mass diagram, fraction of RHs, RH- merger connection…)
- The picture is becoming more complex than it used to be
- Deeper investigation is needed, including more sofisticated statistical tools and theoretical models

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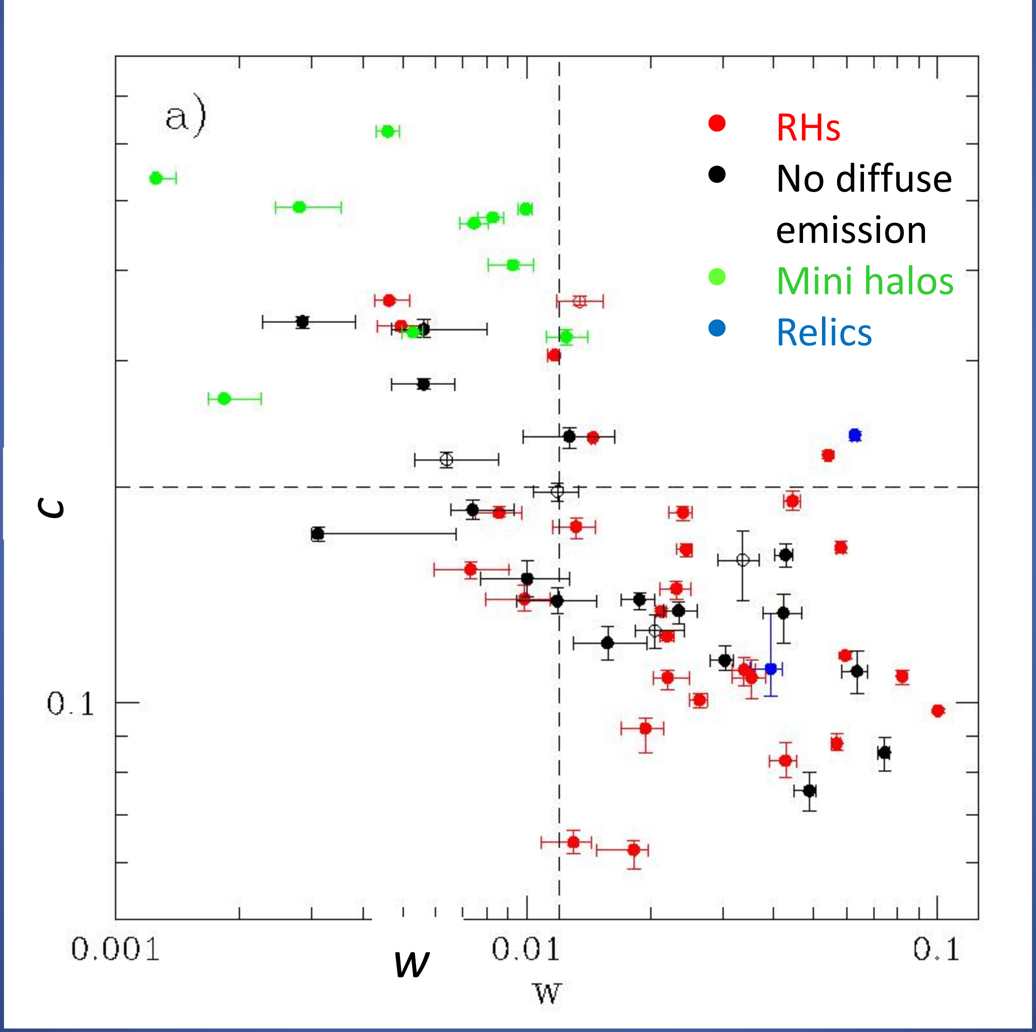
Thank you!

Morphology diagram



Radio halo emissivity

emissivity $\approx \frac{P_{1.4GHz}}{R_H^{\,3}}$ $R_H = \sqrt{R_{min} \times R_{max}}$ from 3σ contours, R_H=500 kpc for UL