# Connection between radio activity in BCGs and cluster dynamics

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# Outline

- What are the Brightest Cluster Galaxies (BCGs) ?
- Does ICM affect occurrence of radio activity in BCGs ?
- Sample of clusters and BCG identification
- ICM morphology as a proxy for dynamical disturbance

## Results

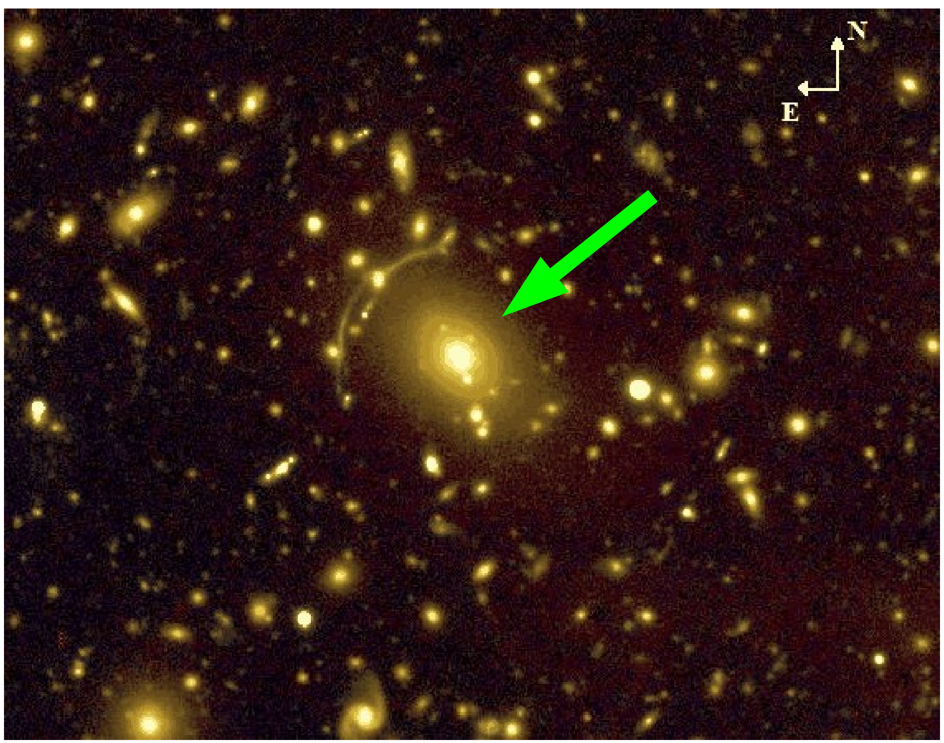
- Fractions of radio BCGs in relaxed Vs merging clusters
- Radio luminosity function of BCGs

Kale, R., Venturi, T. et al. 2015, A&A, 581, A23

# Brightest cluster galaxies (BCGs)

Most massive and brightest galaxies among all the galaxies reside at the centres of galaxy clusters.

## Abell 611




Romano et al. 2010

## Ellipticals and cDs

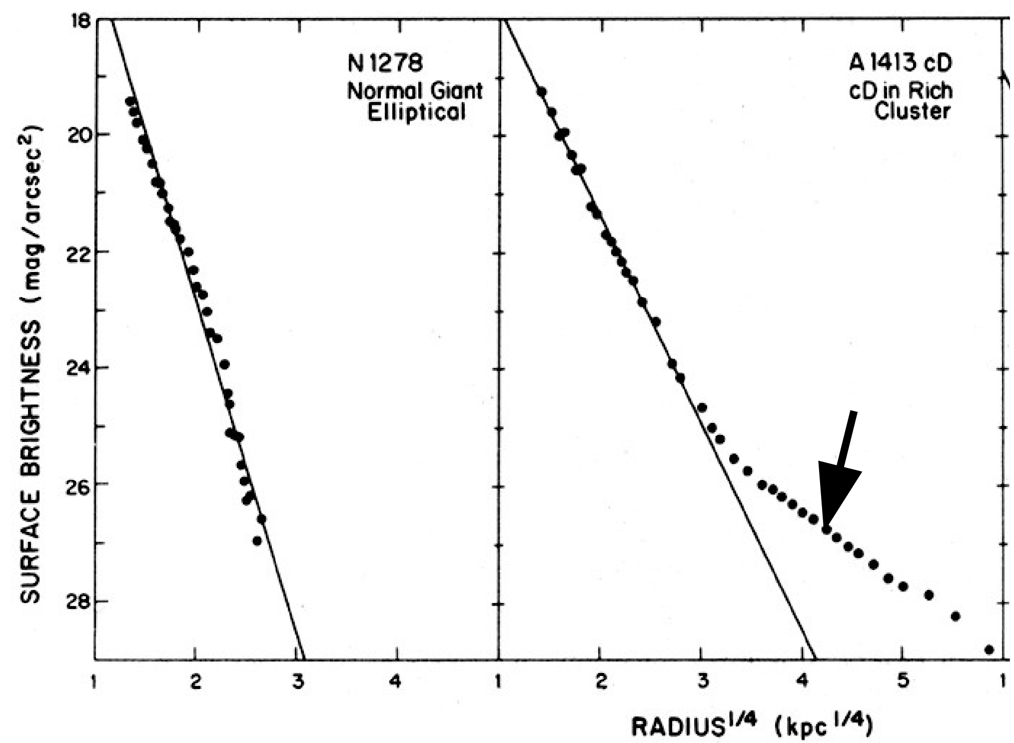
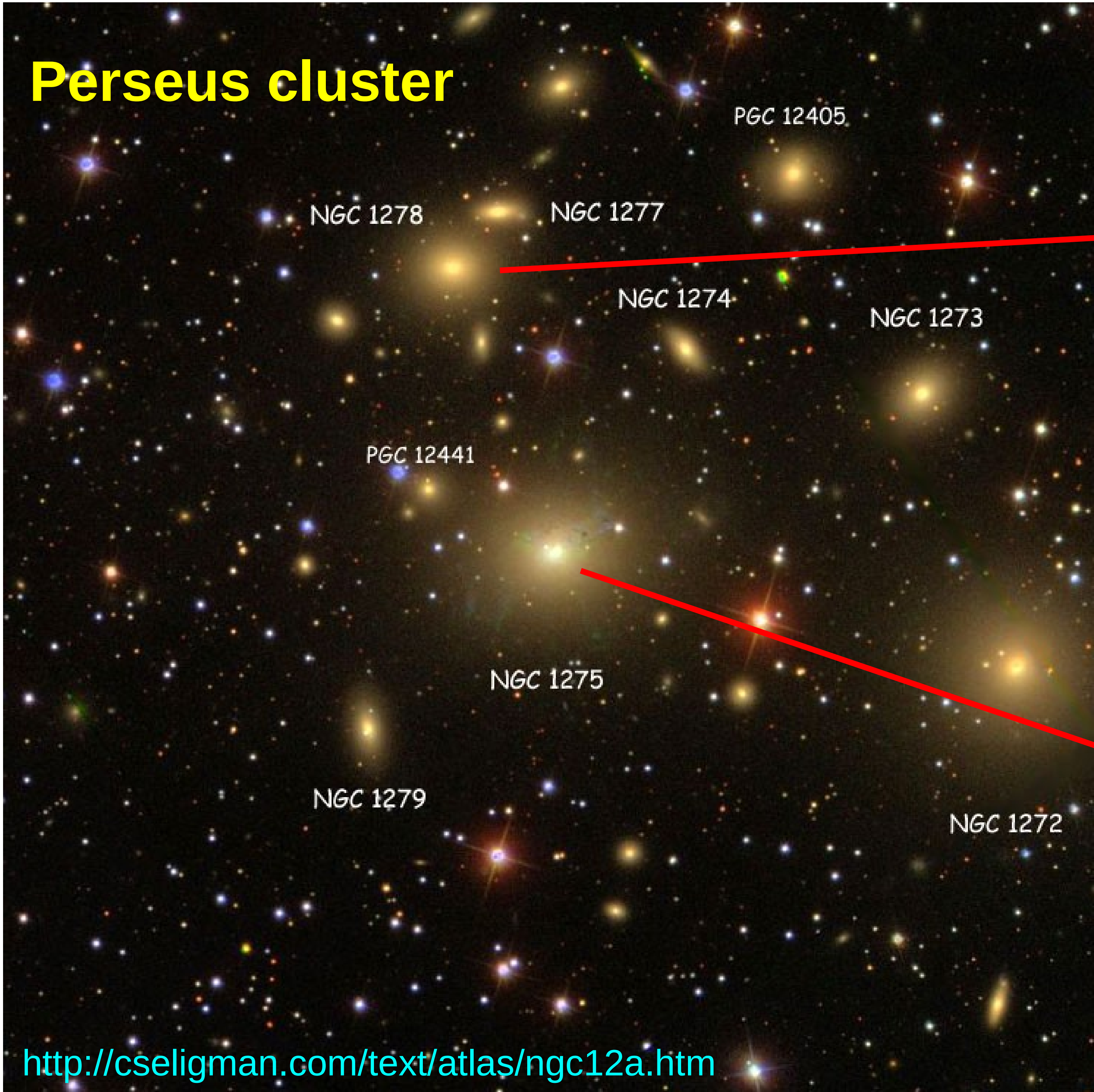
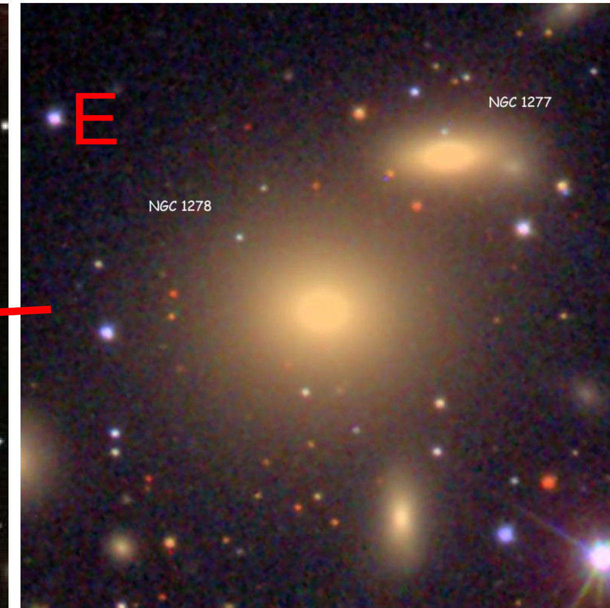
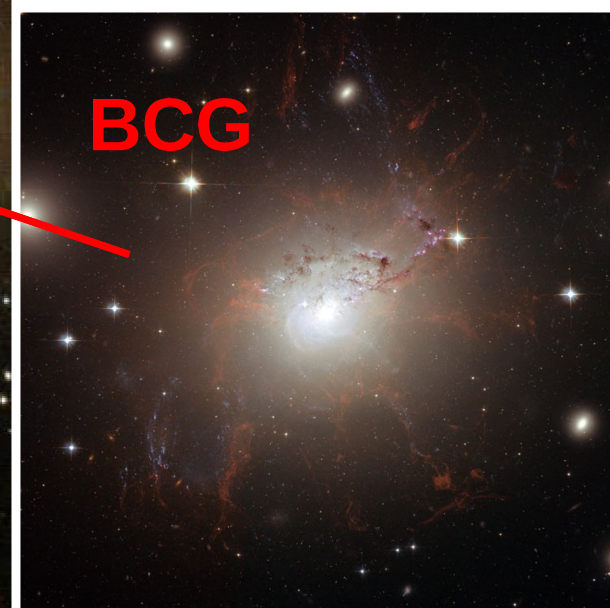



Figure from the book: 'X-ray emission from clusters of galaxies ', C. Sarazin.




NGC1278




NGC1275

# Properties of BCGs

Typical luminosities ~ 10 $L_*$

(e.g. Sandage & Hardy 1973)

-Larger than typical ellipticals (50-100 kpc halo)

-Have higher velocity dispersion (300-400 km/s)

- More likely to be radio loud than other galaxies of similar stellar mass

(Burns 1990, but see also Best et al 2005b)

(von der Linden et al 07)

- Radio powers between FRI and FRII types

(Owen and Laing 1989)

# *Does large-scale cluster environment affect the occurrence of (nuclear) radio emission in the BCGs ?*

## BCG environment

BCG environment:     ~100 galaxies / $Mpc^3$  and ICM gas
Galaxies outside clusters:  < 10 galaxies / $Mpc^3$

- BCGs are more likely to be radio loud than other ellipticals of similar stellar mass

(von der Linden et al. 2007; Best et al. 2007; Bagchi & Kapahi 1994; Valentijn & Bijleveld 1983)

Indicates the role of environment.

Radio loudness also depends on mass; this effect needs to be separated from that of environment.

(Best et al. 2006)

# *Extended GMRT Radio Halo Survey*

**REFLEX + eBCS X-ray catalogues**

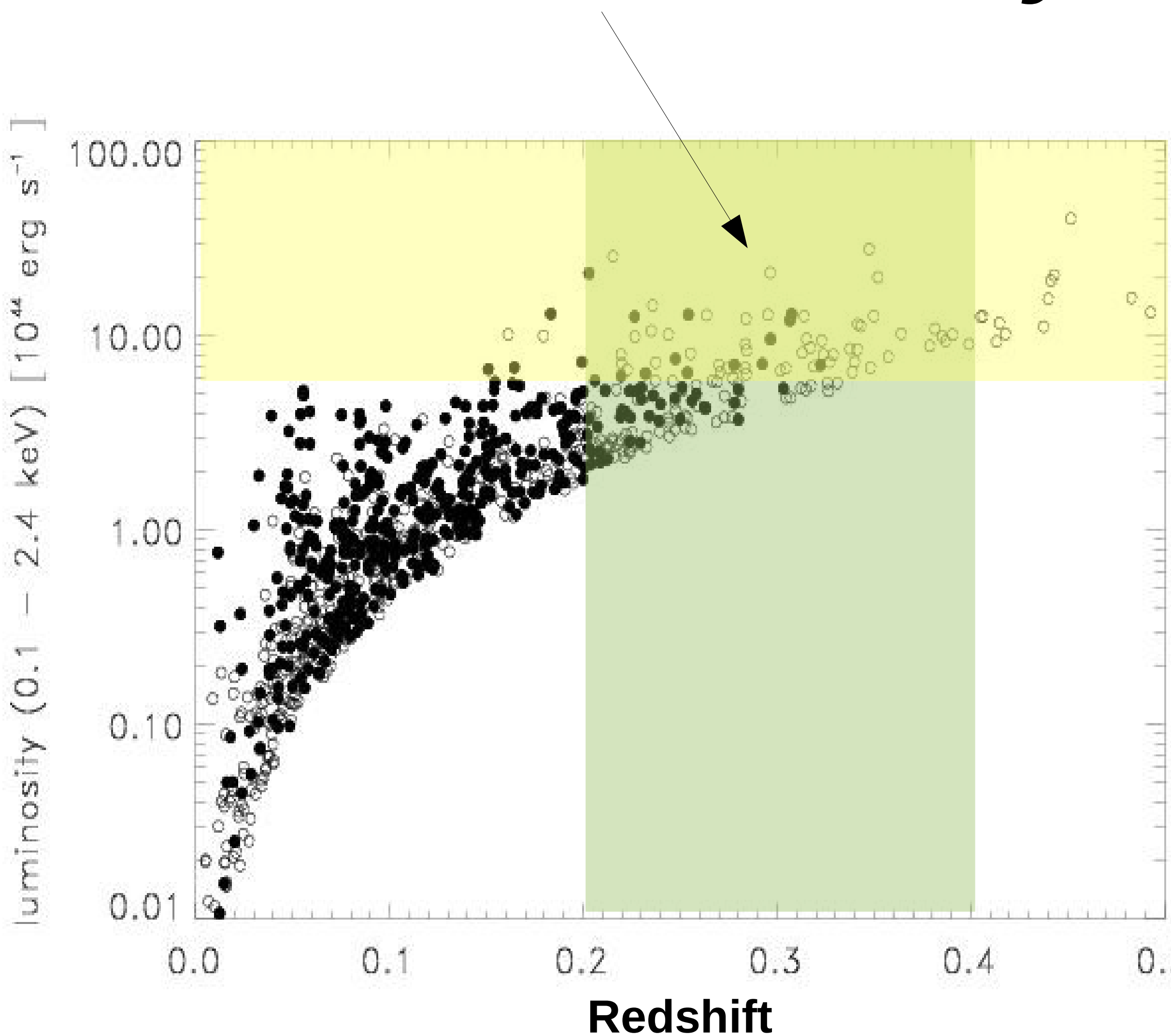
*Bohringer et al 2004;*
*Ebeling et al. 1998, 2000*

$L_{x(0.1\text{-}2.4\ keV)} > 5\times10^{44}$ erg/s

$0.2 < z < 0.4$

Declination > -31°

66 clusters




*Bohringer et al. 2013*

*GRHS: Venturi et al. 2007, 2008; EGRHS: Kale et al. 2013, 2015*

# Steps:

- Identification of BCGs in the EGRHS clusters:

  Use of SDSS where available (44) and DSS otherwise

  Visual inspection, literature

- Find the radio information for the BCG:

  Use of NRAO VLA Sky Survey, FIRST (1.4 GHz surveys)

  GMRT 610 MHz data

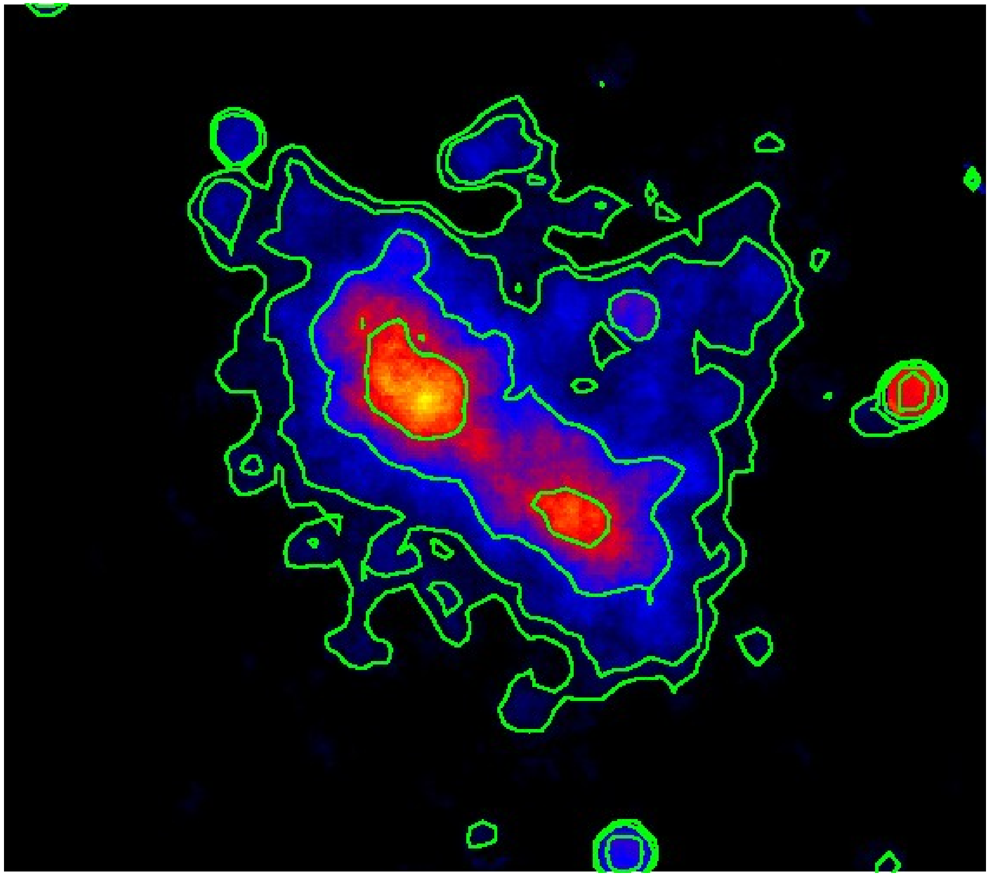
- Morphology parameters for clusters:

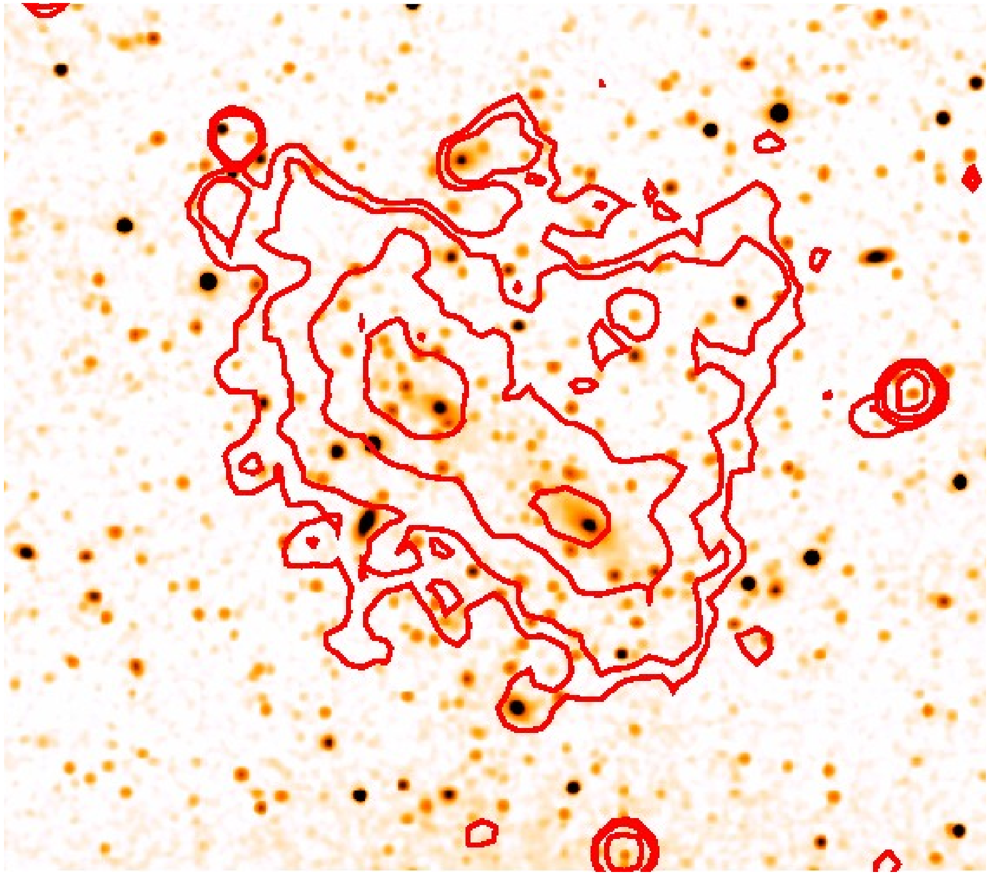
  Classification into merging and relaxed clusters.

**Calculation of the radio loud fractions and RLF separately for merging and relaxed clusters**

# BCG identification

Z5247 More than one BCG



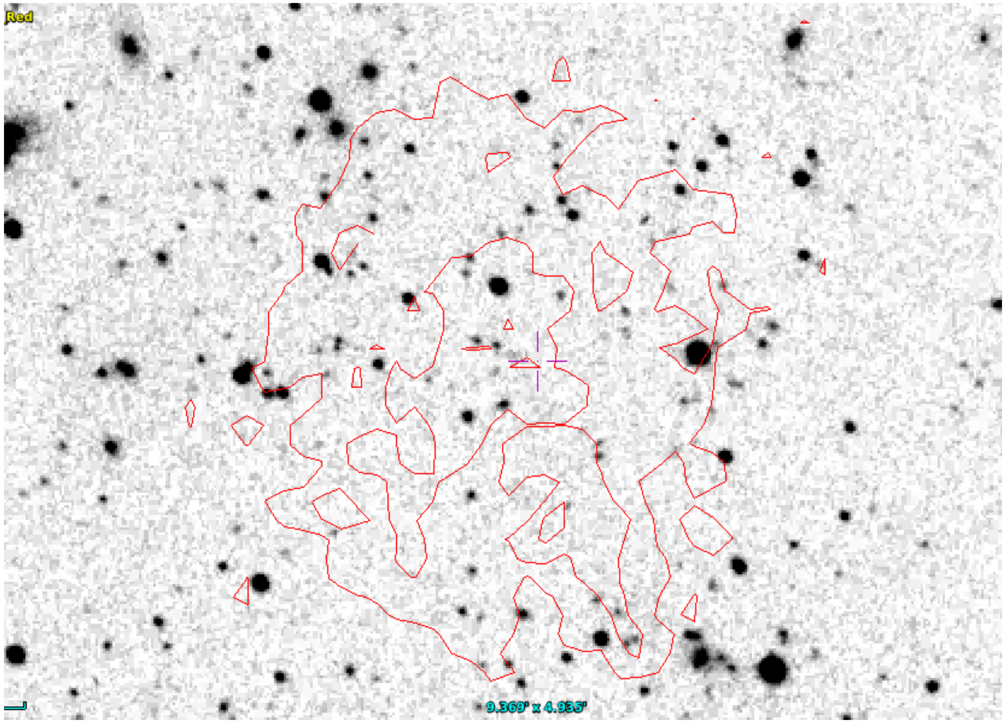


*A773, A2163, A2744, RXCJ1314.4-2515, RXCJ1514.9-1523*

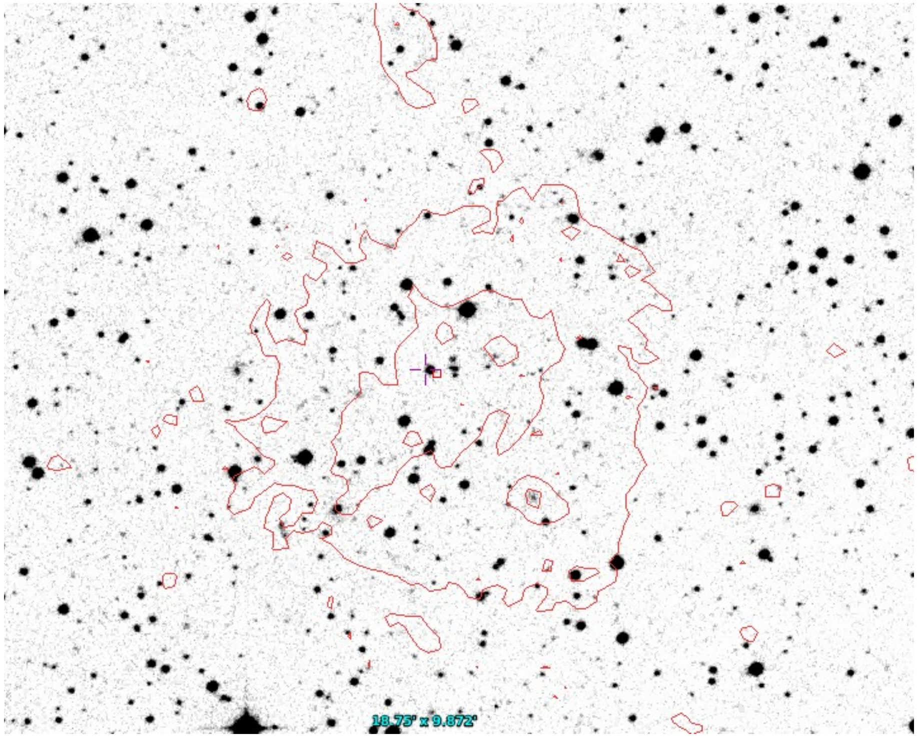
**Visual inspection, optical-X-ray overlays, literature**

# No BCG

Abell 520




RXCJ2003.5-2323

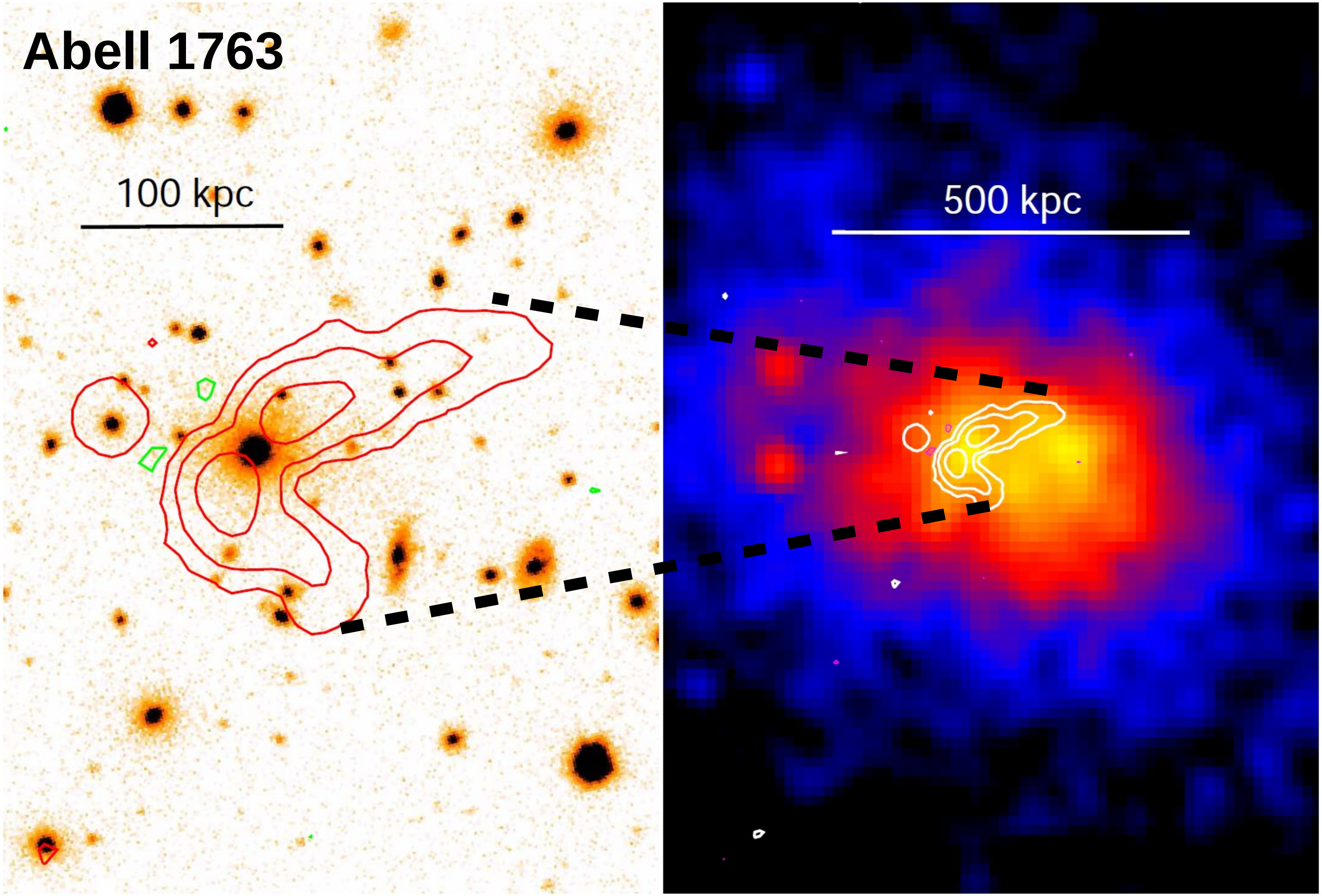



Also RXCJ1212.3-1816.

No BCGs formed or were displaced from the cluster center.

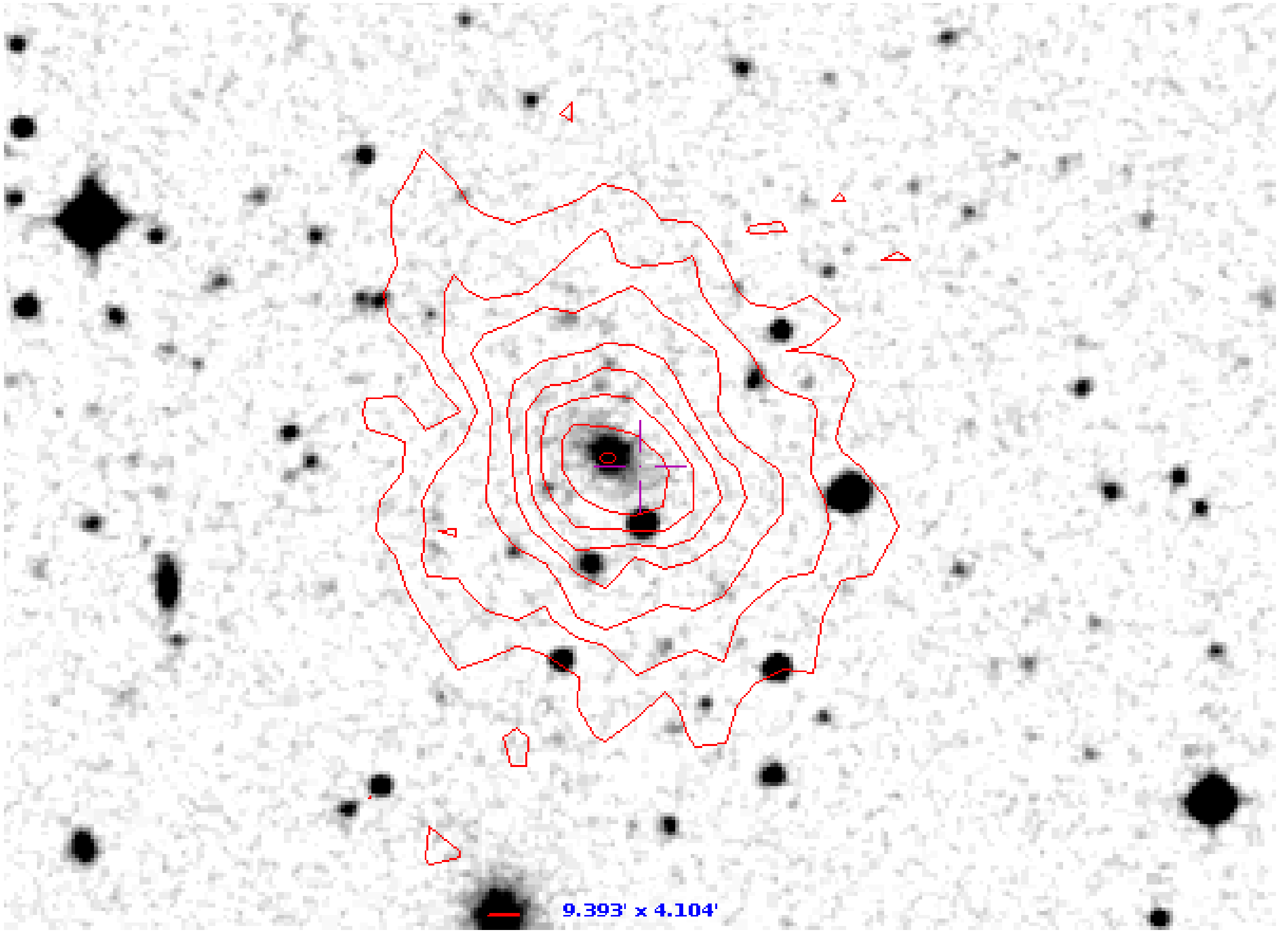
# Radio identification

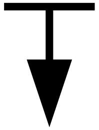
## Radio loud BCG



# Radio quiet BCG

A2485

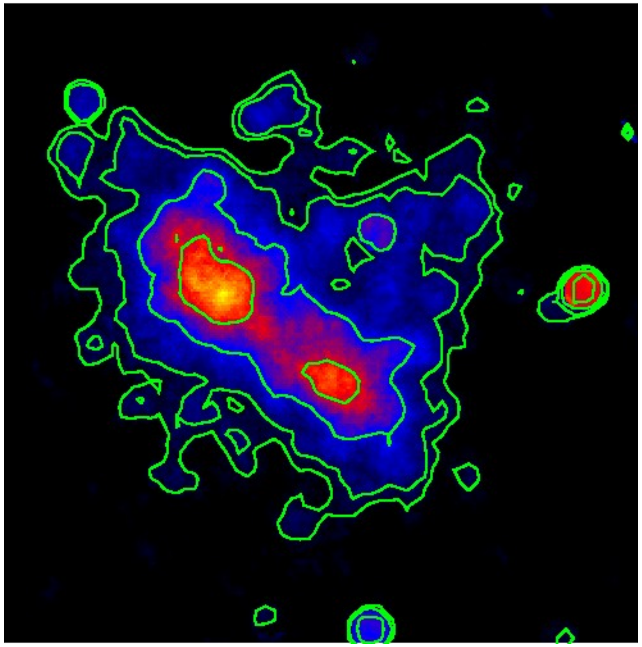


Conservative radio flux density upper limits based on NVSS: 2.25 mJy

# Morphology (measure of disturbance)

Chandra data – surface brightness maps



Morphological parameters:

Concentration parameter $C_{100}$

Centroid shift $w_{500}$

Power ratios $P_3/P_0$

*e.g. Buote & Tsai 1995, Santos et al. 2008, Poole et al. 2006; Cassano et al. 2010, 2013*

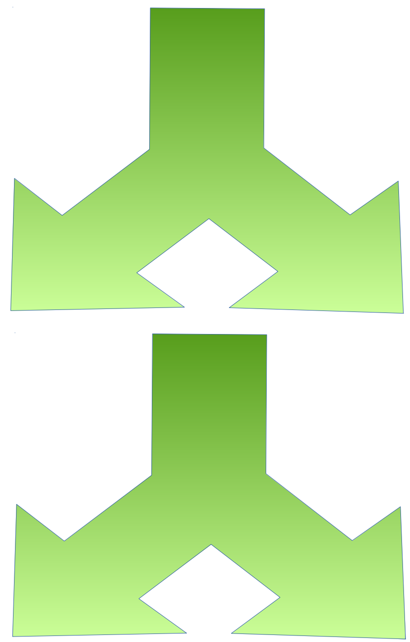
Classification as merger if :

$C_{100} < 0.2$ & $w_{500pe} > 0.012$ & $P_3/P_0 > 1.2e\text{-}7$

*Taken based on the separation indicated by radio halo occurrence. See Cassano et al 2010, 2013.*

# *BCG distribution*

59 BCGs



**Merging**
**33**

**Relaxed**
**26**

**Radio loud**
**28**

**Radio quiet**
**31**

# BCG distribution

59 BCGs

Radio loud
**28**

Radio quiet
31

**Merging**
**8**

**Relaxed**
**20**

**Merging**
**25**

**Relaxed**
**6**

# BCG distribution: comparison with random distribution

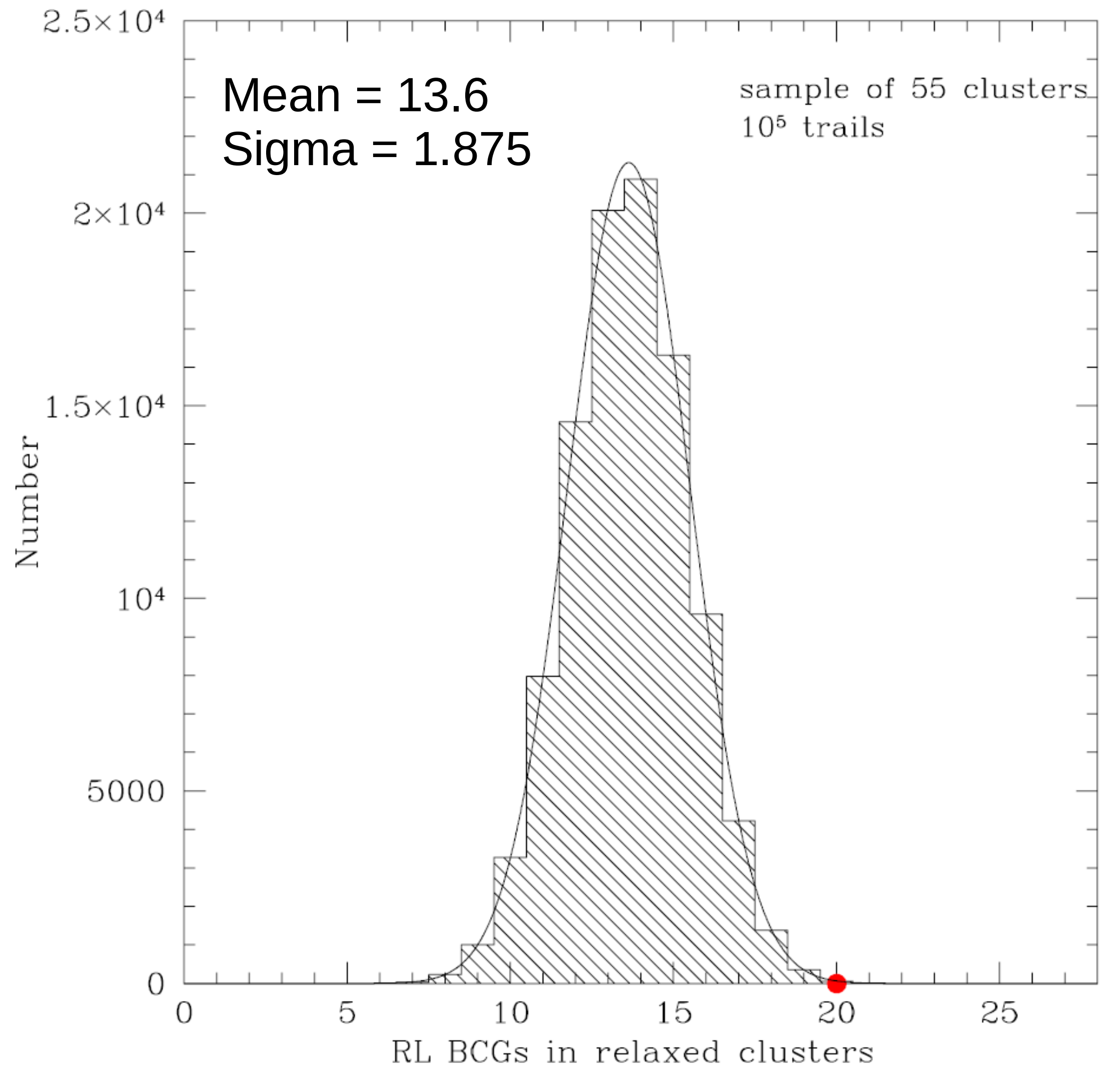
Monte Carlo trials:

Example:

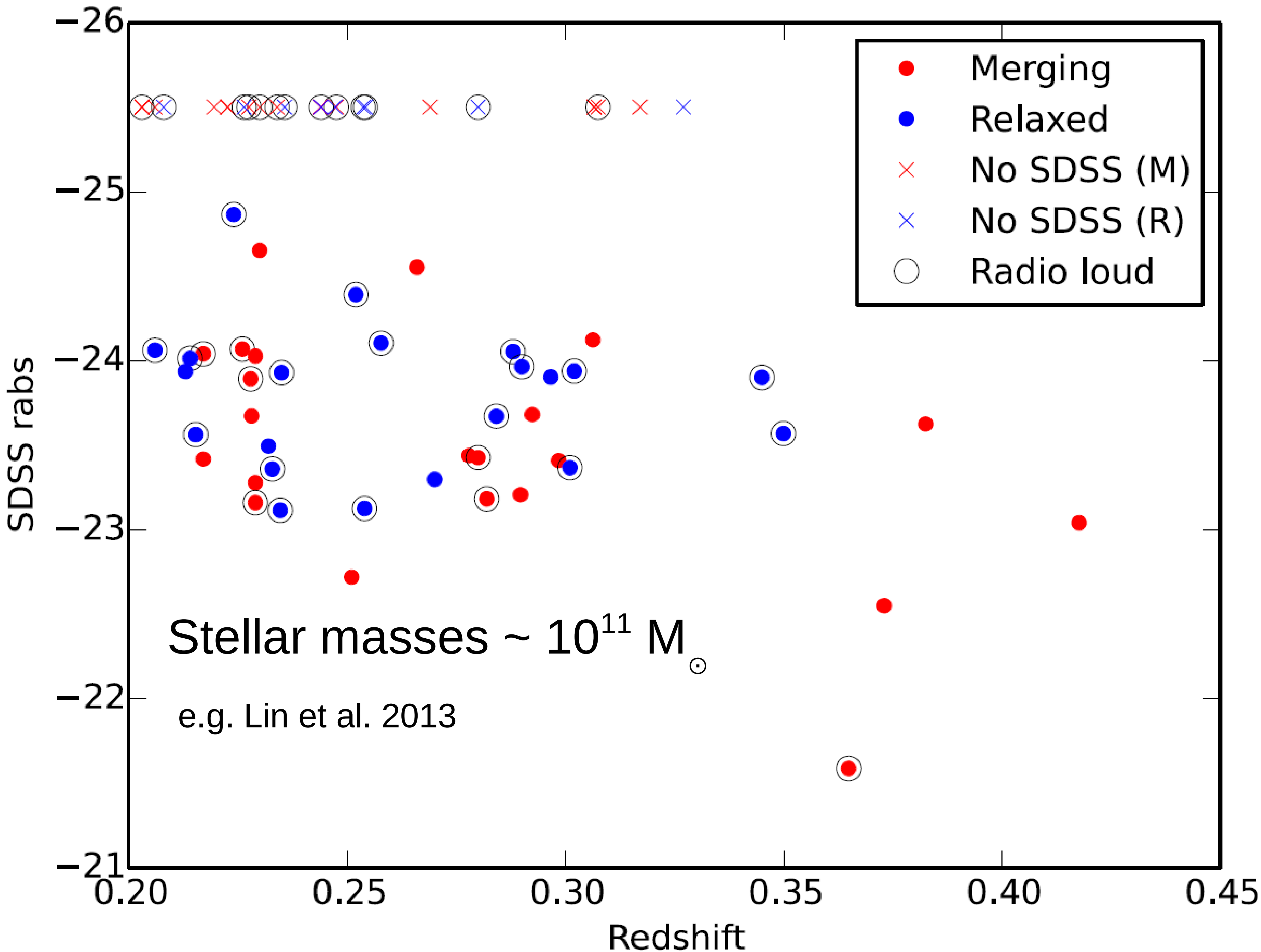
Randomly assign 28 radio loud BCGs in 55 clusters.

20 BCGs in relaxed clusters is at 3.4sigma.

Probability of chance detection is less than 3.4 x $10^{-4}$



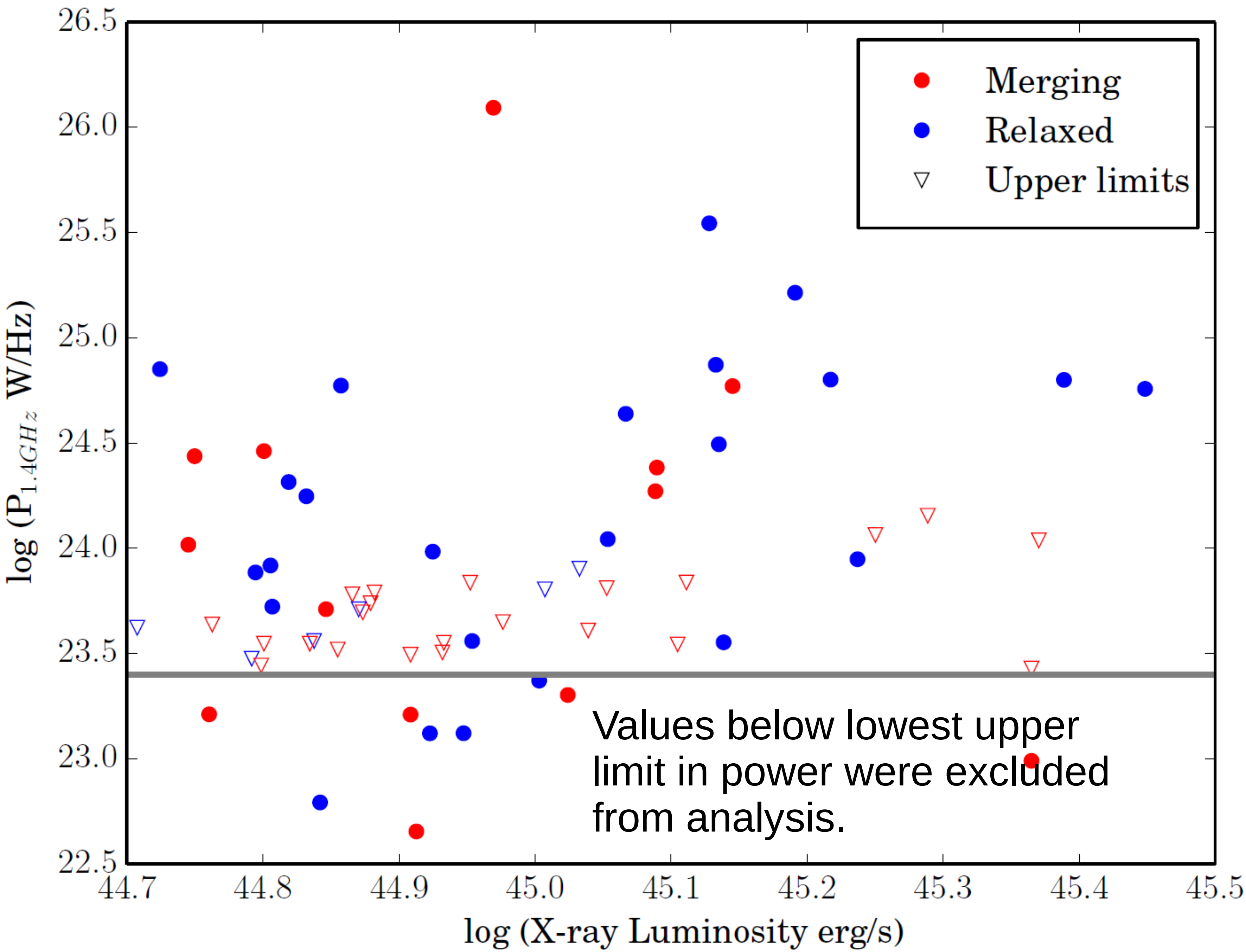
# BCG sample: R Vs z distribution



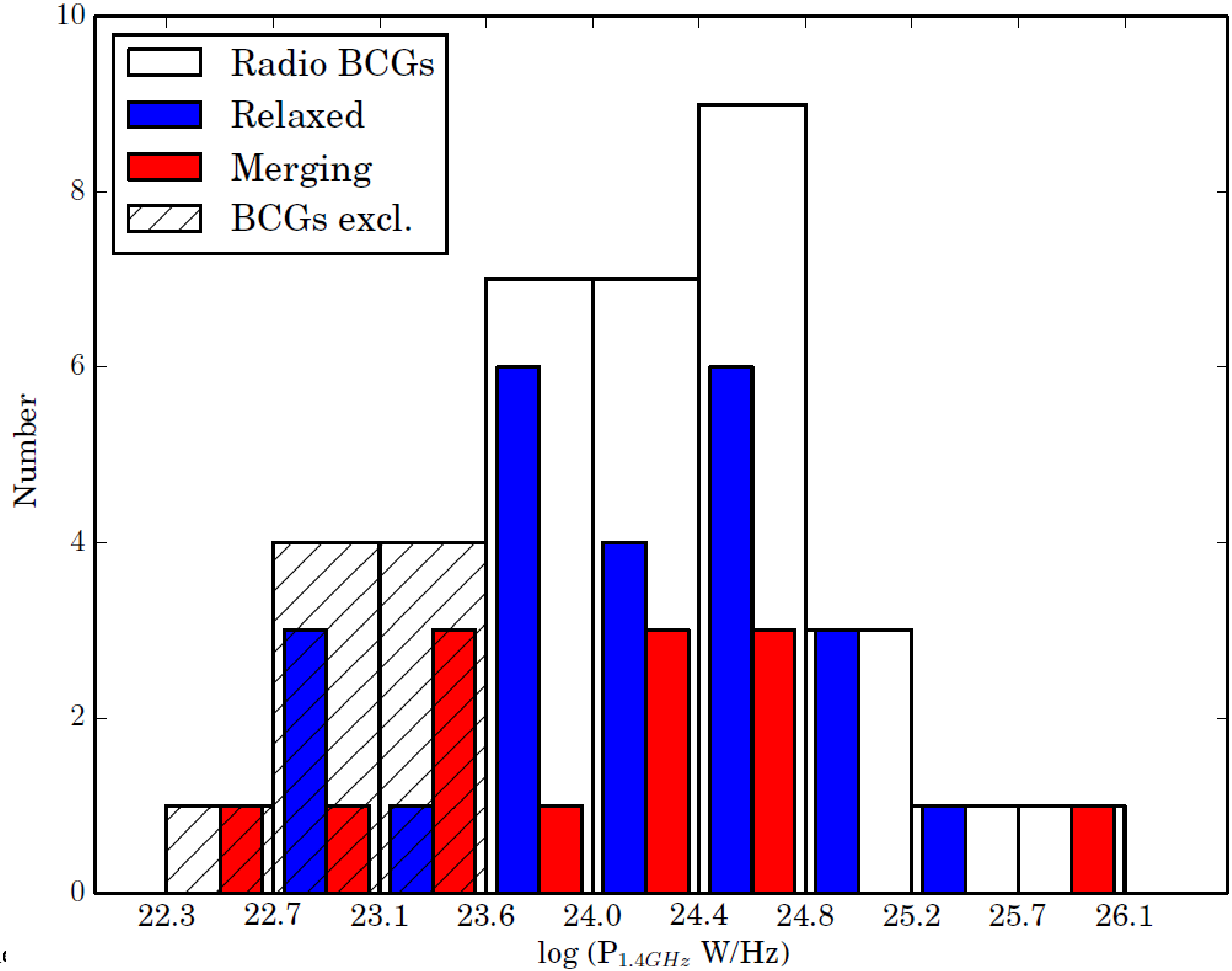

Stellar masses ~ $10^{11}$ $M_\odot$

e.g. Lin et al. 2013

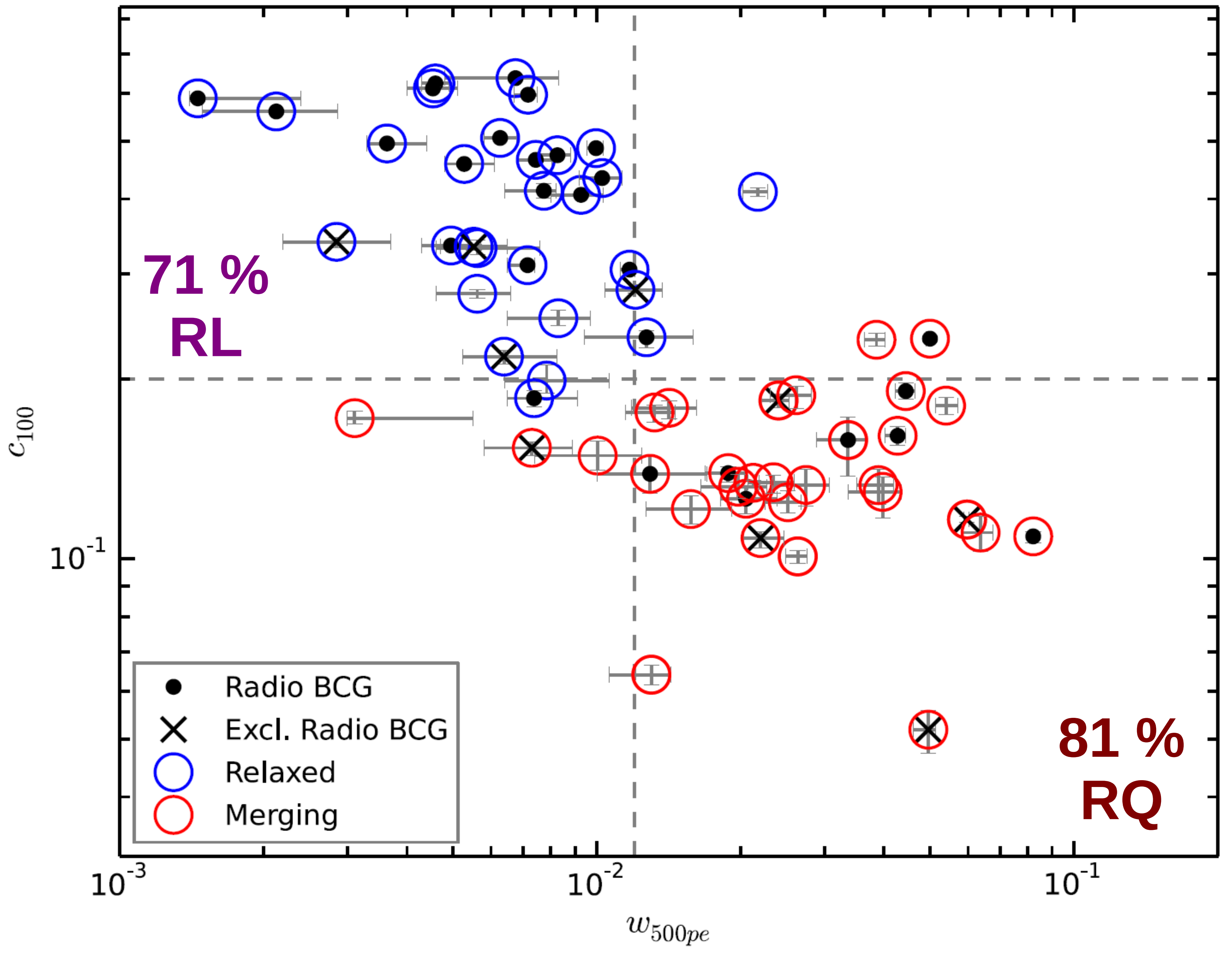
# BCG sample: Radio power Vs X-ray luminosity



# BCG sample: Radio power histogram



# Cluster morphology and radio BCGs

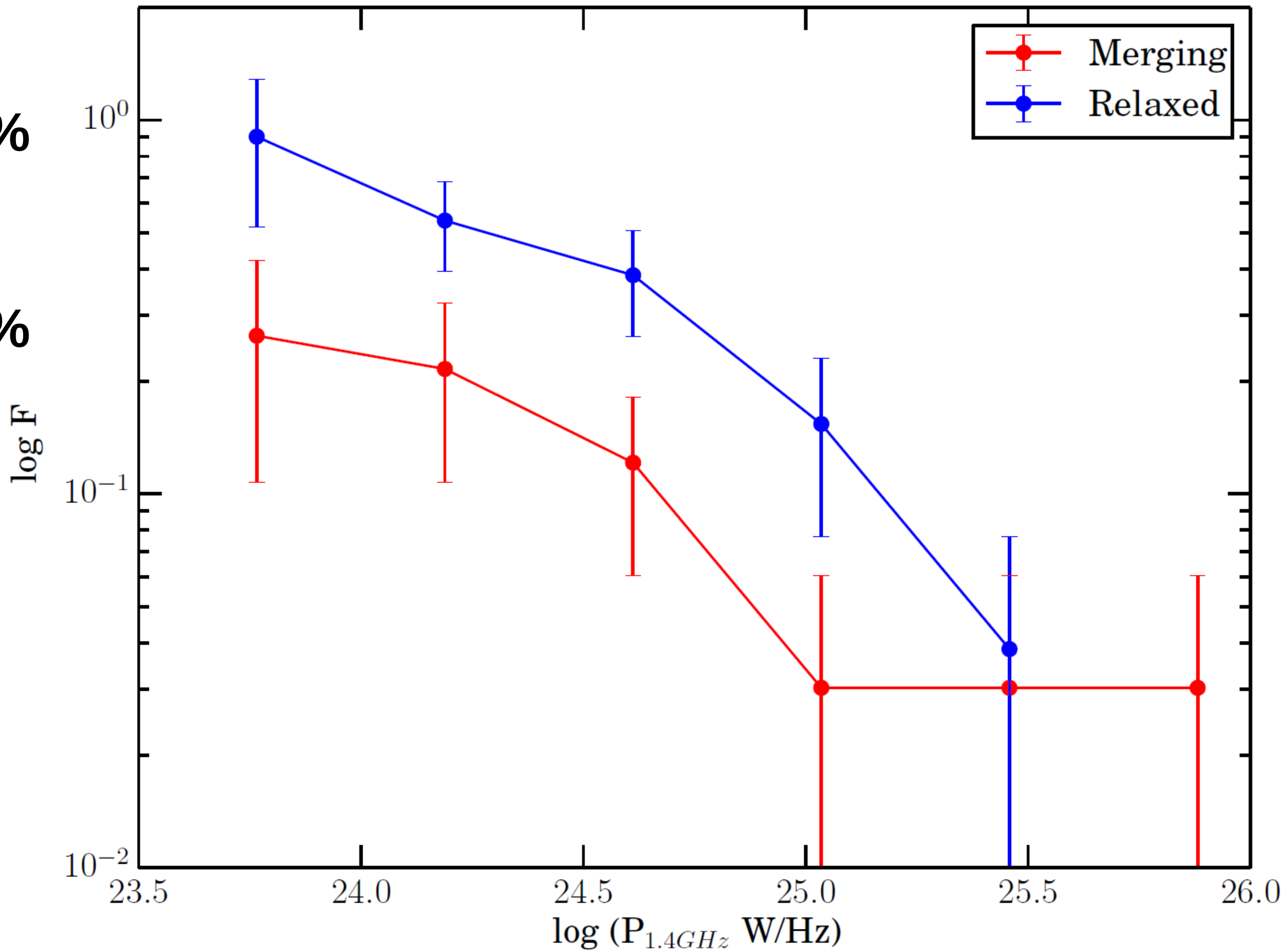


# Radio luminosity function

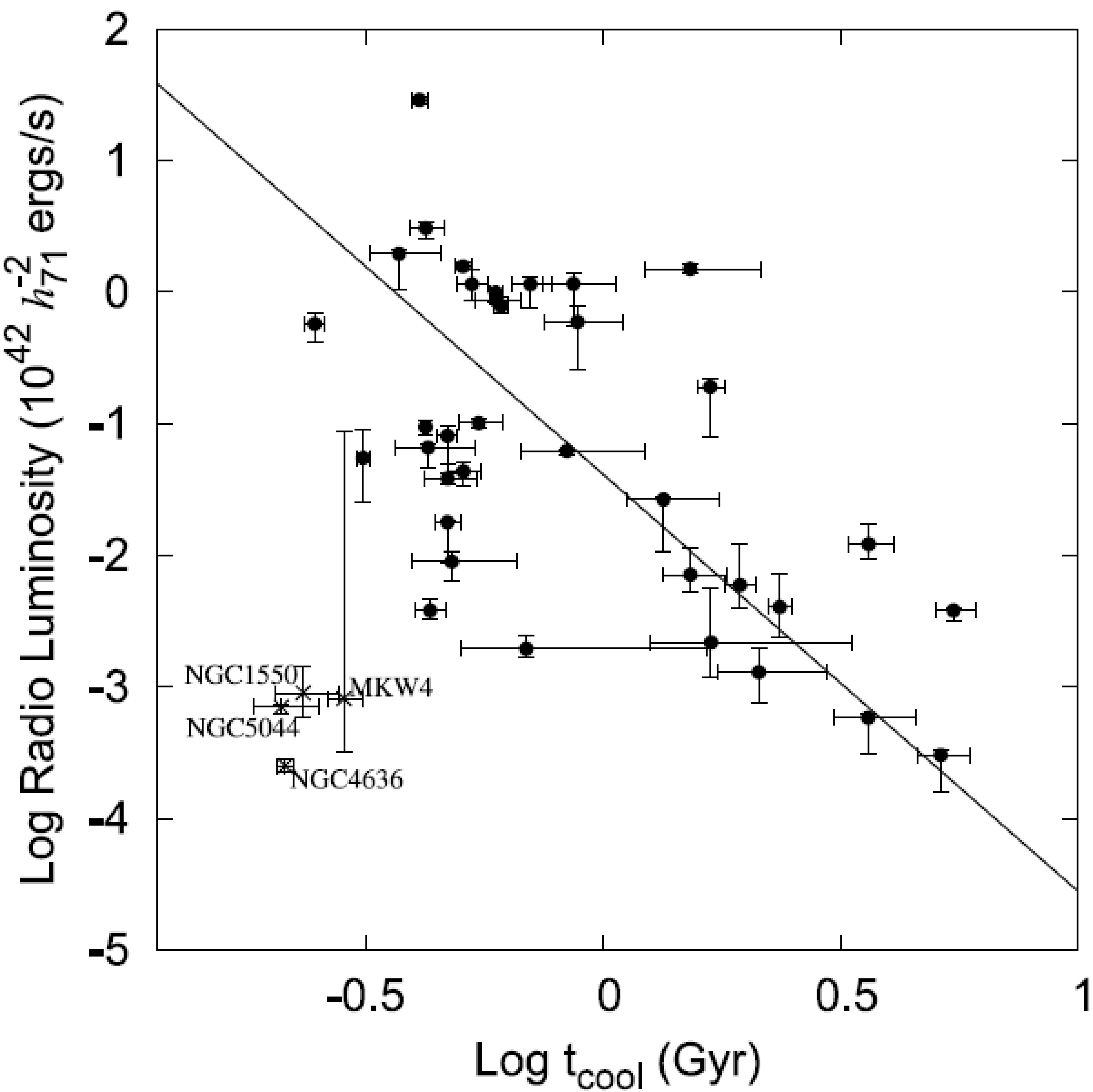
Method by R. Fanti (Hummel 1981)

~90%

~30%



# Radio power scales as strength of cooling time




$P_{1.4GHz} \propto t_{cool}^{(-3.16+/-0.38)}$

Mittal et al. 2009

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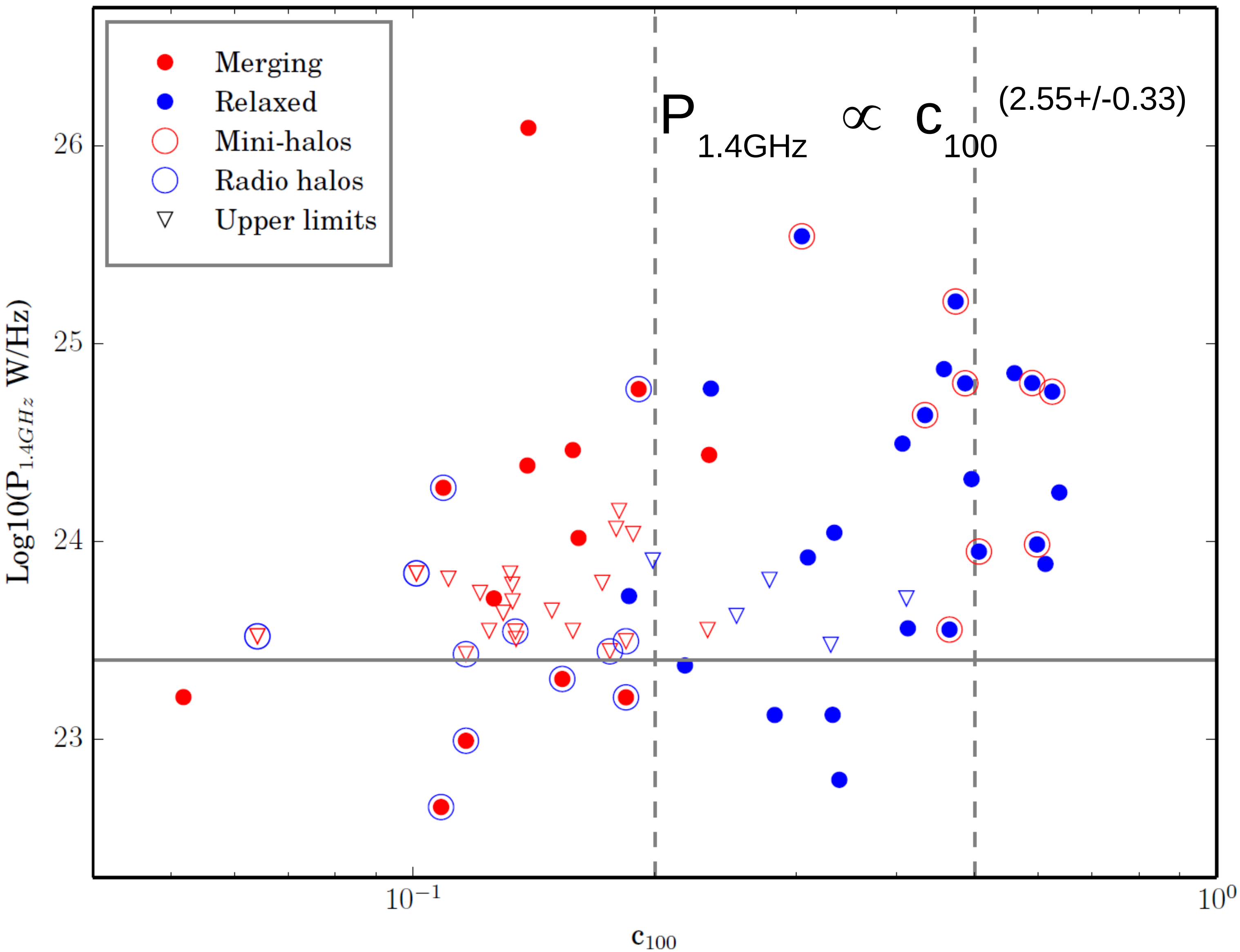

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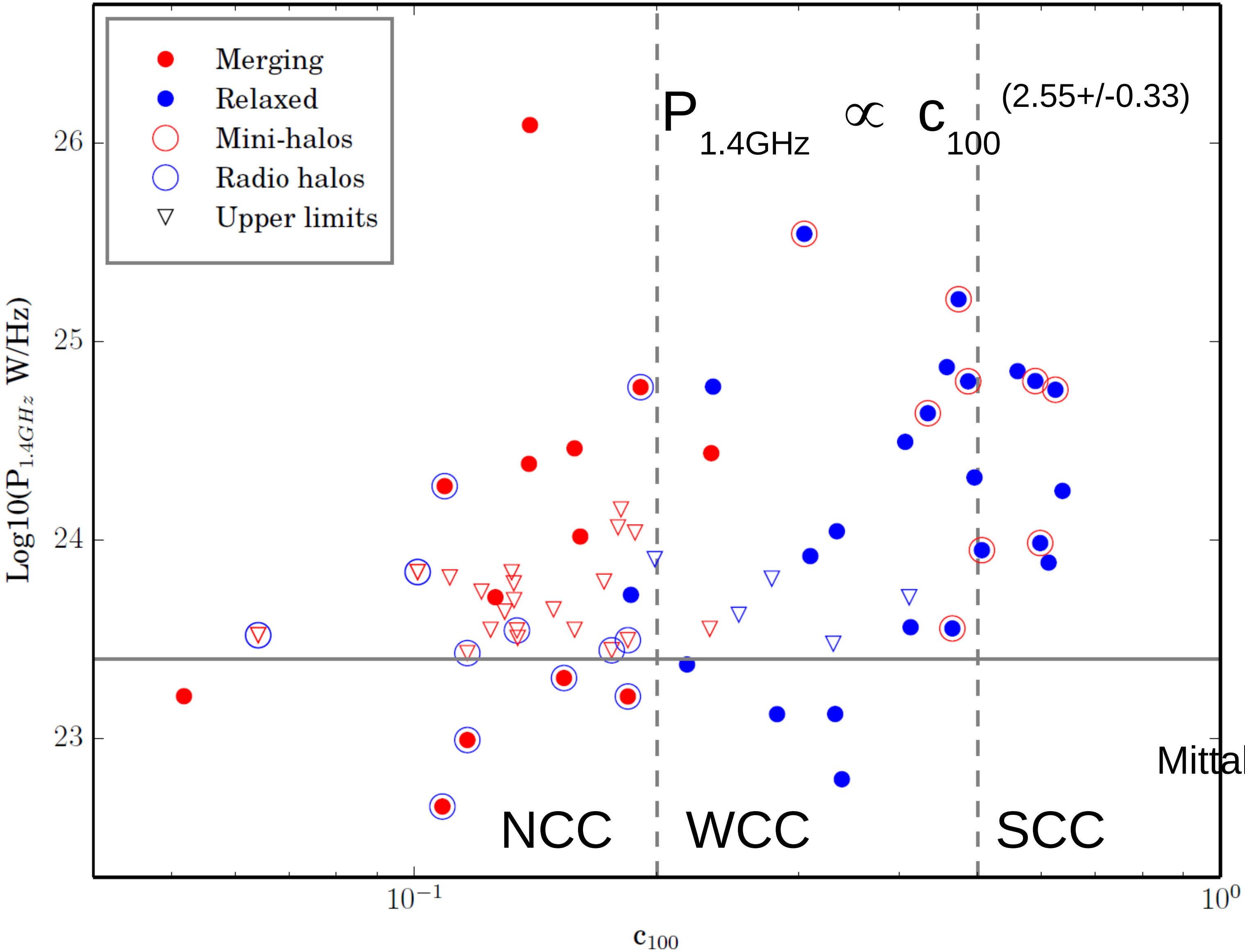



Mittal et al. 2009

$P_{1.4GHz} \propto t_{cool}^{(-3.16+/-0.38)}$

$t_{cool} \propto c_{100}^{(-1)}$ e.g Santos et al. 2008

# Optical spectra (Ongoing work)

SDSS spectra are available for 28 BCGs.

19 radio loud

5 in merging

14 in relaxed

9 radio quiet

7 in merging

2 in relaxed

Emission lines found in optical spectra of 11 out of 19 radio loud BCGs. All of these are in relaxed clusters.

All BCGs with mini-halos show emission lines.

# Summary and Conclusions

We extracted a sample of BCGs from the EGRHS sample of galaxy clusters (0.2< z < 0.4, Lx > $5 \times 10^{44}$ erg/s, dec>-31 degrees).

Morphological parameters based on X-ray maps were used to classify the cluster sample into merging and relaxed clusters.

Radio BCGs occur in ~71% of relaxed clusters whereas ~81% of BCGs in merging clusters are radio quiet.

Fractional radio luminosity function also shows this difference in the likelihood of finding a radio loud BCG in relaxed versus that in merging cluster. Larger sample needed to find if there is a difference in the two BCG populations.

**This work provides support for a strong link between the radio properties of BCGs and the dynamical state of the host cluster.**

# Morphological parameter definitions

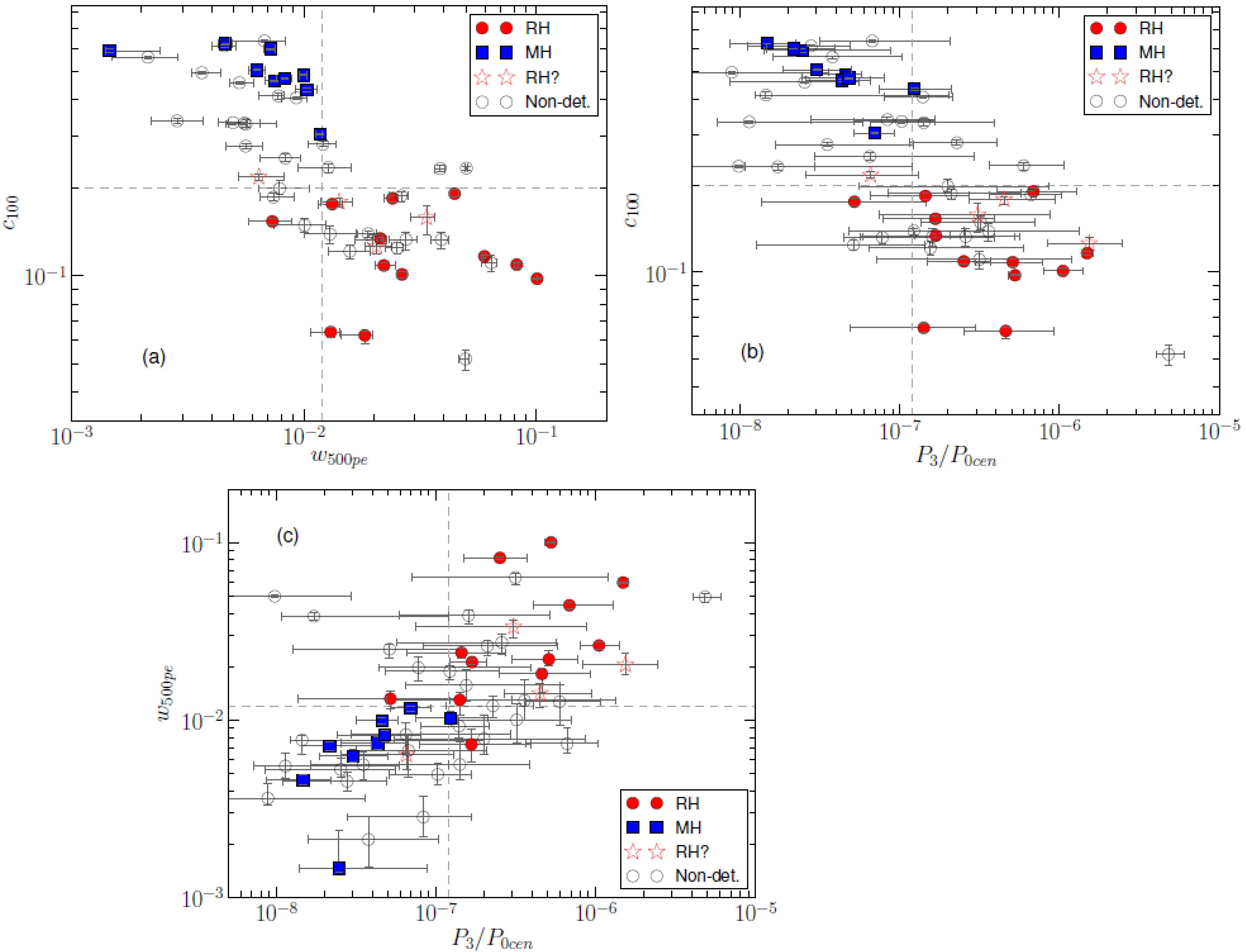
$C_{100}$ The ratio of the central (<100 kpc) over the ambient surface brightness

$w_{500pe}$ The projected separation between the peak and the centroid of aperture

$P_3/P_0$ The power ratio is a multipole decomposition of the two-dimensional, projected mass distribution inside a given aperture Rap.

→ The lowest power ratio moment that provides a measure of substructure in the cluster.

References: Cassano et al. 2010 and references therein.



RH
MH
RH?
Non-det.
(a)
$c_{100}$
$w_{500pe}$
$10^{-1}$
$10^{-3}$
$10^{-2}$
(b)
$P_3/P_{0cen}$
$10^{-8}$
$10^{-7}$
$10^{-6}$
$10^{-5}$
(c)


R