BACK AND FORTH FROM COOL CORE TO NON-COOL CORE: CLUES FROM RADIO HALOS

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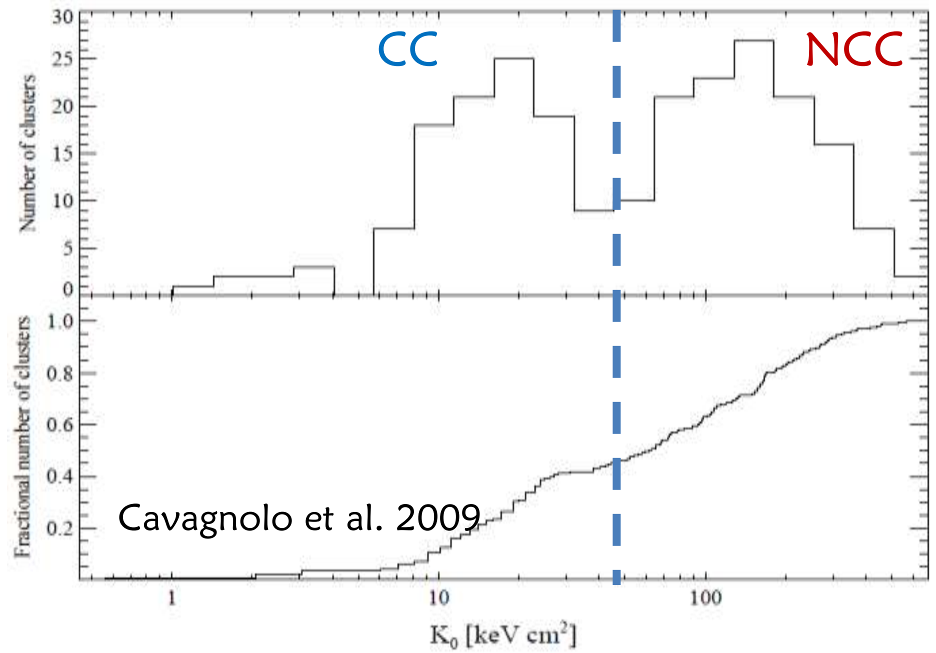
Radio Halo of A1758 (Credits: S.Giacintucci)

“Cool core” vs “Non cool core”

X- ray astronomers usually divide clusters into two classes:
COOL CORE (CC) and **NON COOL CORE (NCC)** clusters.

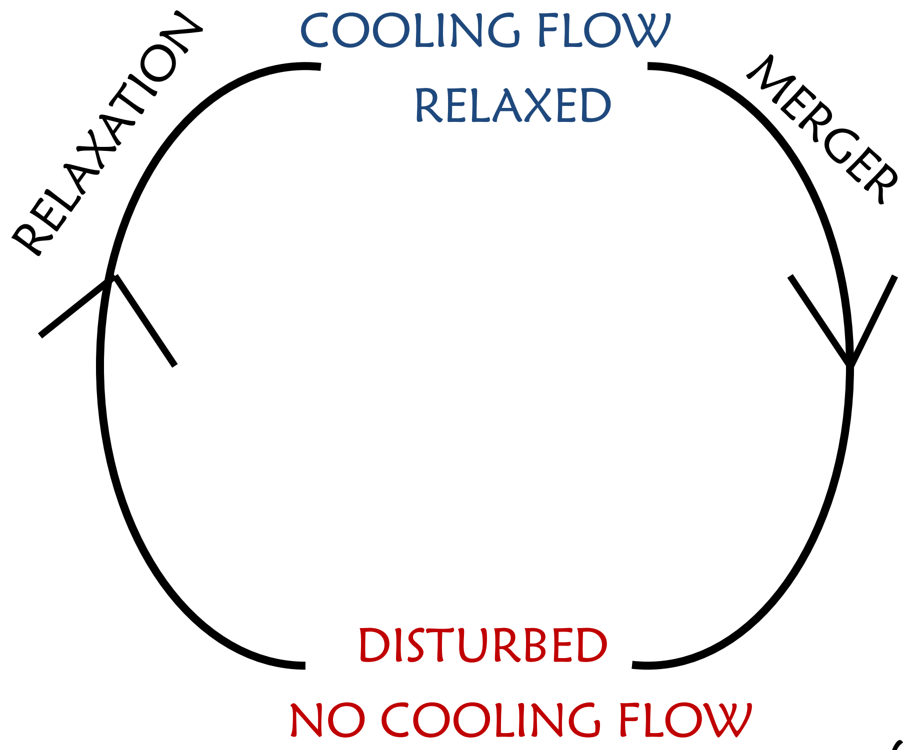
While the precise results depend strongly on the indicators used to classify clusters, the fraction of CC is about 35-50% in local samples. The cluster population is likely bi-modal, with some intermediate objects (Cavagnolo et al. 2009).



What is the origin of the CC-NCC dichotomy?

Life of a cluster

A cyclical evolution



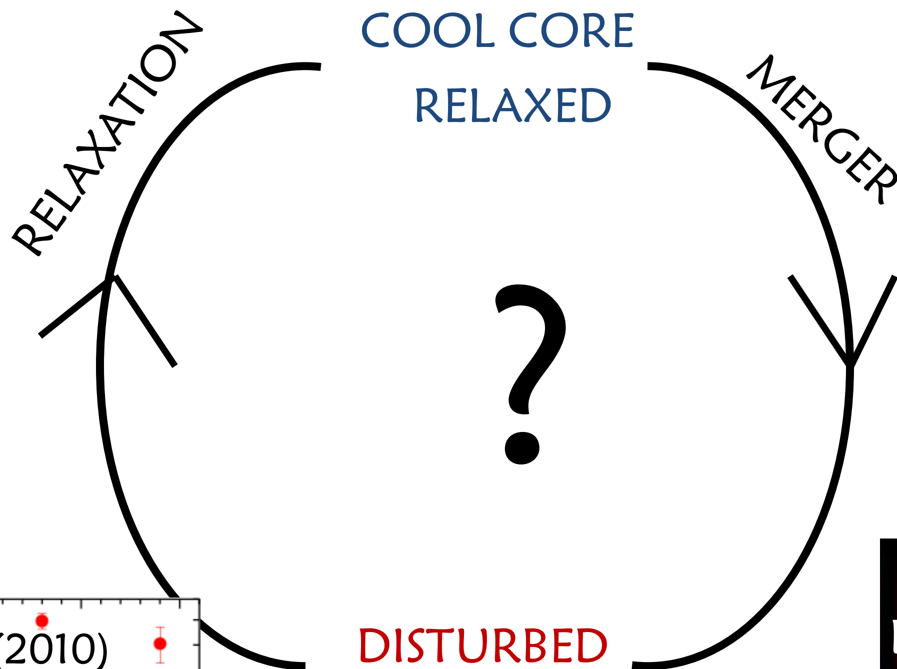
(e.g. Buote 2002)

Life of a cluster

A cyclical evolution ?

CAN CLUSTER RELAX FROM NCC TO THE CC STATE?

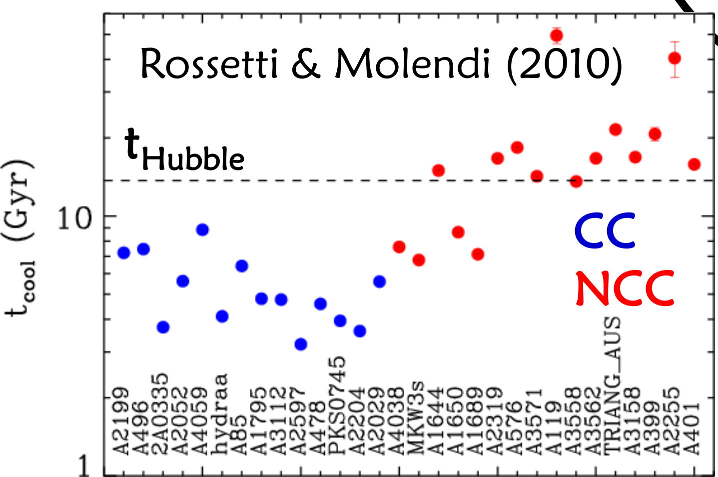
$T_{cool} > t_{Hubble}$ for most NCC objects

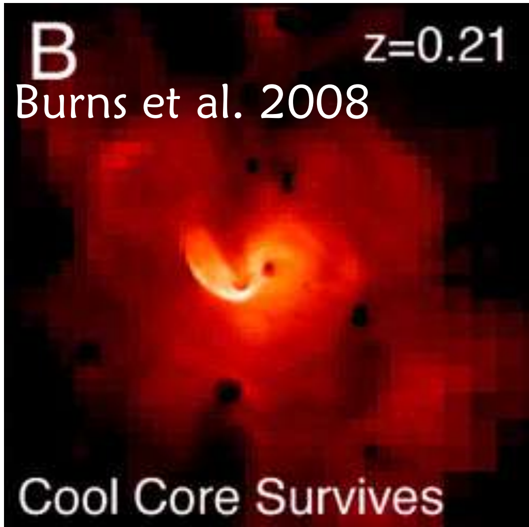


COOL CORE = RELAXED ?

NON COOL CORE = DYNAMICALLY DISTURBED ?

CAN MERGER DESTROY CCs?





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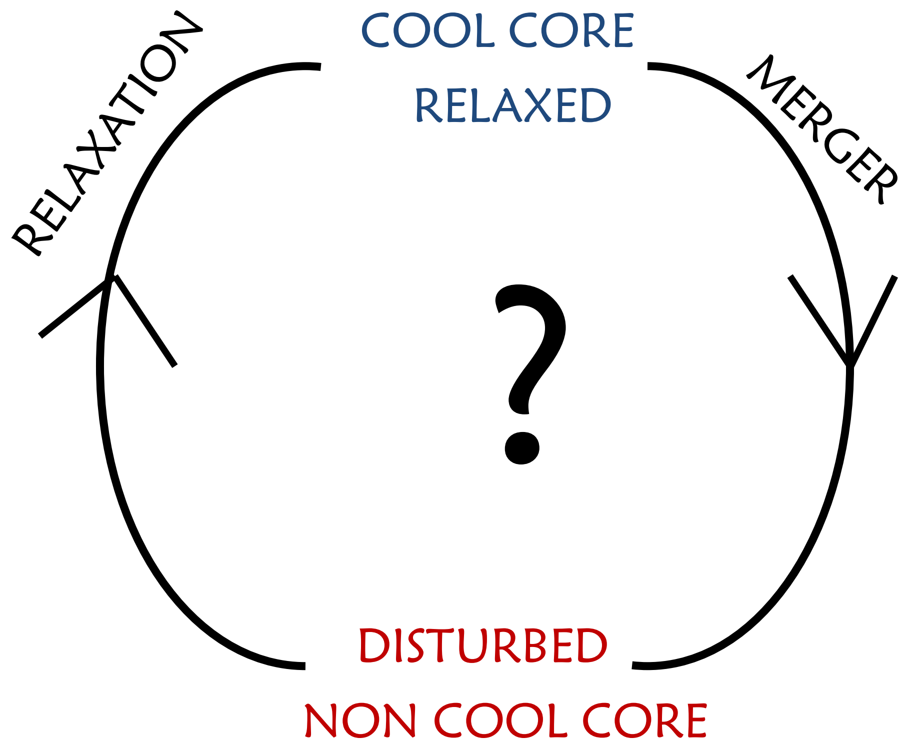

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CAN MERGER DESTROY CCs?

Observations are still supporting this evolutionary scenario:

Correlations between CC and morphology indicators (Sanderson et al. 06, 09, Hudson et al. 10, Bohringer et al 10) and presence of regions with properties reminiscent of their former CC in most NCC objects (MR & Molendi 10).

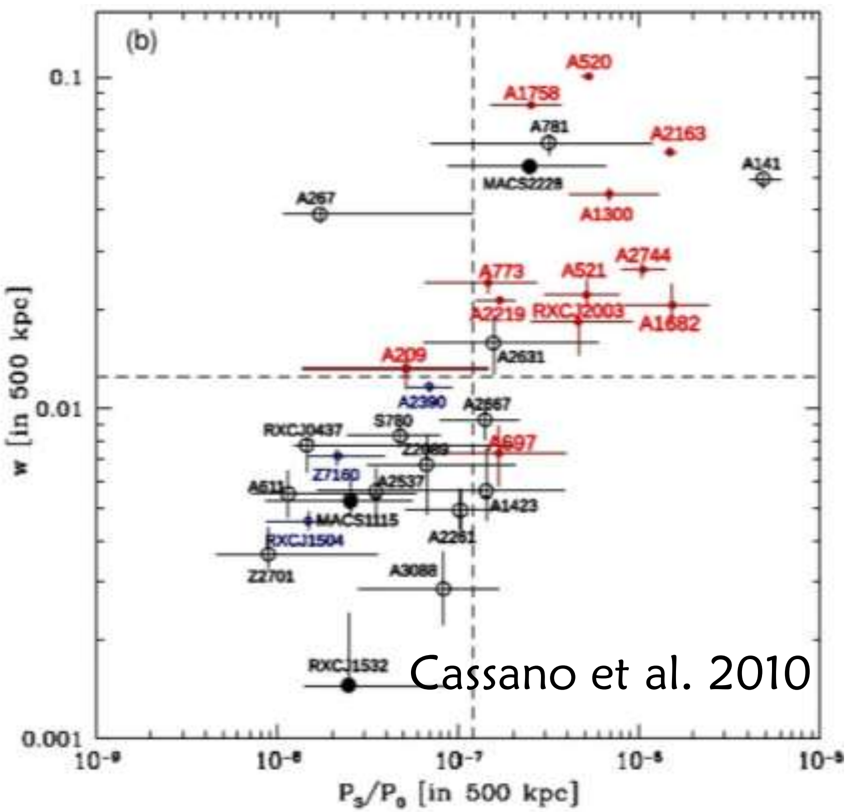
Radio Halos

Some galaxy clusters show extended radio emission on Mpc scales: presence of relativistic particles and magnetic fields in the ICM. If this emission is centrally located: radio halos.

The life time of relativistic electrons is smaller than the diffusion time scale: need for acceleration or reacceleration mechanisms

Radio Halos

We need a mechanism able to accelerate particles and/or to increase the magnetic fields, effective on scales larger than 1 Mpc.
CLUSTER MERGERS are the ideal candidates (e.g. Sarazin 2001), through shocks and turbulences.



Cassano et al. 2010

Increasing evidence in the literature that they are found only in dynamically active clusters. (Buote 2001, Hudson et al 2010, Cassano et al 2010)

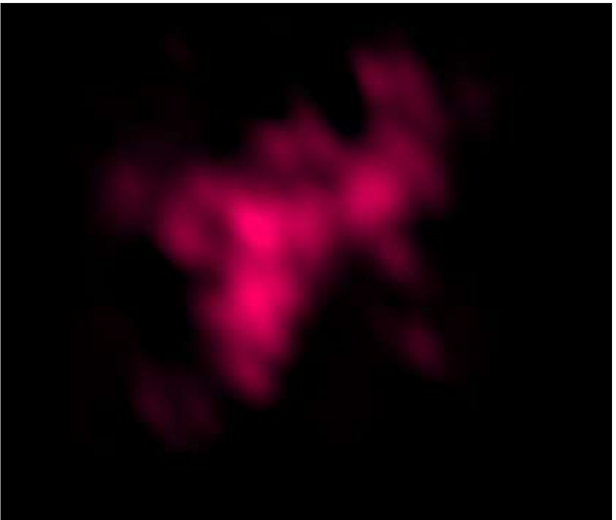
CAVEAT:
Not all merging clusters host a radio halo (even at relatively low frequencies)

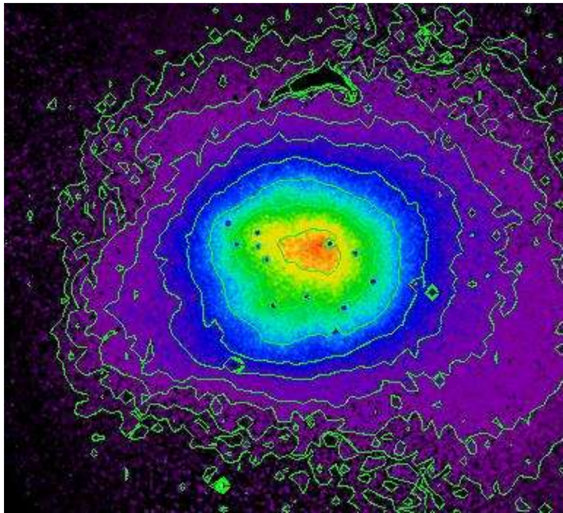
A radio approach to the CC-NCC dichotomy

Present data clearly suggest a connection between radio halos and mergers

In the cyclical evolutionary scenario, mergers are responsible of the CC-NCC dichotomy

Do mergers cause a relation between the lack of a cool core and the presence of a **GIANT RADIO HALO**?





The sample

RADIO DATA

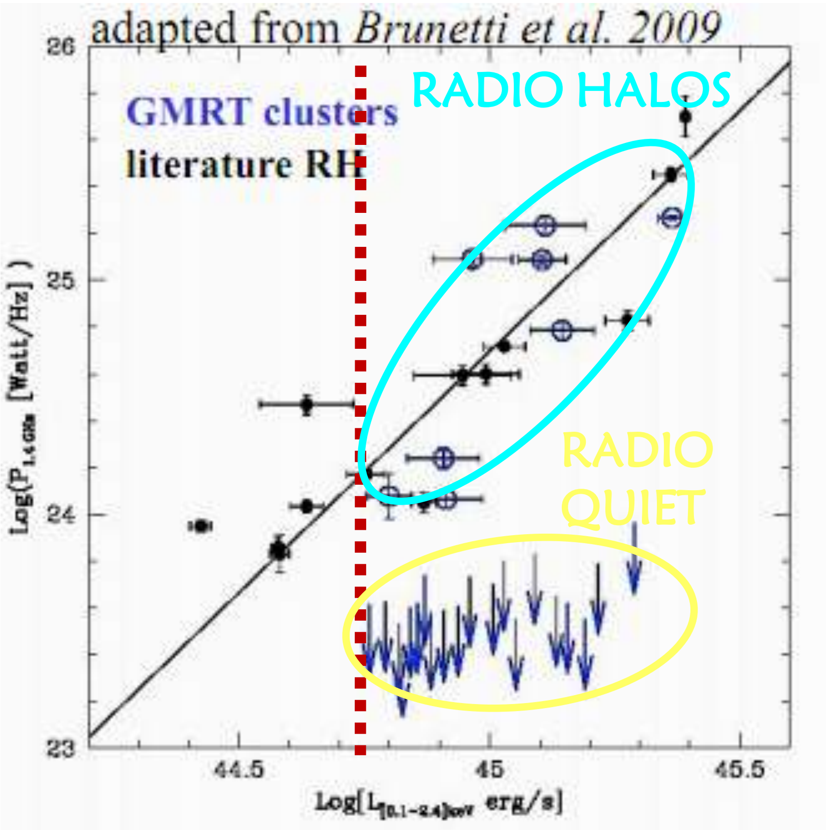
GMRT Halo survey in cluster at z=0.2-0.4
(Venturi et al. 2007,2008):
large observational project devoted to the search of radio halos in a well defined sample

→

Selected from X-rays complete samples (REFLEX and eBCS) with:

- $L_x > 5\ 10^{44}$ ergs/s
- z=0.2-0.4
- $-30° < \delta < 60°$

35 clusters for which we can either detect the halo or put strong upper limits on the extended radio emission.



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X-RAY DATA

We searched the **Chandra archive** for public observations of clusters in the GMRT Halo Survey.

In case of scarce quality of the Chandra observations (<1500 counts in each spectrum) we analized also **XMM-Newton** observations, when available.

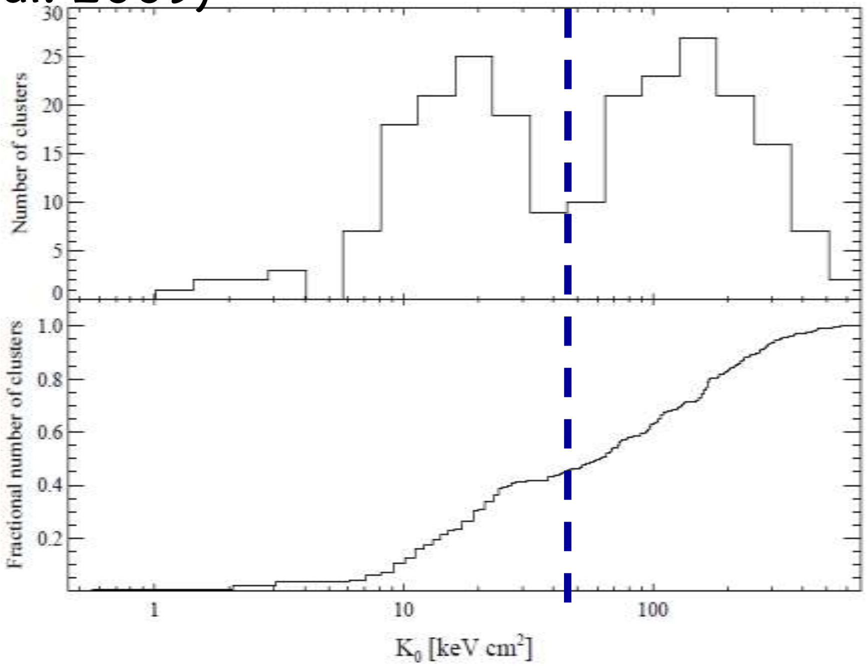
Final sample of **22 objects with radio and good X-ray data:** 10 RH and 12 RQ

Cool core indicators

Central entropy (K_0)

$$K(r) = K_0 + K_{100}\left(\frac{r}{100\ \text{kpc}}\right)^{\alpha}$$

The central entropy K_0 is a good indicator of the CC state (Cavagnolo et al. 2009)



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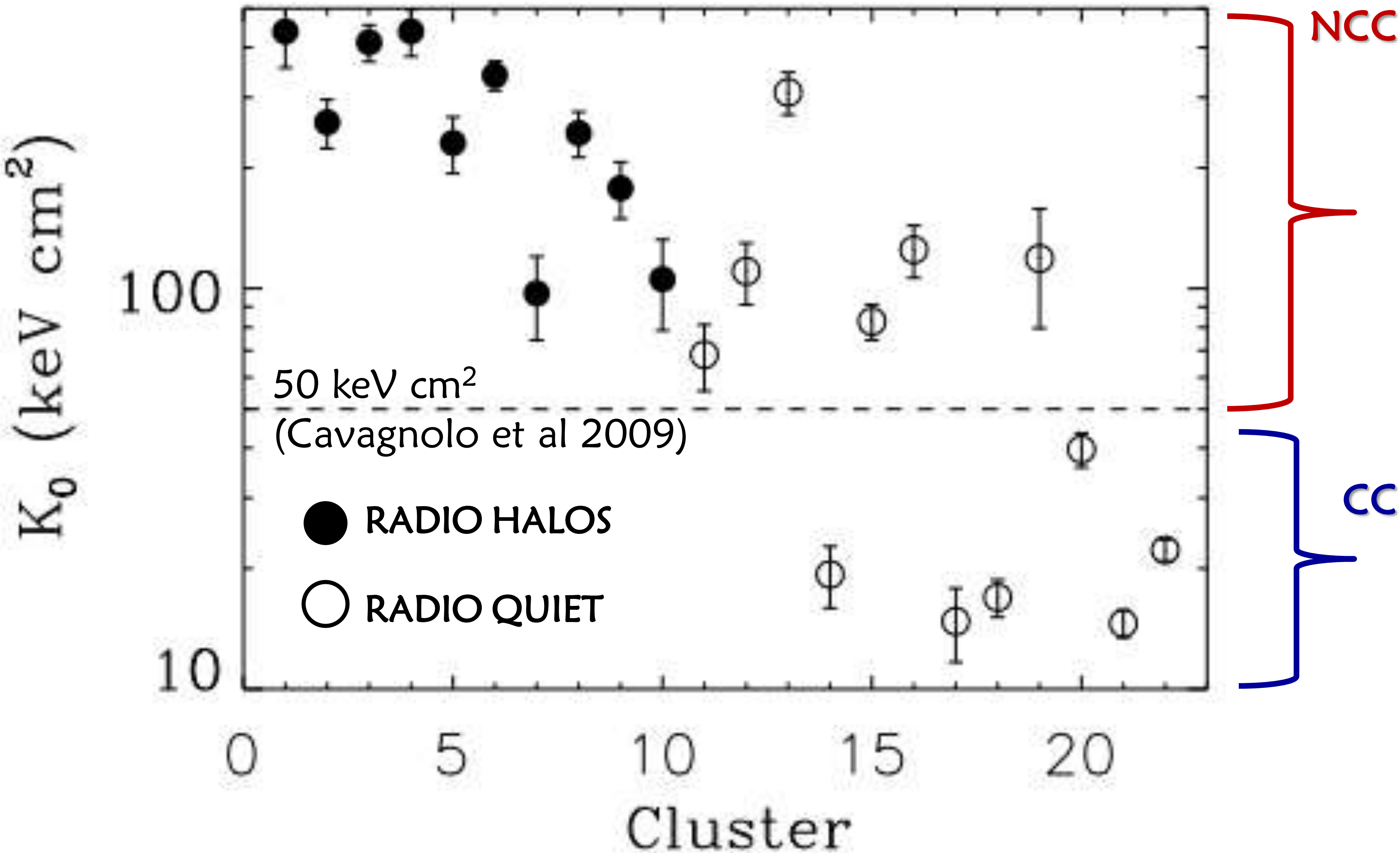

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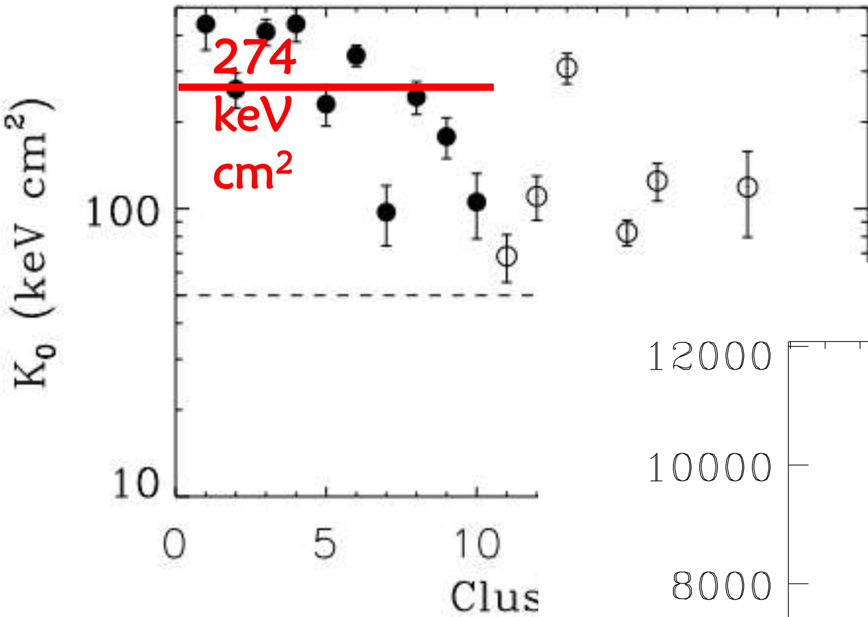
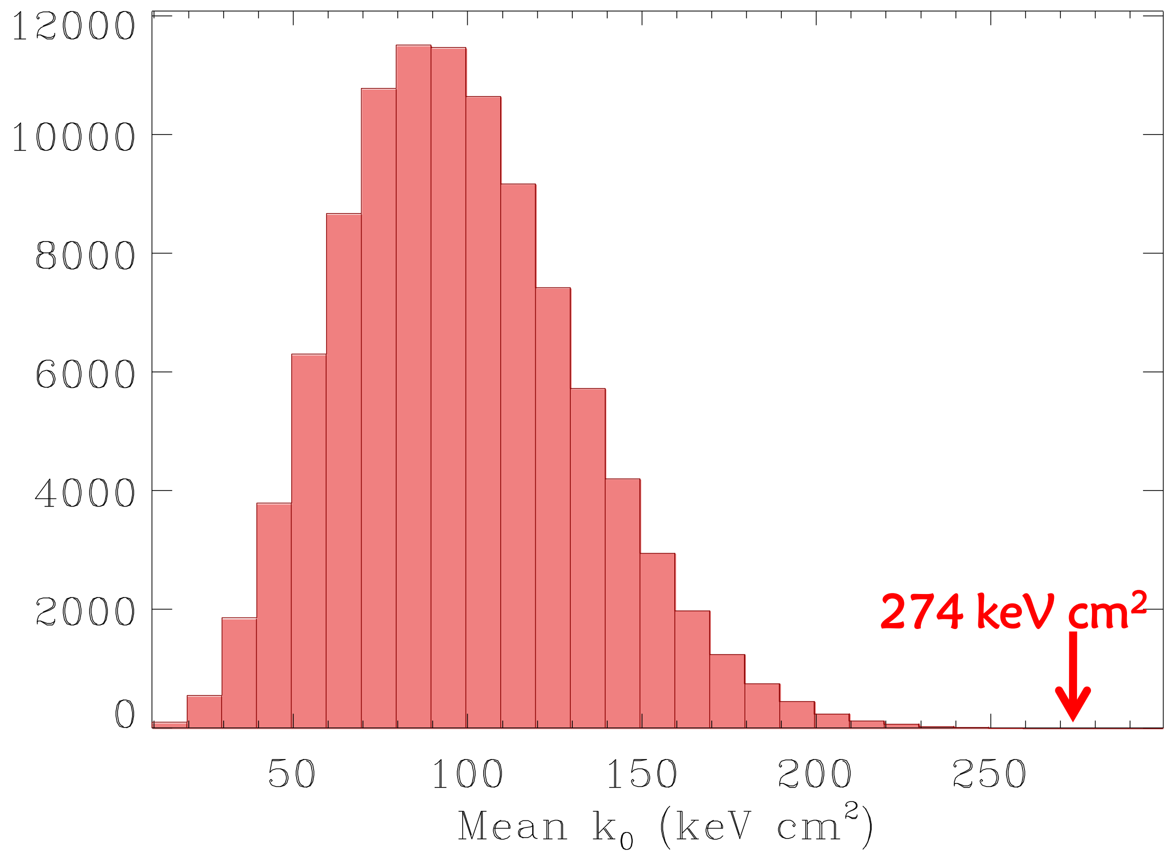


Monte Carlo simulation:
random selection of 10 k_0 values in the ACCEPT catalogue (≈250 clusters, Cavagnolo et al. 2009)
WWW.PA.MSU.EDU/ASTRO/MC2/ACCEPT/



The probability of finding by chance 10 clusters with mean $k_0 \geq$ 274 keV cm² is

0.003 % (4,2 σ)

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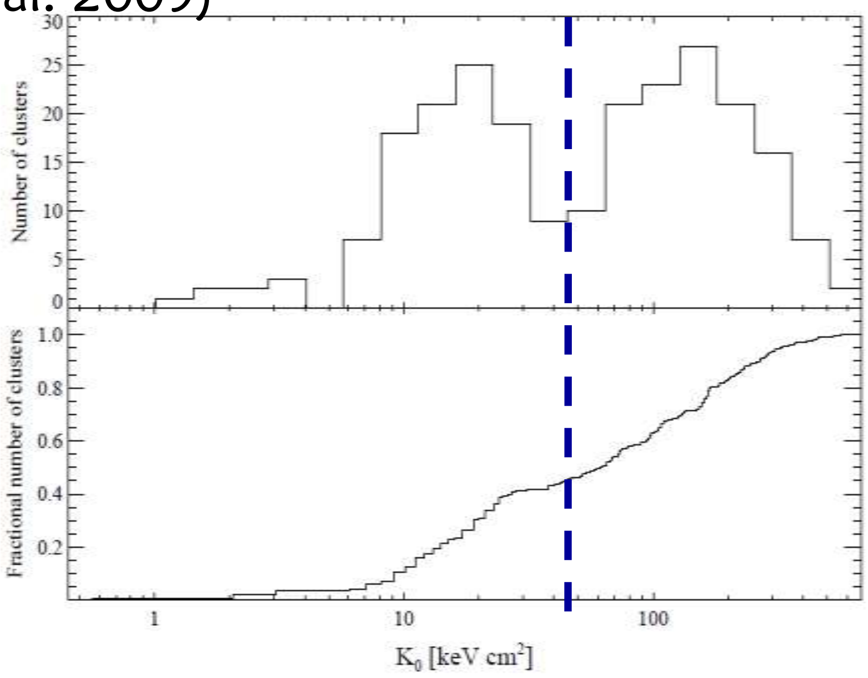


Pseudo-entropy ratios (σ)

$$\sigma = T_{in}/T_{out} * (EM_{in}/EM_{out})^{-1/3}$$
$$\sim K_{in}/K_{out}$$

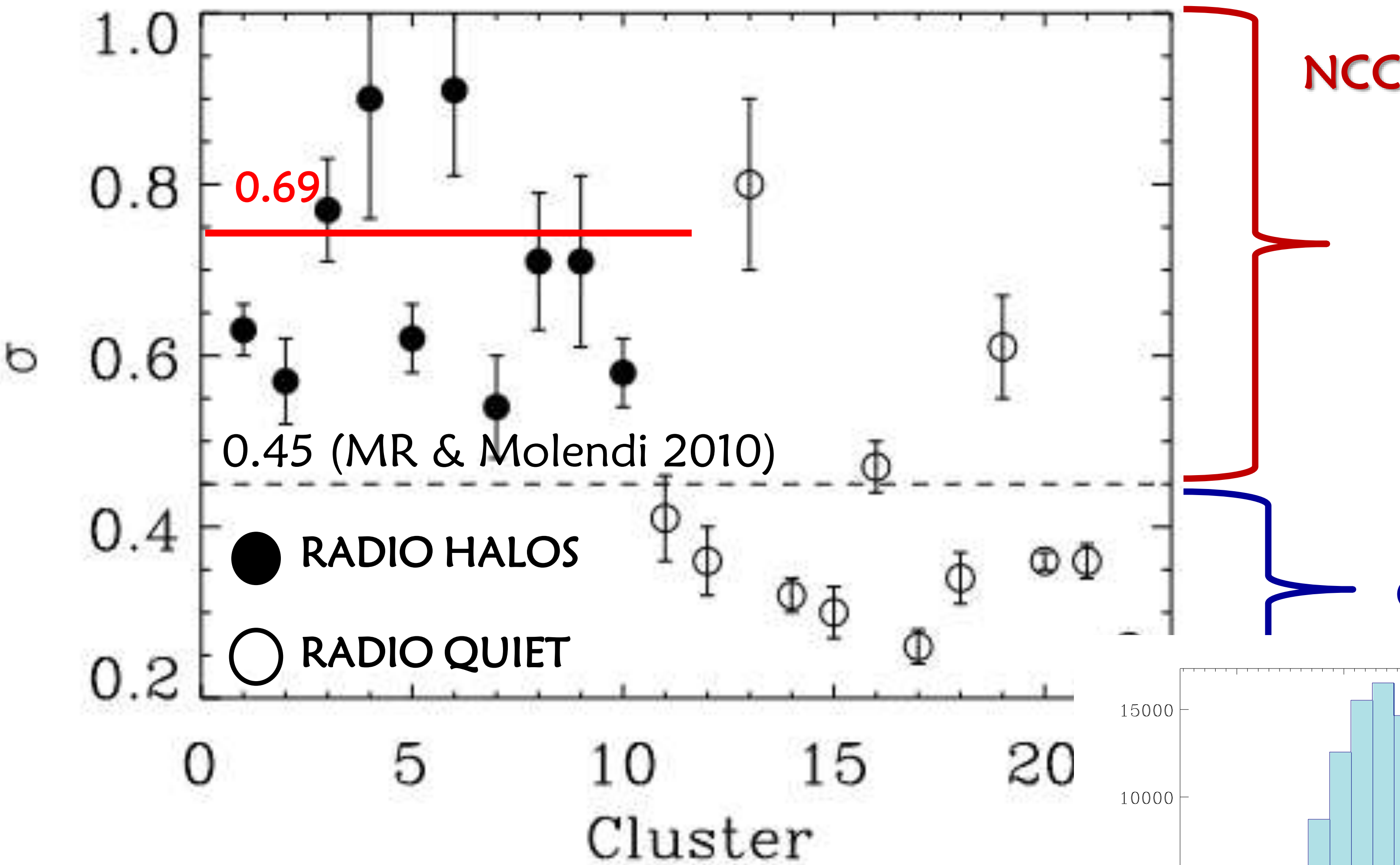
Combines the information on the temperature decrement and on the SB peak, on physical radii

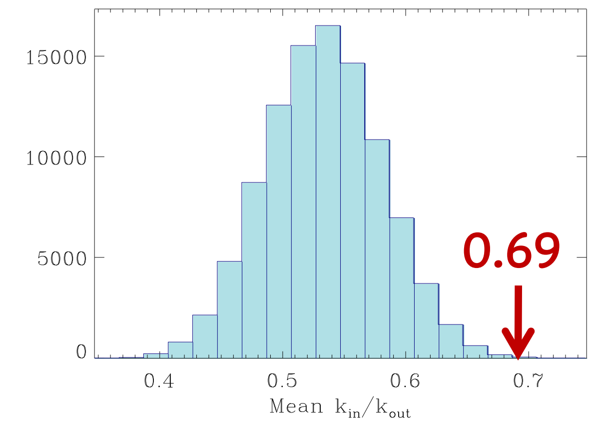
in : $r<0.05r_{180}$

out : $0.05r_{180}<r<0.2r_{180}$

(Leccardi, MR & Molendi, 2010)

(Pseudo-)Entropy Ratio(σ)





The probability of a chance result is

0.26% (3.01σ)

Life of a cluster

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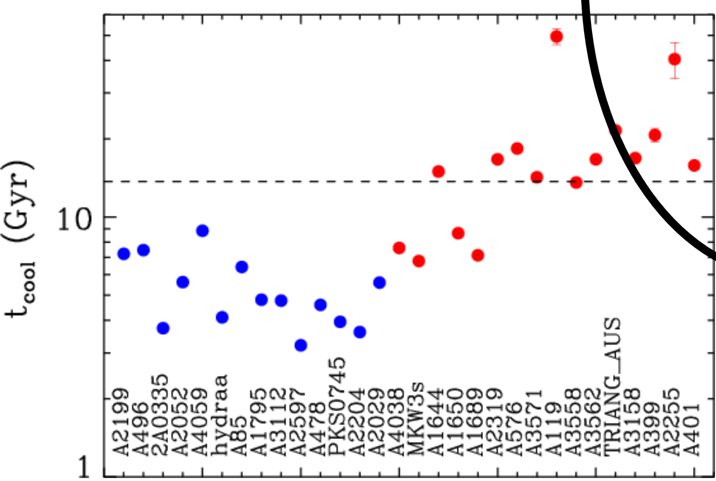
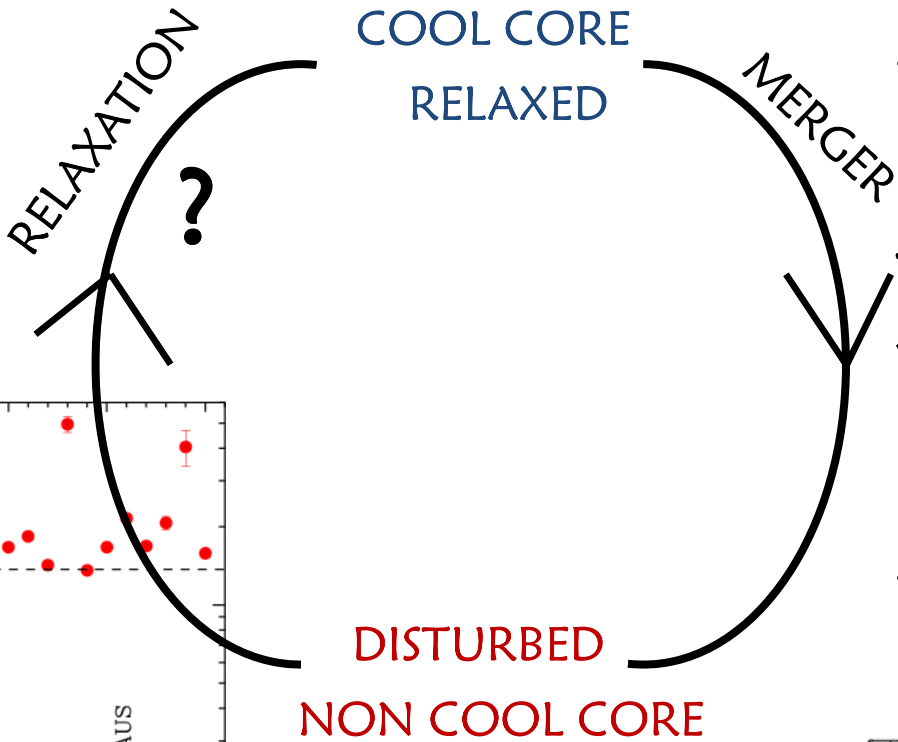
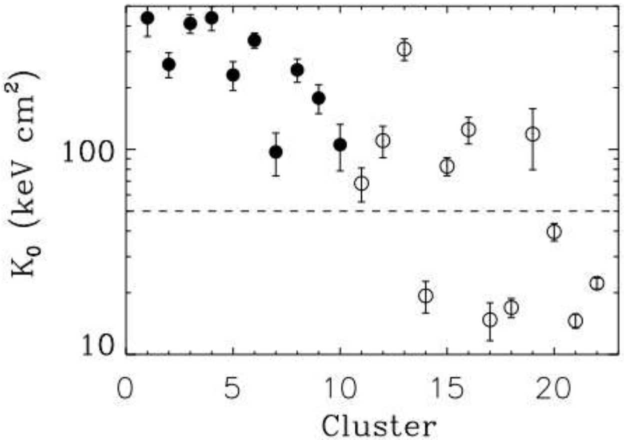




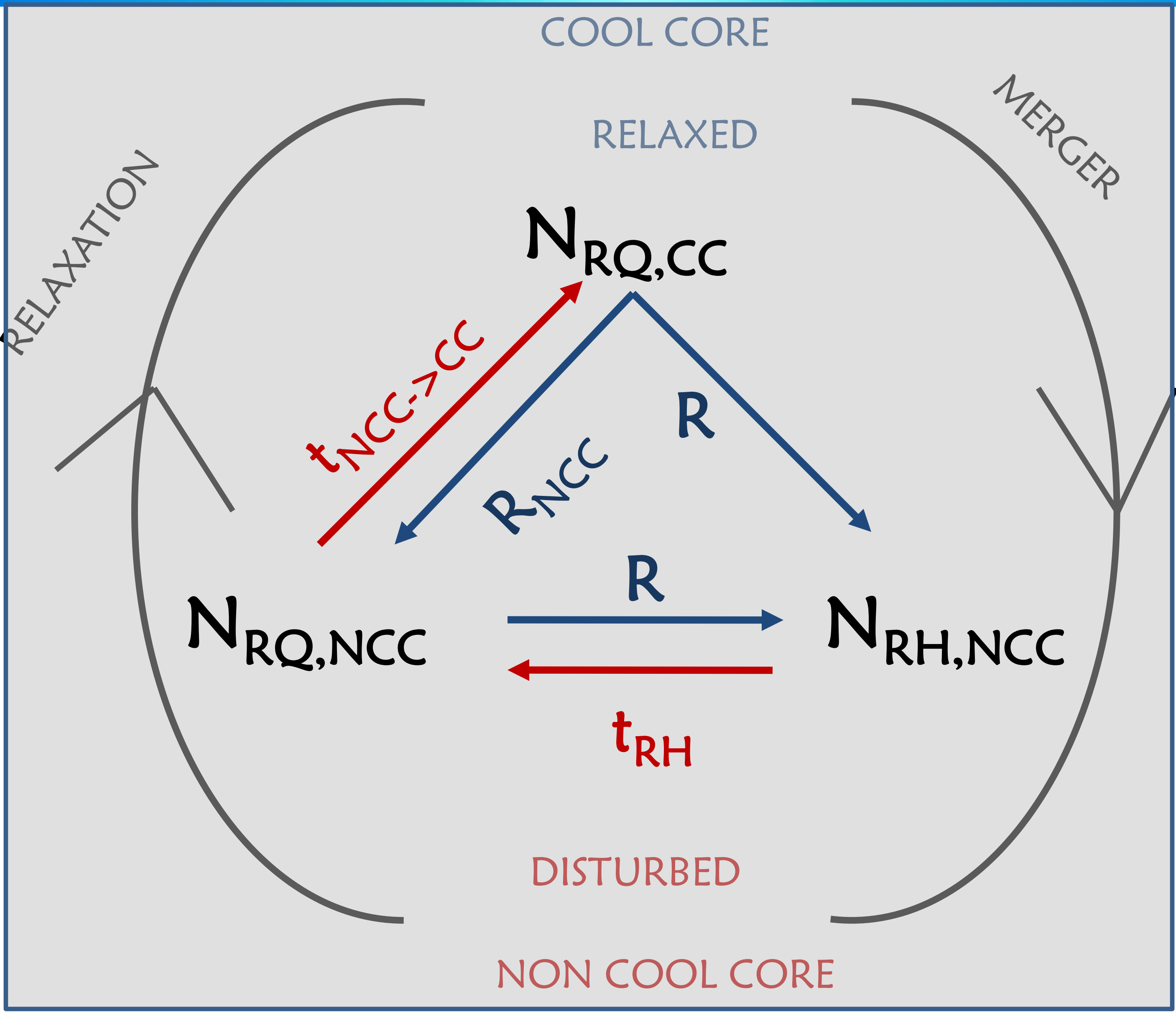
All clusters which host a radio halo are NCC.

The mechanisms which generate a radio halo (merger) are likely the same that destroy CC



What about the return journey to the CC state?

Life of a cluster



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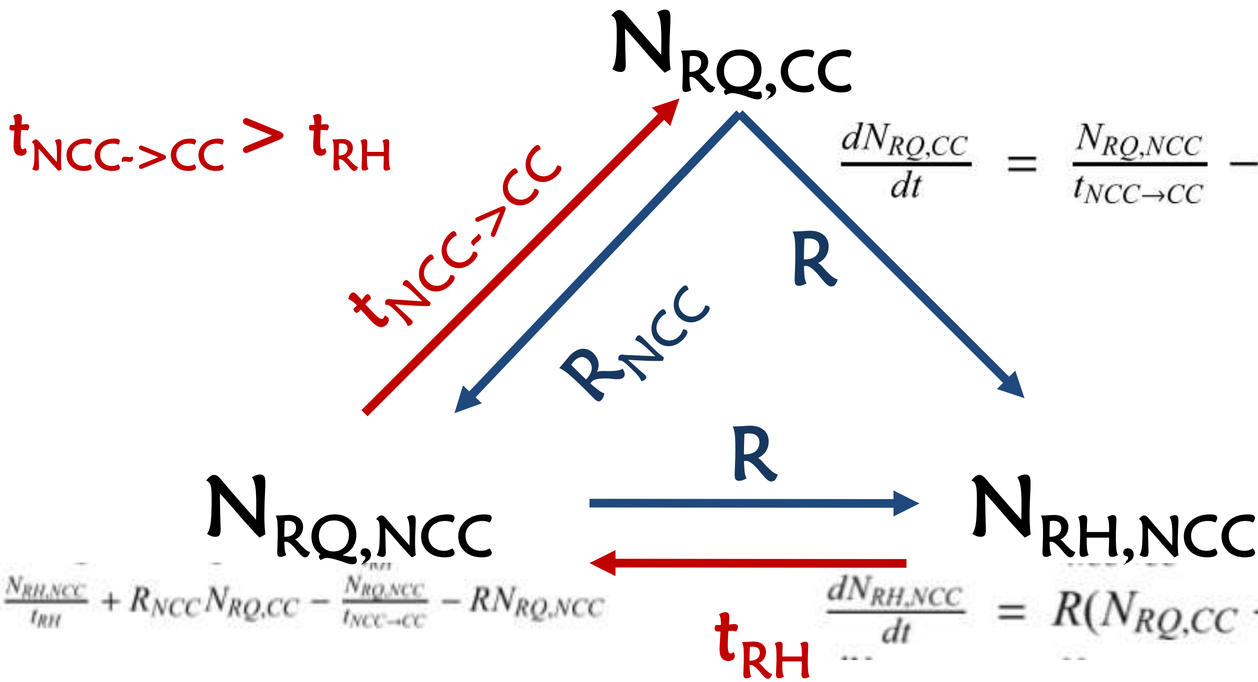


$$\frac{dN_{RQ,CC}}{dt} = \frac{N_{RQ,NCC}}{t_{NCC\to CC}} - (R + R_{NCC})N_{RQ,CC}$$

$$\frac{dN_{RQ,NCC}}{dt} = \frac{N_{RH,NCC}}{t_{RH}} + R_{NCC}N_{RQ,CC} - \frac{N_{RQ,NCC}}{t_{NCC\to CC}} - RN_{RQ,NCC}$$

$$\frac{dN_{RH,NCC}}{dt} = R(N_{RQ,CC} + N_{RQ,NCC}) - \frac{N_{RH,NCC}}{t_{RH}}$$

≈1 Gyr (Brunetti et al 2009)

Assuming a stationary situation:

$$1 < \frac{t_{NCC\to CC}}{t_{RH}} \le \frac{N_{RQ,NCC}}{N_{RQ,CC}} \frac{N_{RQ}}{N_{RH}}$$

=2.5 (Venturi 2008)

8/17-13/12 (CC fraction 0.35-05)

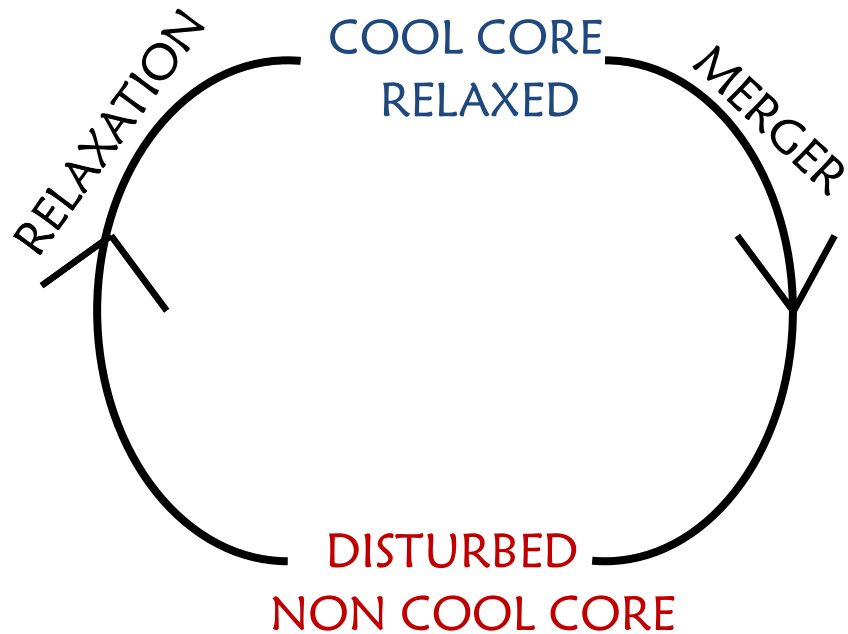
1 Gyr <$t_{NCC\text{->}CC}$ <3 Gyr !!

NCC clusters can relax to CC quicker than predicted by the cooling time

Conclusions

We analyzed X-ray observations of clusters in the GMRT RH survey. These results support the evolutionary cyclical scenario of the CC-NCC dichotomy.

•The mechanisms that generate RH (merger) are likely the same that destroy CC
•NCC can relax to the CC state in ≤3 Gyr << t_{cool}.
This is possible if the mixing of the gas during merger is not perfect (-> ASTRO-H)



Future radio (LOFAR) and X-ray (eROSITA) surveys will verify and improve these results

Rossetti et al. (2011) A&A accepted astro-ph: 1106.4563