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# Exploring the diffuse emission from clusters of galaxies with MSSS

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on behalf of the MSSS clusters working group

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# Outline

- Scientific goal: Study diffuse radio emission from GC using the all sky survey MSSS
- Can we really do that? Data quality assessment: OK go ahead
- The sample: GC hosting known diffuse emission + few new unknown
- Results: first time L\_X correlation at 138 MHz.
- Future plan...

# Clusters of galaxies



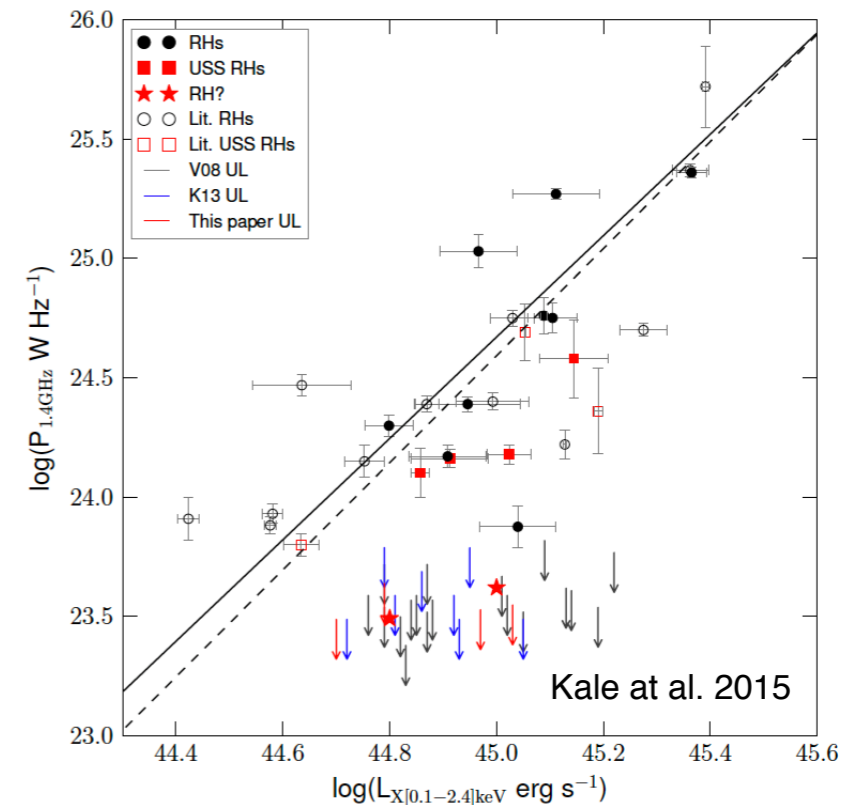
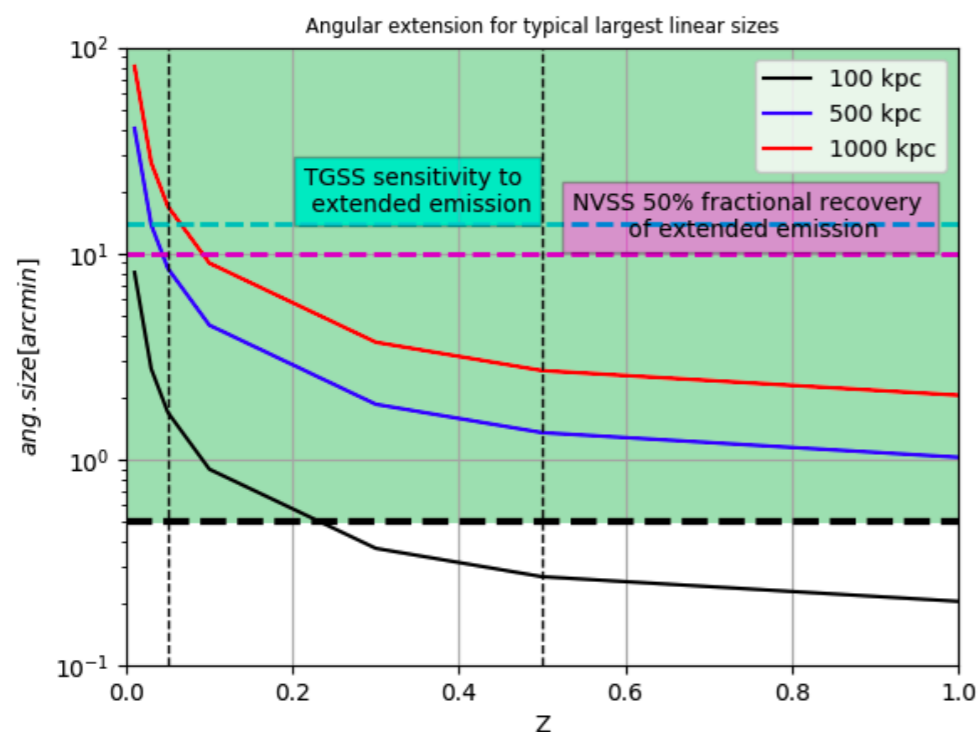
- Clusters of galaxies: the largest known gravitationally bound structures
- Cluster eco-system: dark matter, galaxies and intra cluster medium (ICM)
- Fields (gravitational, magnetic), thermal and relativistic particles
- Tracers: from radio waves to gamma photons

# Diffuse emission

## Why so difficult so far?

(mini-/giant-) halos, relics show low surface brightness extended radio emission

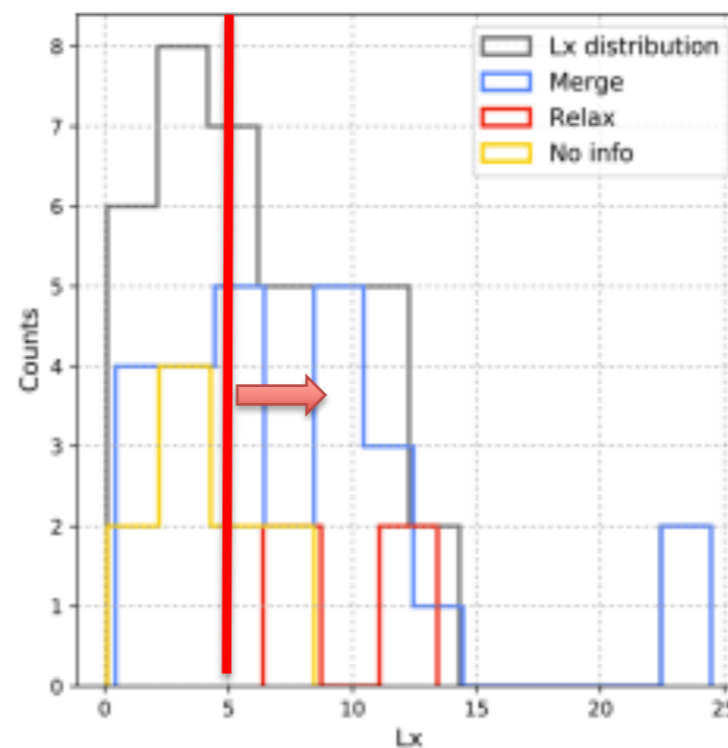
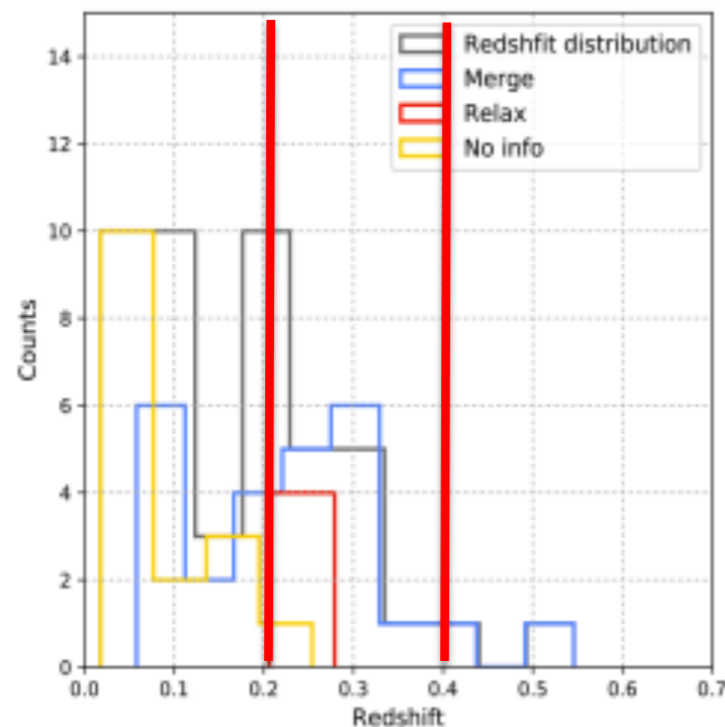
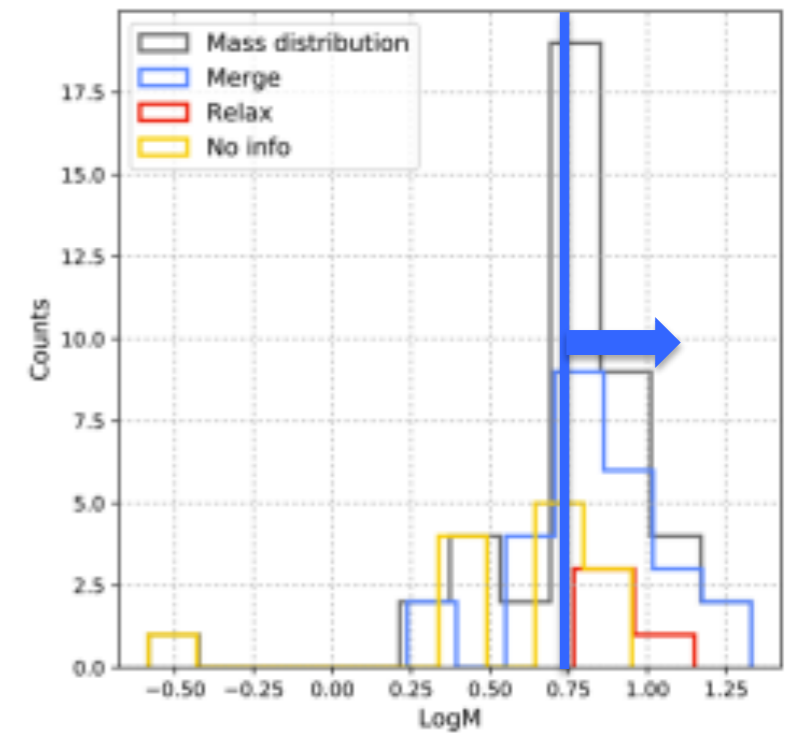
- Known / well studied objects: bright intermediate-z objects
- Unknown / poorly studied objects: very extended and/or low-z fainter objects, as well as high-z bright and less massive objects



Unprecedented power of LOFAR to recover low surface brightness diffuse emission.

# Expand the parameter space

- Given the observational limitations and theoretical hints previous studies are limited to a set of parameters ( $M$ ,  $L_x$ ,  $z$ )
- Few observational evidences showed that diffuse emission can be hosted on low luminosity clusters or non-merging clusters
- Our goal is to open up the parameter space in order to have a global and statistically relevant study of diffuse emission in clusters of galaxies.



Cuciti et al. 2015

GMRT RH Survey  
(Venturi et al. 2007,2008;  
Kale et al. 2013,2015)



# Project plan

- **Step1: checking feasibility** (commissioning)
  - Selection of a test sample to select proper processing strategy
  - Check data quality and sensitivity
- **Step2: exploiting a pilot sample**
  - Extending work done in previous step and preliminary science analysis (with summer student Chen Xie & A. Shulevski)
- **Step3: searching through the full survey**
  - Set up and run a “blind” search for extended radio features in catalogued clusters

# MULTIFREQUENCY SNAPSHOT SKY SURVEY: MSSS

Heald et al. 2015

## Observations

Observing frequency 115-180 MHz (**8X2MHz** bands)

Observing time **14 min** (2X7 min)

Area: 20.000 degrees

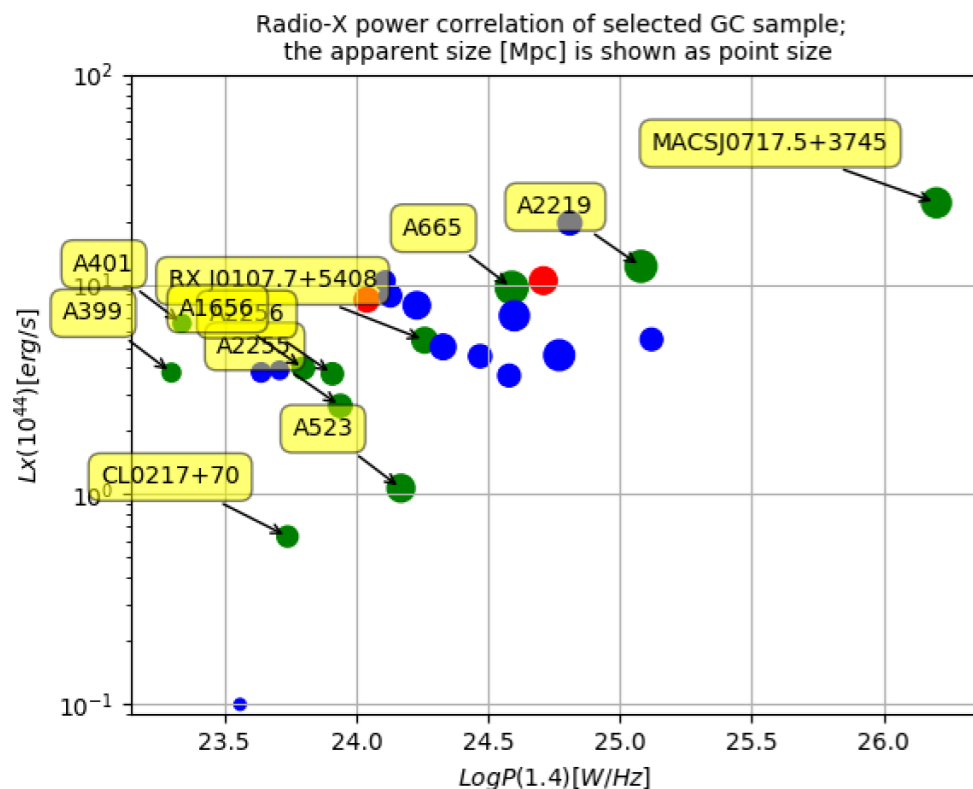
Number of fields 3616

## Processing

Raw data from the LTA  
Re-calibration with state of the art software

Calibration strategy:

**Direction Independent**  
imaging **MFS-clean**



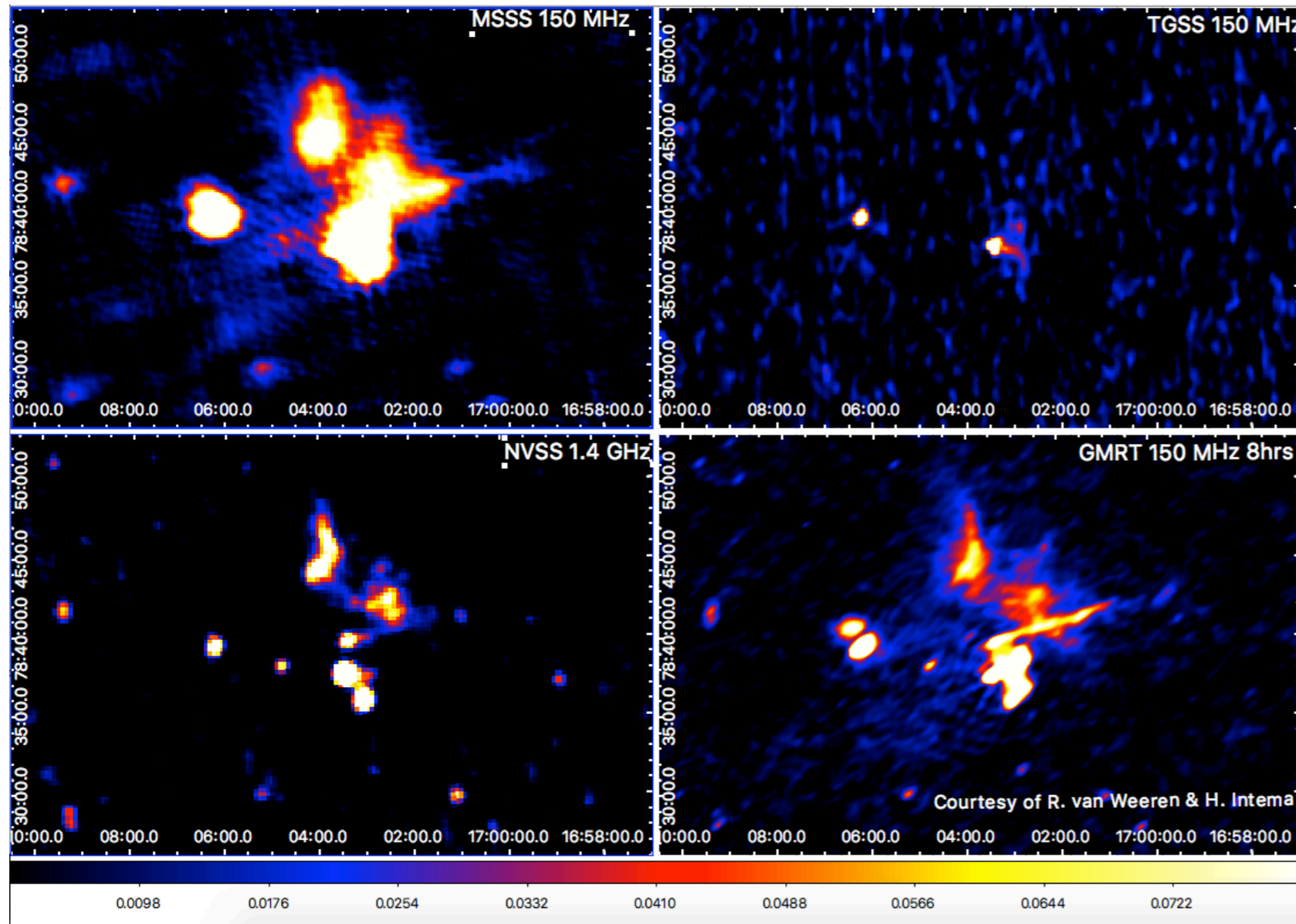
Testing on a sample of well studied targets from Feretti et al. (2012) at DEC>15deg:

Processed 14 fields: 12 successfully / 2 problematic

Typical/max angular resolution: **30-40''**/  
**10-20''**

Typical sensitivity: rms~**3-5 mJy/beam**,  
for a psf of ~30''

# Comparison with other telescopes

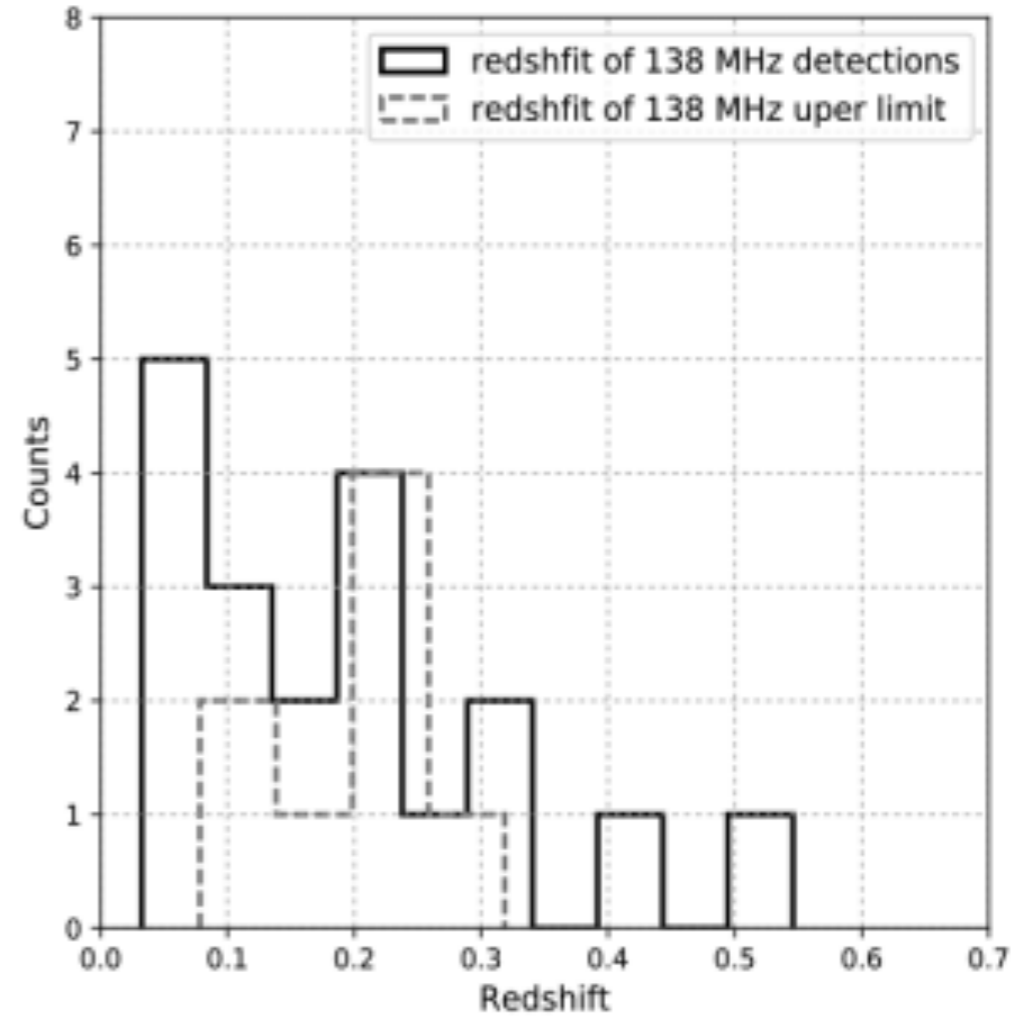
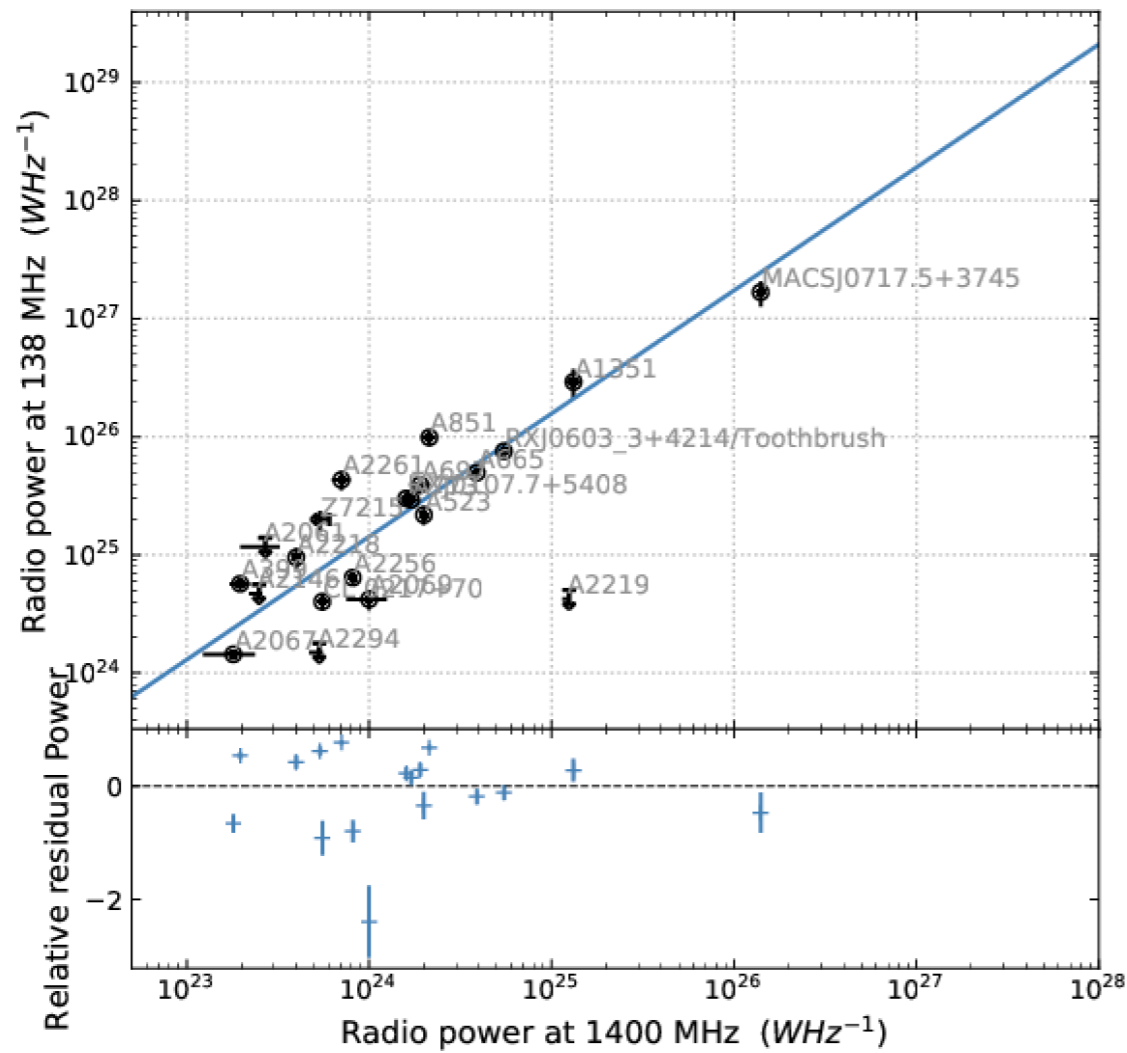


- The comparison with other instruments used to detect diffuse emission give confidence
- Few minutes of LOFAR are comparable to long runs obtained with GMRT at 150-225 MHz.



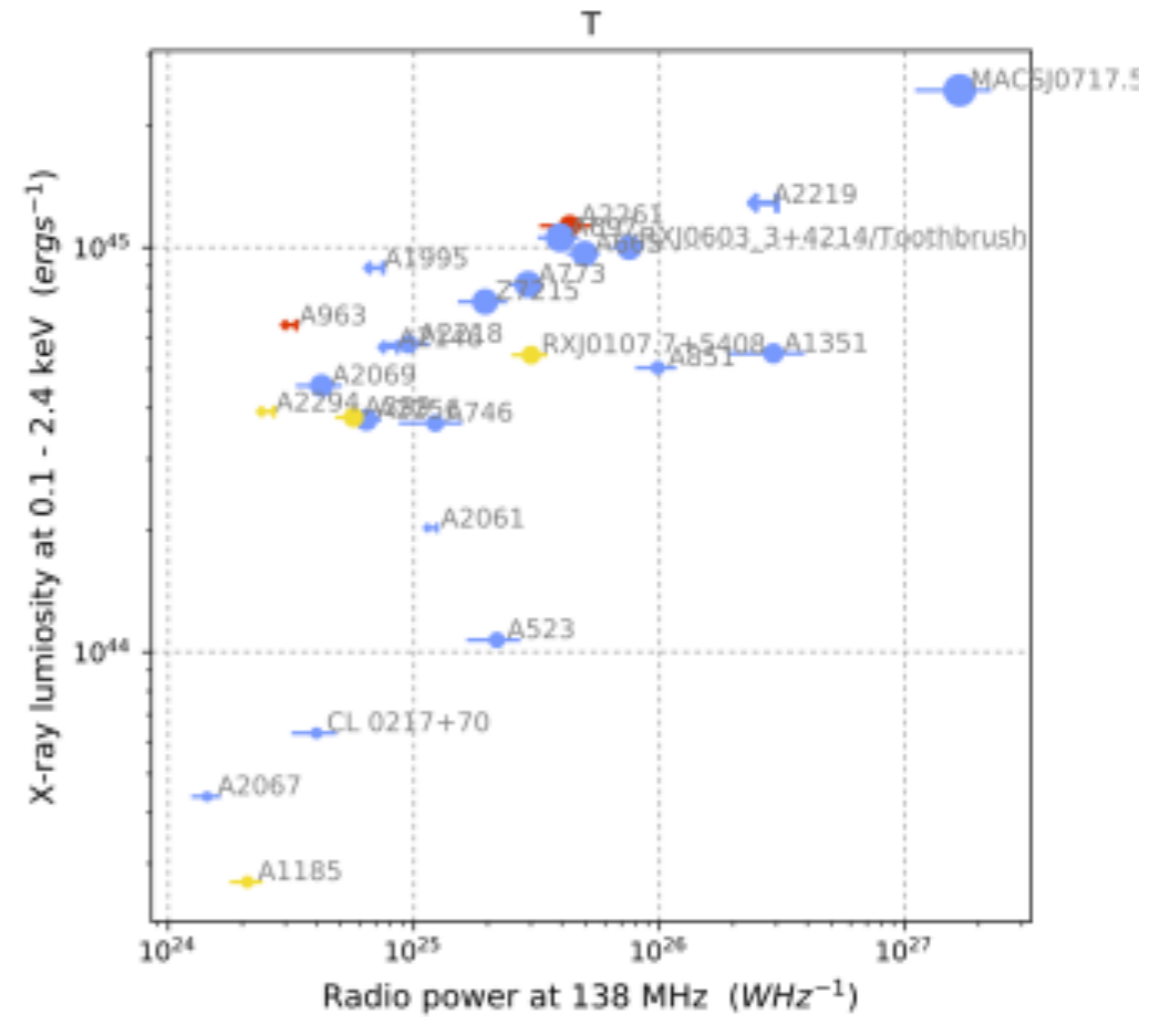
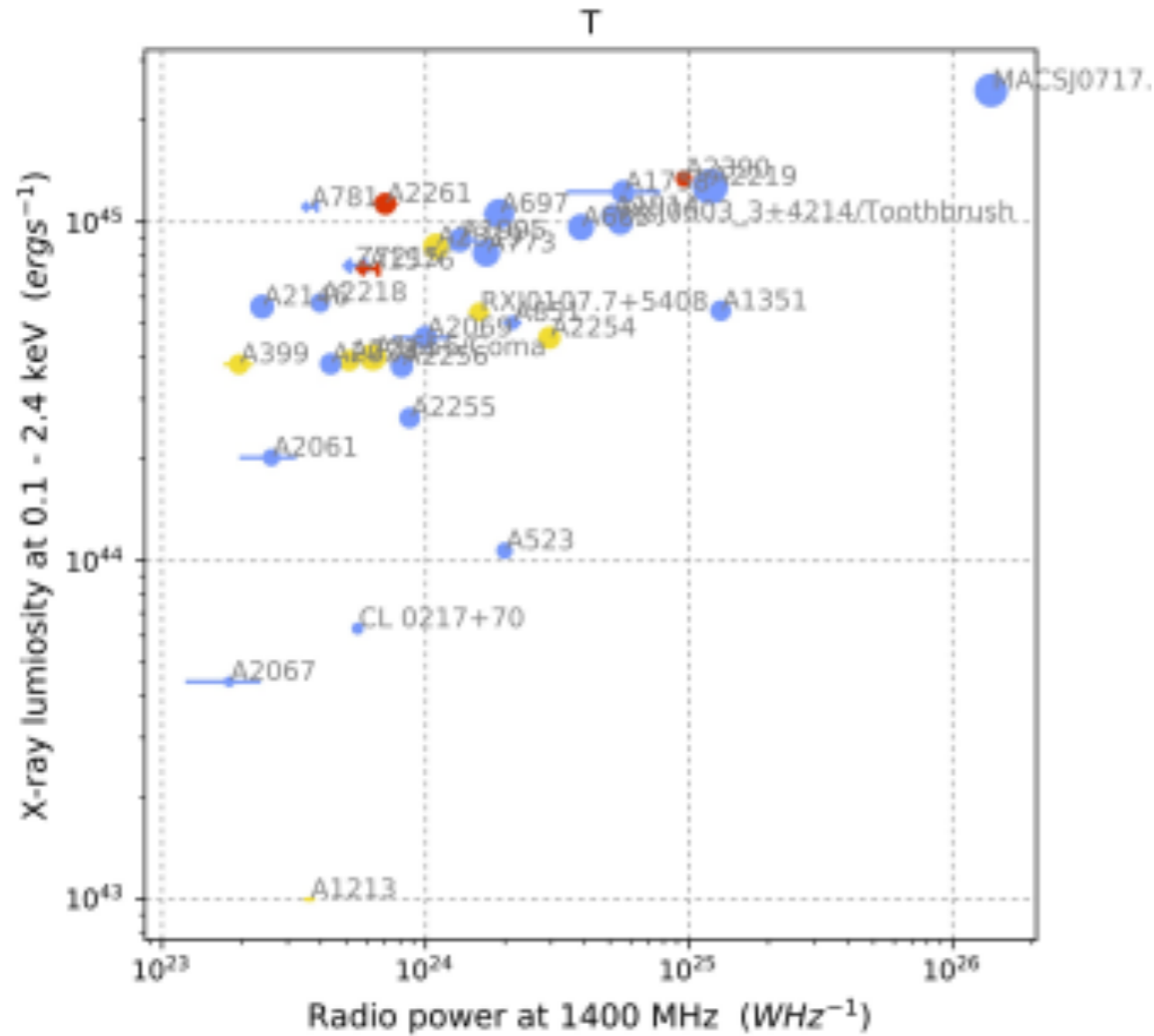


# Scaling relations



# Scaling relations

A connection between their origin and the dynamics of the diffuse intracluster medium (ICM).



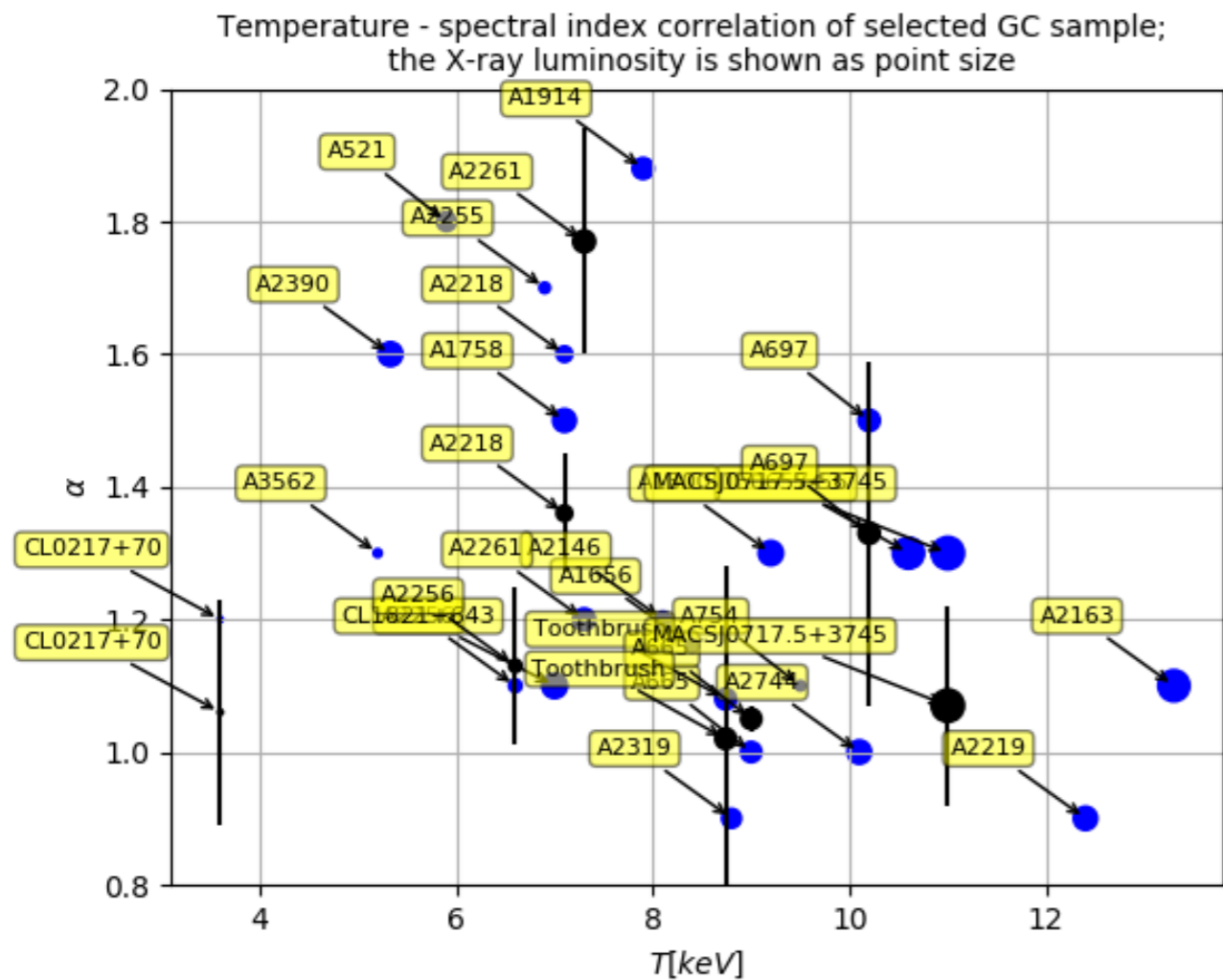
Blue: Merge Red: Relax Yellow: no data Size: T

Slope (1.4MHz) :  $2.0 \pm 0.3$

Slope (138MHz):  $2.1 \pm 0.5$

# T vs $\alpha$ correlation?

improve statistics of spectral index measurements of radio halos to test / extend the correlation T vs  $\alpha$ .



a key clue in favour of re-acceleration models

The Spearman rank order correlation coefficient for (T,  $\alpha$ ) is -0.42 with an associated p-value of 0.04

# Detection rate and new candidates

Including all the PSZ sources in our field, our halo detection rate is about **30%**.  
From literature (Venturi et al. (2007, 2008)), the fraction of clusters hosting radio halos is:

**0.29**  $\pm$  0.09 ( $0.2 < z \leq 0.4$ ,  $L_x > 5 \times 10^{44}$  erg s $^{-1}$ )

**0.38**  $\pm$  0.13 ( $L_x > 8 \times 10^{44}$ )

We expect to detect at least part of halo emission in about 100 clusters using MSSS survey data with declination  $> 15$  degree.

new potential (i.e. 2 sigma) halos at 138 MHz

A781, A963 (mini halo?), A1185, A1763, Z7215 (RXCJ1501.3+4220)

A2261 recently discovered by Sommer et al. 2017

A2146 recently discovered by Hlavacek-Larrondo et al.2017 with JVLA

LOFAR deep HBA observations proposed for A1185, A1763, Z7215 (RXCJ1501.3+4220) in Cycle 9.

# Summary

- The MSSS survey can be used to investigate and search for diffuse emission in galaxy clusters.  
Has provided the largest sample of radio halo at low frequency (<325 MHz).
- For the first time, we derive the correlation between P138 and L<sub>x</sub>, which is consistent with the result at 1.4 GHz.
- We confirm the previous observational evidence at lower frequency that (giant) radio halo can be associated with low luminosity X-ray clusters.
- We started to explore the correlation between spectral index and temperature
- Candidates for new discoveries (TBC), i.e. 5 new halos
- Detection rate is about 30%.

## Future/ongoing work

Improve calibration + further automatise data reduction in a form of pipeline.  
Set up and run a “blind” search for extended radio features in catalogued clusters.  
Deep investigation of Cycle 9 proposed targets and work in synergy with LoTSS.