Clusters and the X-ray Connection

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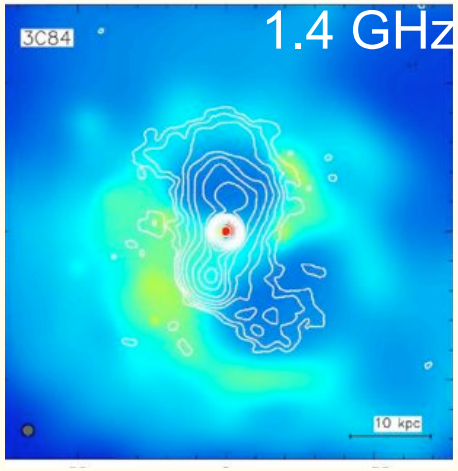
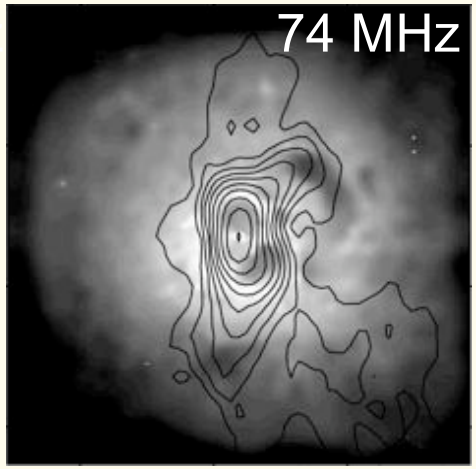
X-ray / radio connection : cluster thermo-dynamical history

Complementary information on



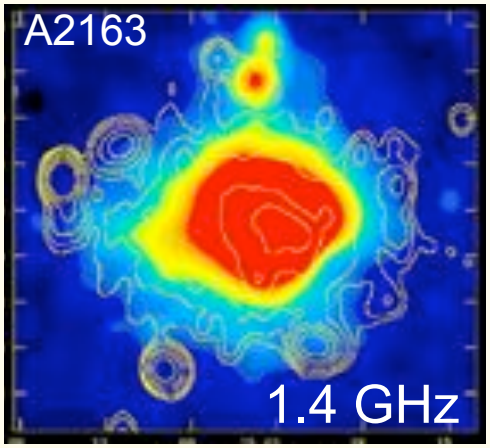


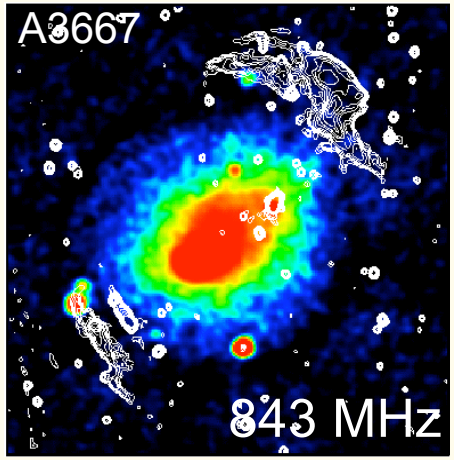
Fabian et al, 00, 02

- AGN feedback
  - in center
    the CF pb
  - at large scale ?
    the entropy excess
    see R.Dunn & M.Wise this conf

- The dynamics of cluster (hierarchical) formation
  (this presentation)

see e.g. reviews by L. Feretti, 04,05

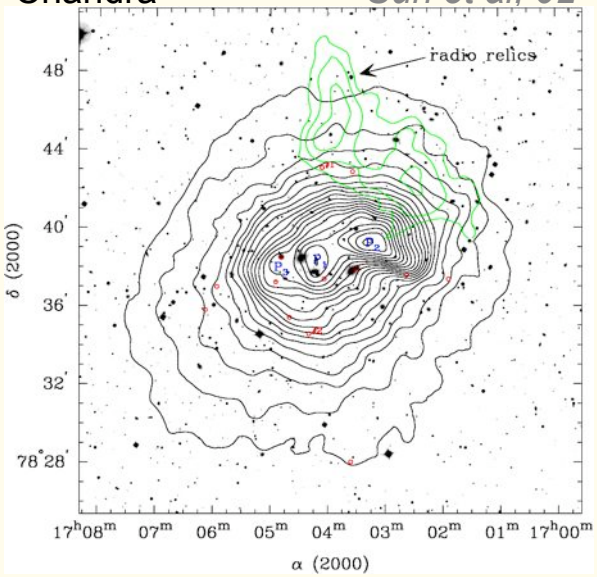




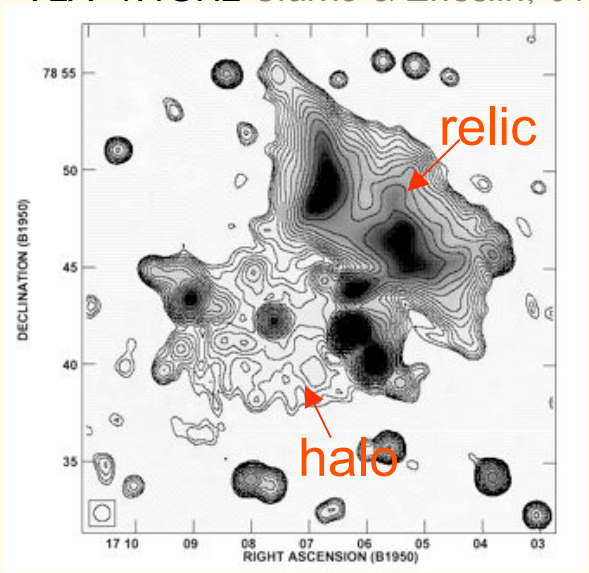
Feretti, 05 adapted from Feretti et al, 01 ; Röttgering et al, 97

X-ray/radio thermal and non-thermal components

Chandra *Sun et al, 02*



VLA 1.4GHz *Clarke & Ensslin, 01*



X-ray thermal - diffuse

⇒ Hot plasma (T~2-10 keV)

Main baryonic component

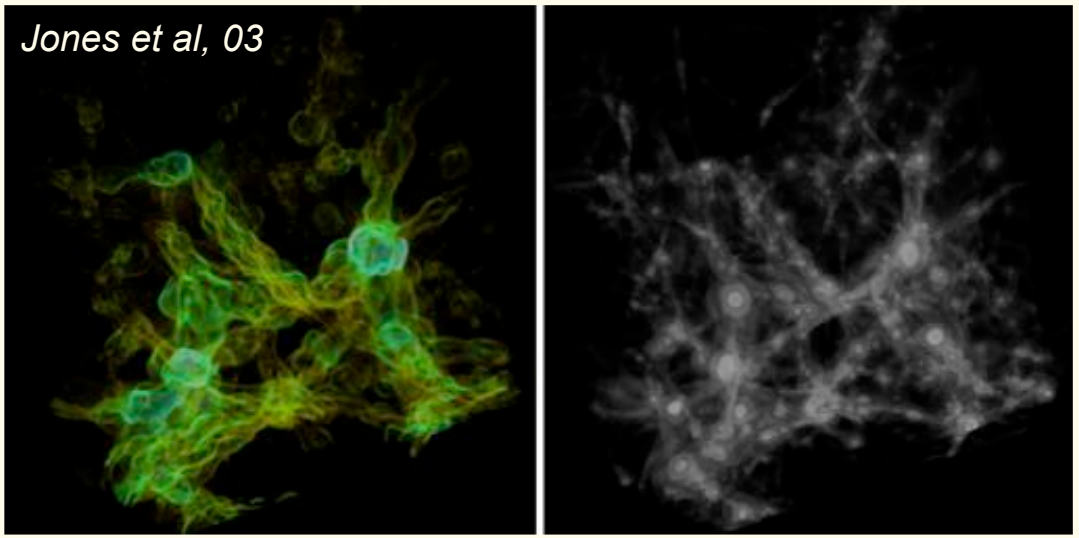
Radio synchrotron - diffuse - steep (α >1)

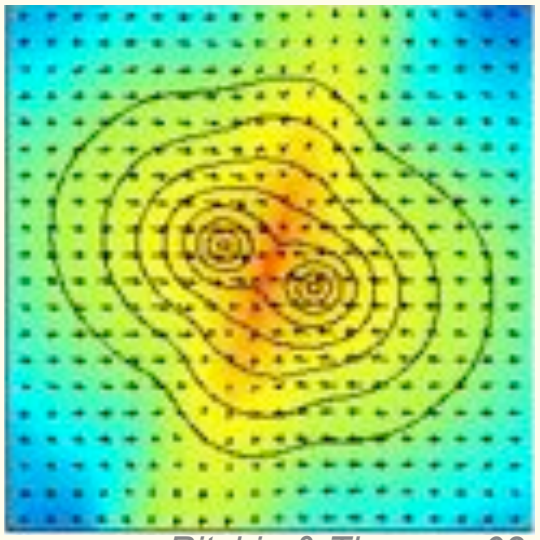
⇒ Relativistic electrons (~1-100 Gev)

⇒ Magnetic Field (0.1 - 1μG)

IC e- on CMB ⇒ Non thermal X-ray emission

Origin and acceleration of the relativistic electrons?





Ritchie & Thomas, 02

Cluster hierarchical formation => Shocks (heat the gas at T_{virial})

- Radio halos/relics detected in un-relaxed (merger) clusters only
- Problem: ~Mpc size but t_{life} ~10^7 - 10^8 years << $t_{diffusion}$

  ⇒ Recent creation or (re) acceleration by a mechanism at cluster scale

Several Models
- Thermal electrons accelerated by shocks /turbulence
- Non thermal electrons (from above or from AGN/Winds) re-accelerated
- Secondary electrons from inelastic collisions of NT protons with ICM

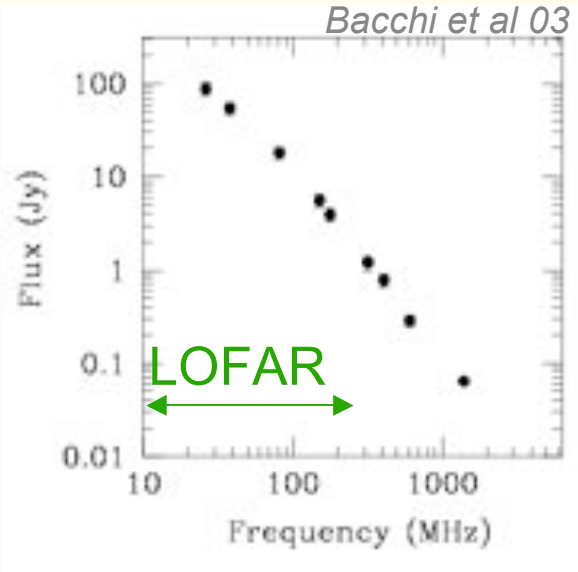
Why study the NT cluster component ?

- Non thermal e- creation and acceleration mechanism not understood!

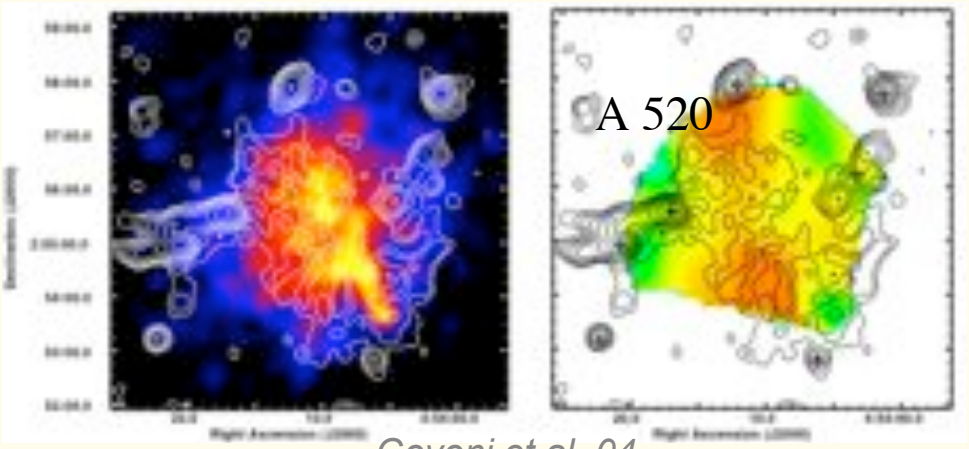
- Diagnostic information on the hierarchical formation process
  - ⇒ probe the *physics* of merger events (shocks, turbulence, redistribution of energy …)
  - ⇒ probe the ICM *magnetic field*
  - ⇒ tracer of merger/formation *history*

- Possible impact on cosmological parameters estimate (from N(M) or f_{gas})
  - ⇒ May contribute to the overall pressure
  - ⇒ Mass > estimated from HE Eq. and P_{therm} only

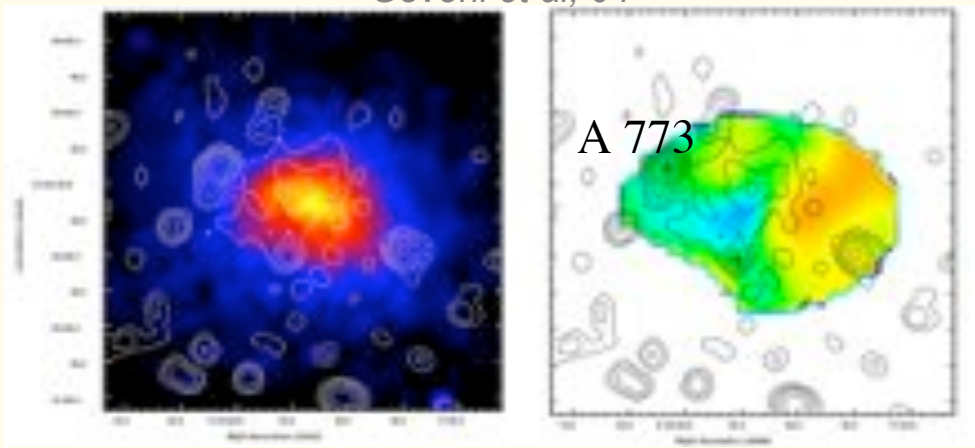
Need (new LOFAR) radio observations combined with X-ray information



Radio- X-ray comparison for individual clusters (I)



Govoni et al, 04



Radio versus kT map ⟹

<u>Constraints on models</u>

density (radio maps) and
energy (radio spectra)
distribution of NT electrons

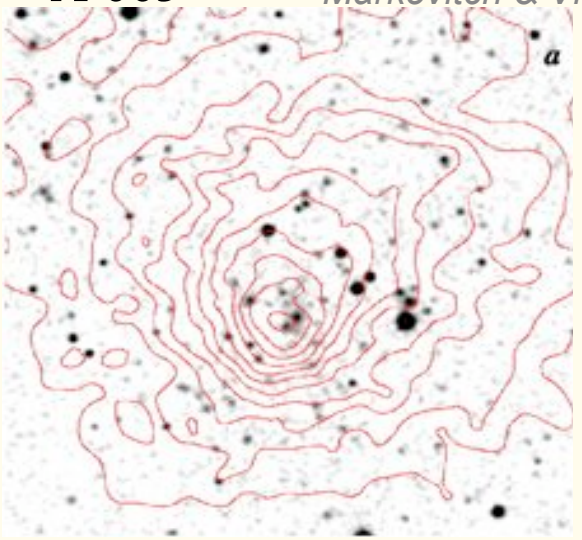
compared to that of

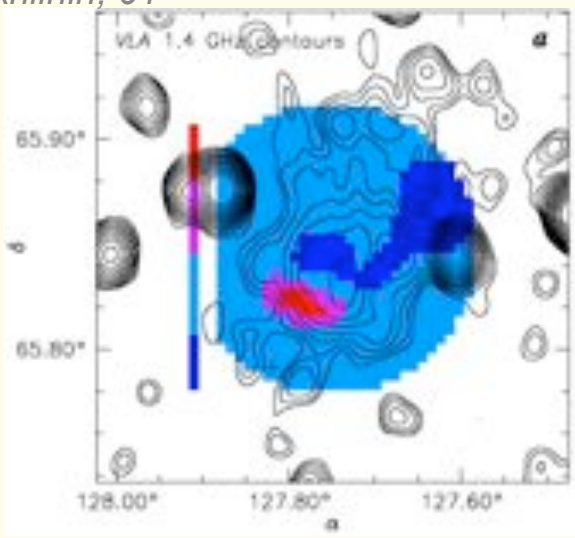
thermal electrons (X-ray)

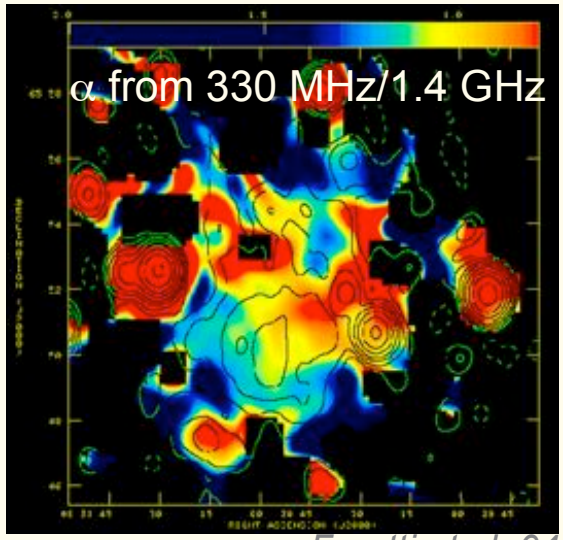
Probably mostly acceleration by turbulence

Radio- X-ray comparison for individual clusters (II)

A 665 *Markevitch & Vikhlinin, 01*







Feretti et al, 04

Strong(er) constraints given by spectral index maps

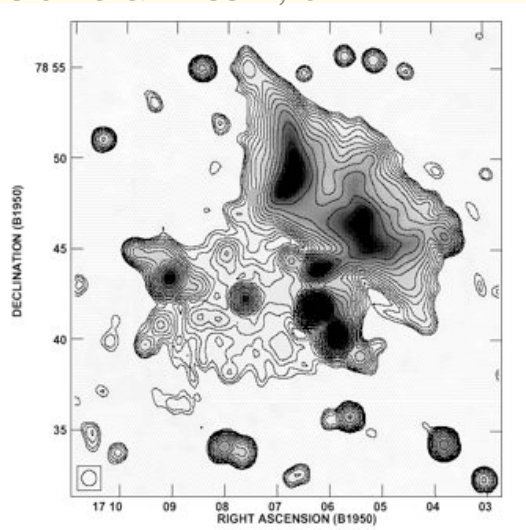
Flattening in region affected by merger ⇒ mergers do supply energy to radio halo
No connection to the (weak M ~2) shock ⇒ re-acceleration by turbulence

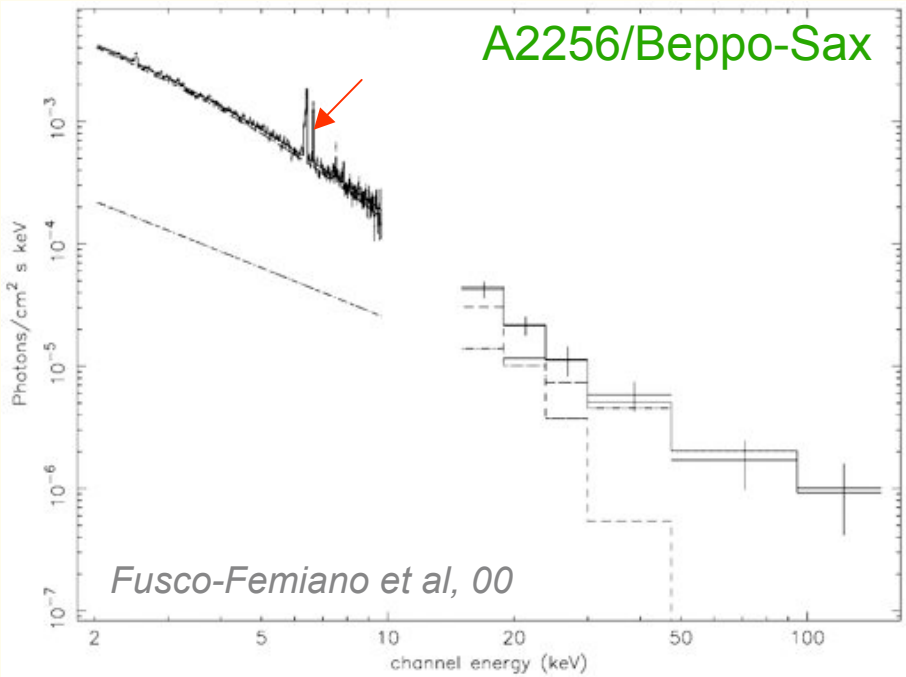
Extend to much larger cluster samples

Radio map (α / S_{rad})	versus	X-ray map (ne/kT/P/S)
sensitive multi ν imaging		spatially resolved specroscopy
LOFAR		XMM/Chandra

Radio- *NT X-ray* comparison for individual clusters

Clarke & Ensslin, 01





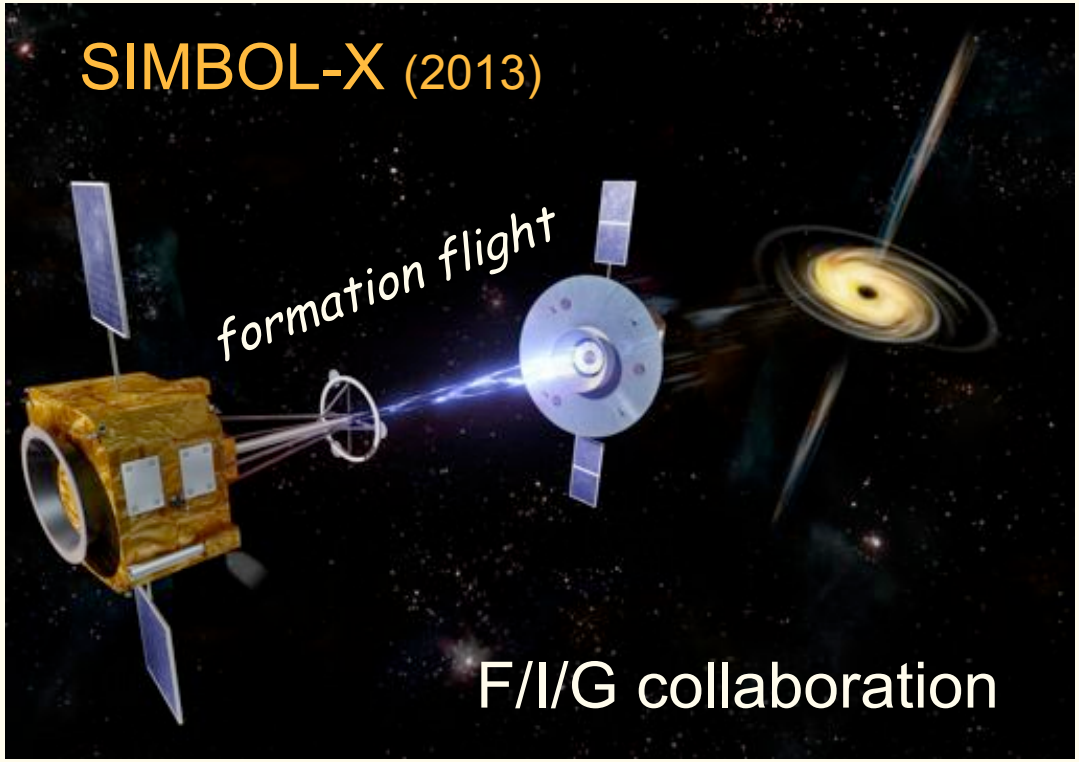
Radio synchrotron emission:
⇒ degenerate information on B, NT e-

Faraday Rotation (B, Te-)
⇒ B in few directions

Polarisation

Combined with Hard X-ray = IC (NT e-)
⇒ break the degeneracy
⇒ compl. info on e- spectra

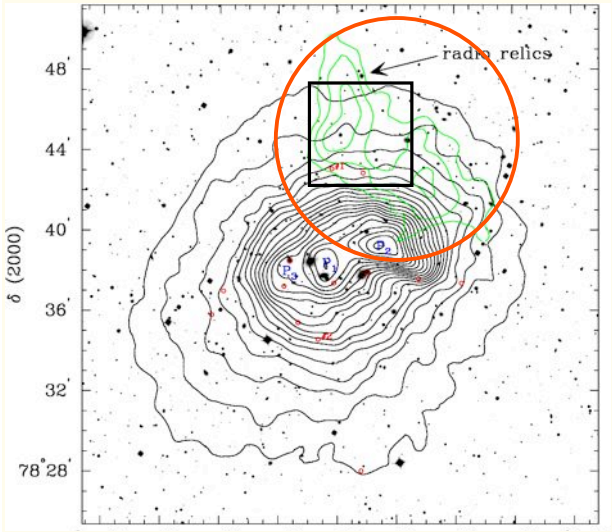
☹ No imaging capability of XTE/Beppo-SAX
⇒ Global spectrum
⇒ Low S/N and ambigous

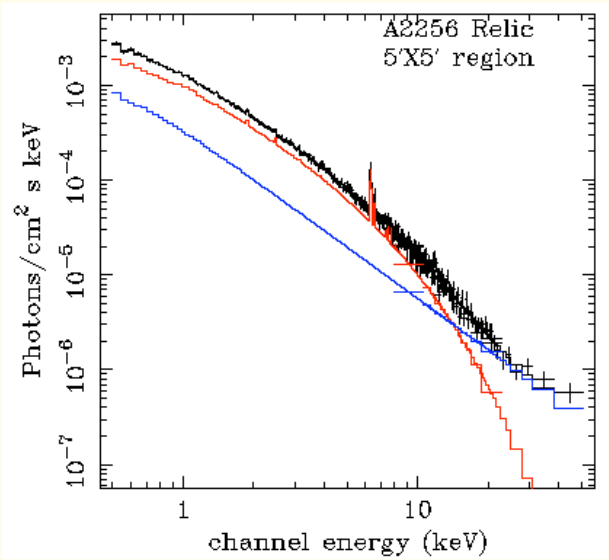


Unique spectro-imaging capabilities up to high energies (80 keV)

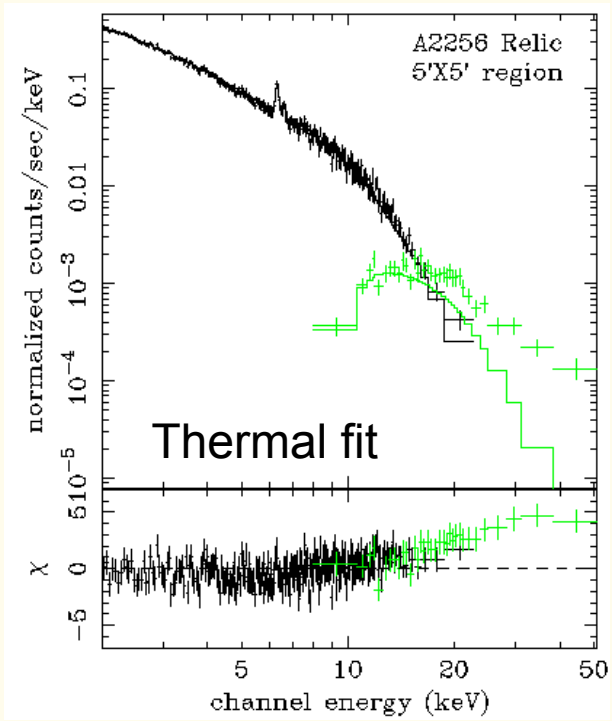
unambiguously measure the IC emission
(or provide tight upper limits).

SIMBOL-X FOV (ϕ =12')

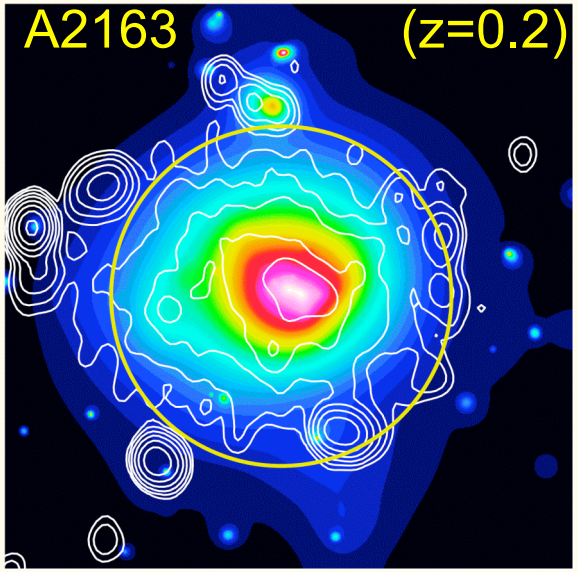




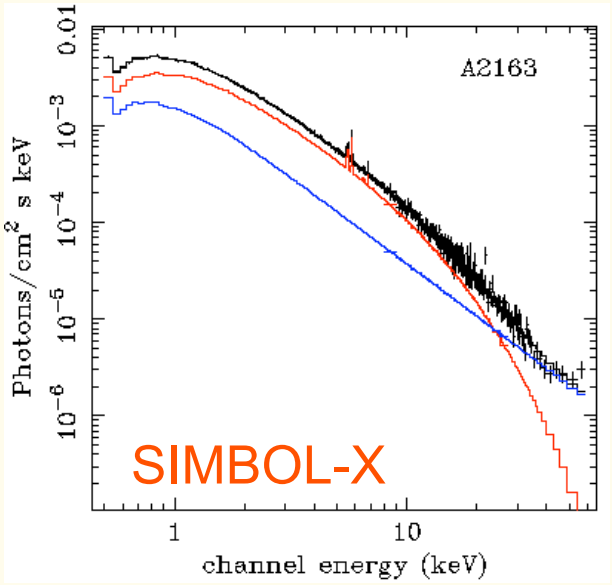
Simulated spectrum

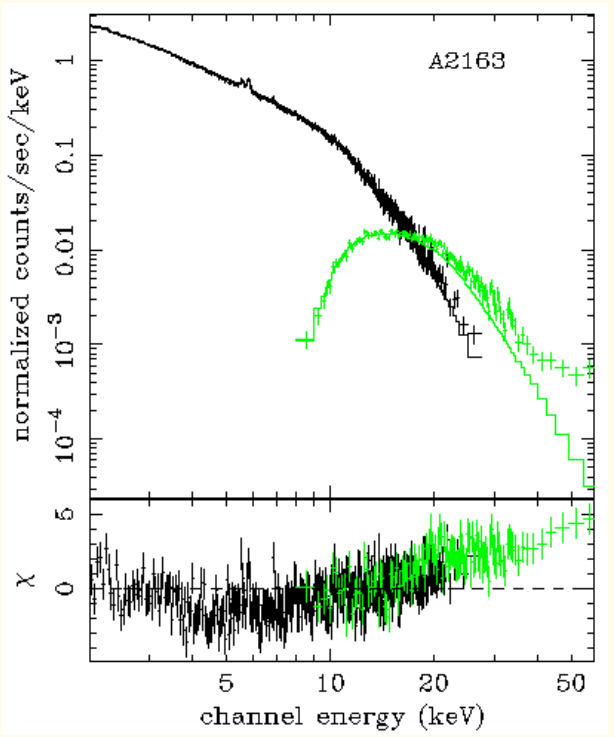


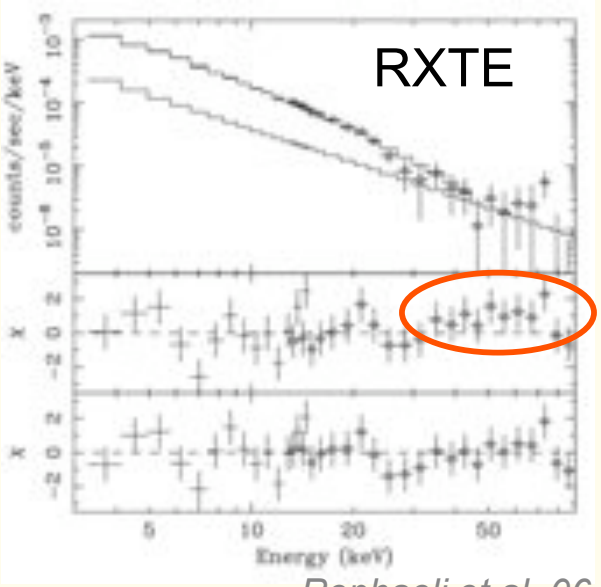
particularly powerful for study of radio relics IC emission



Radio (Ferettti et al, 01) and XMM







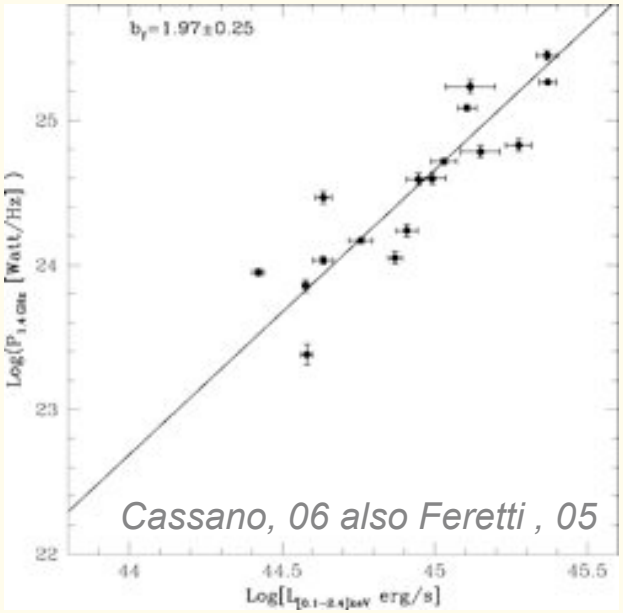
Rephaeli et al, 06

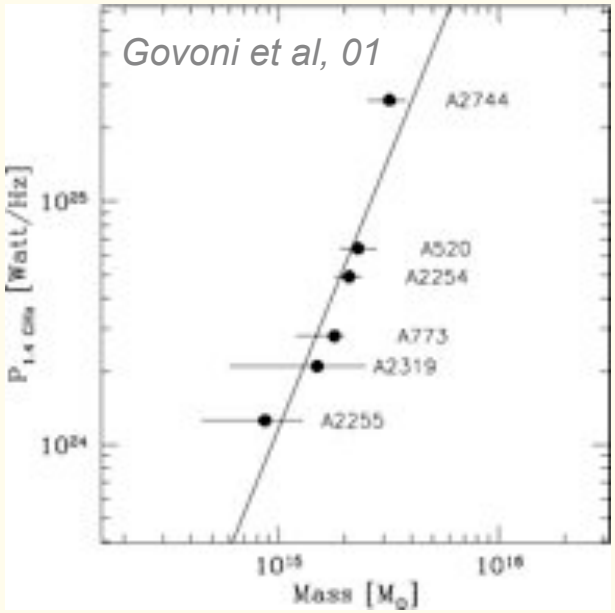
thermal fit

thermal +IC fit

and medium z major merger clusters
with high luminosity radio halos.

Statistical studies (I): correlations with global properties





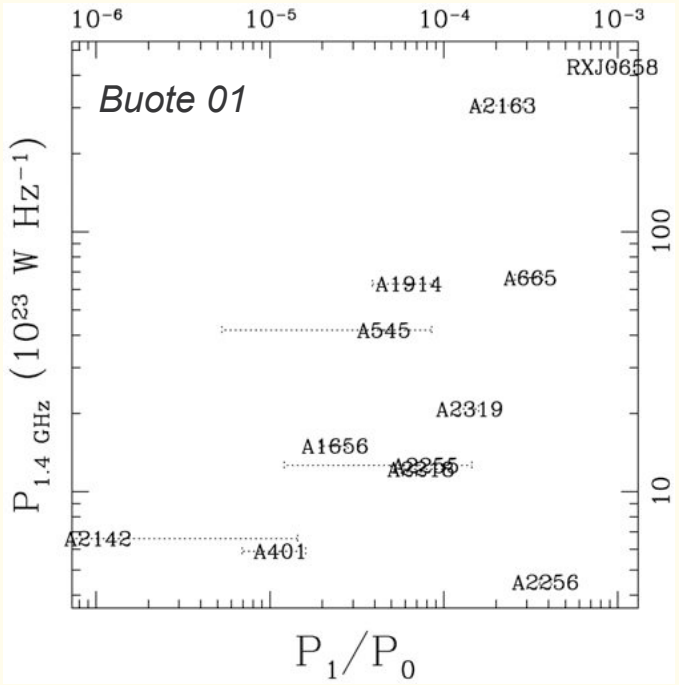
Open questions:

- Do all clusters with a recent merger have halos/relic?
- Do ALL clusters have a radio halo ?
- What is the most relevant X-ray quantity and what is the slope/dispersion/evolution of the correlations ⇒ quantitative test of models

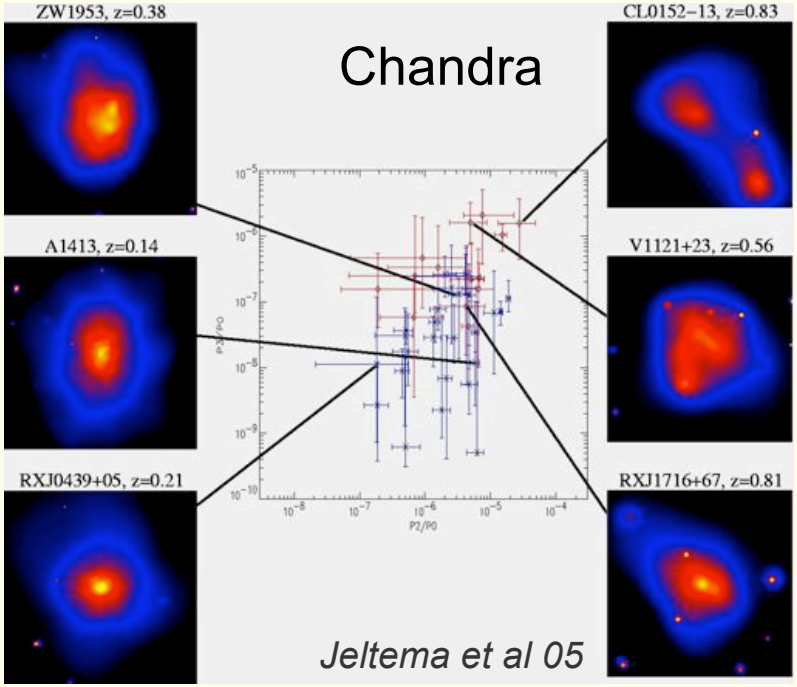
We need:

- X-ray data: exist (XMM/chandra follow-up of ROSAT samples; XMM serendipitous surveys)
- Much higher sensitivity radio survey/ follow-up: LOFAR

Statistical studies (II): correlations with dynamical state



Correlation with departure from relaxation



High z clusters are dynamically younger

(as expected in hierarchical scenario)

The frequency/properties of radio halos is expected to evolve with z

… a test of structure formation and merger physics ….

also combination with SZ (Planck) data ….

CONCLUSION

- Detailed combined X-ray/radio spectro imagery
  ⇒ Physics of hierarchical cluster formation
  (shocks, turbulence, particles acceleration, B amplification etc…)

⇒ LOFAR (adapted to cluster steep spectrum)
+ XMM/Chandra
+ SIMBOL-X hard X-ray particularly interesting!
} well matched spatial resolution

- Discovery of new relics/halos and statistical properties (correlation with X-ray/SZ) and evolution with z
  ⇒ again constraints on model PLUS tracer of cluster formation

LOFAR: key 'survey' capability ! + XMM (unbiased samples, XCS, follow-up) + Planck