AGN heating in the centres of galaxy groups

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The Cooling Problem

- Cooling time in centres of groups and clusters significantly less than Hubble time.
- Expect to see cool gas in centres of groups and clusters.

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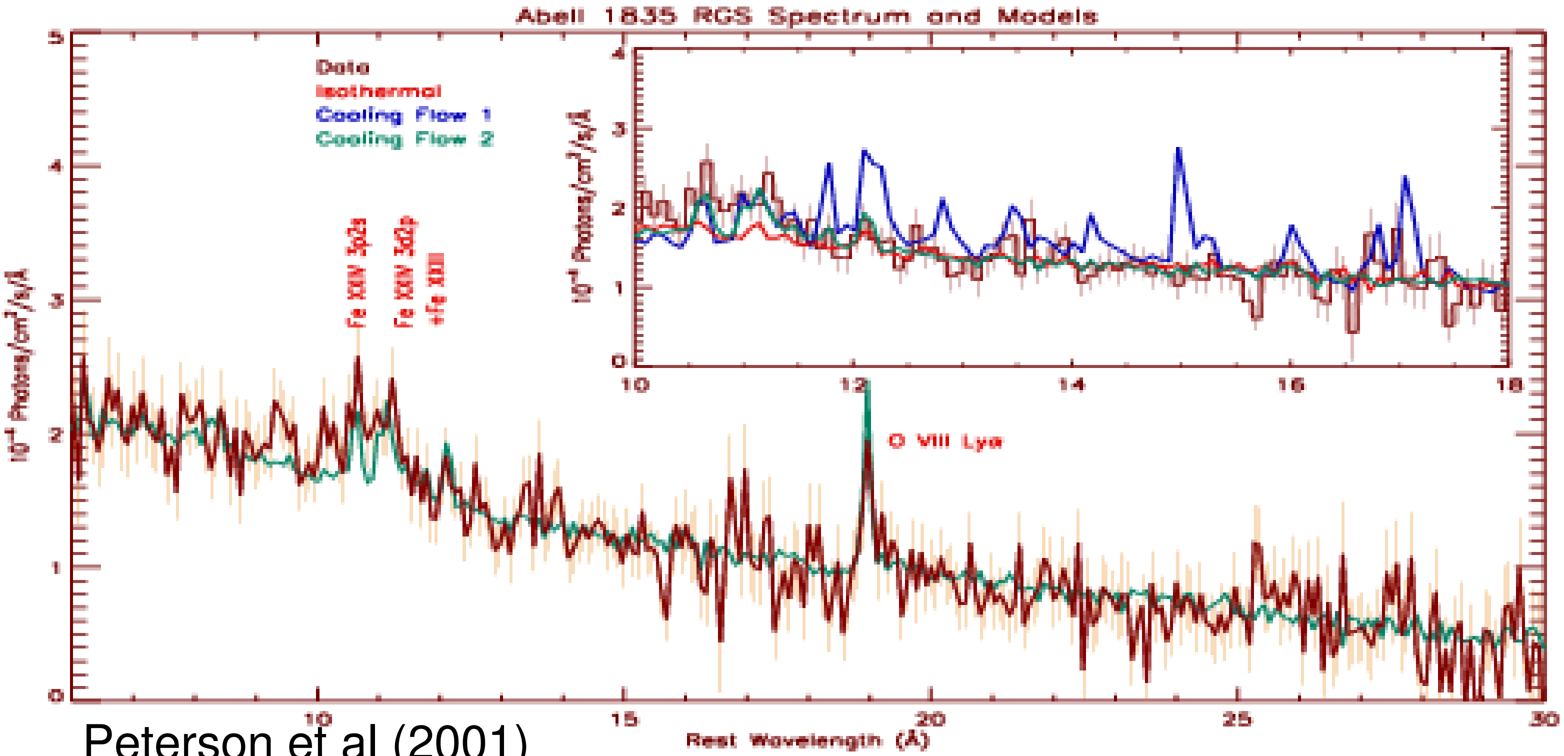


Peterson et al (2001)

This is not seen!

Stopping Cooling

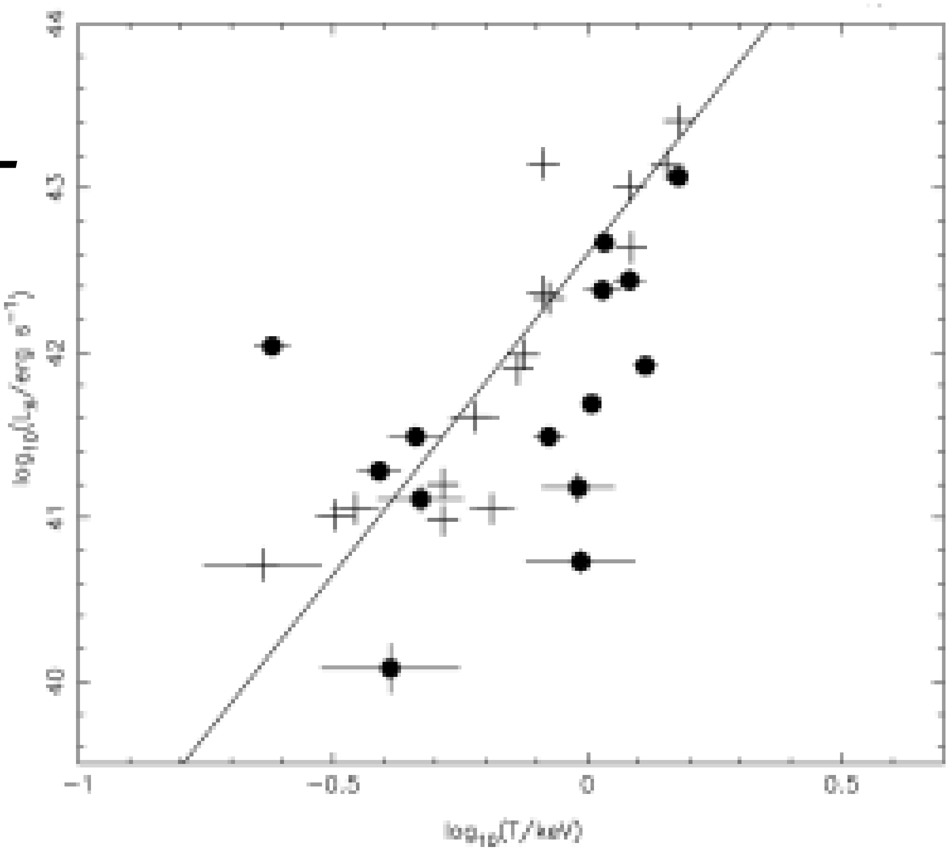
- Energy input required to prevent catastrophic cooling.
- AGN hosted by BCG/BGG could provide this (e.g Binney & Tabor 1995, Brüggen & Kaiser 2001).

Why Groups?

- Expect stronger effect of AGN heating in groups: shallower potential ⟶ energy injection has stronger effect on gas.

Why Groups?

- Recent work, based on *ROSAT* data (Croston et al 2005) shows some effect of current AGN activity on group temperature.



The cores of groups

- Expect strongest impact of AGN activity in group core because:
  - BGG tends to be close to core.
  - Cooling times shortest in core.
- To do this, have studied a sample of 15 galaxy groups from GEMS sample (Osmond & Ponman 2004)
- Corresponds to a subsample of the Croston et al (2005) sample.

The Sample

- 15 nearby galaxy groups ($z \leq 0.027$).
- $0.35 \leq T_{ROSAT} \leq 2.5$ keV
- Have 1.4GHz flux data available
- Good *Chandra* data for each group.

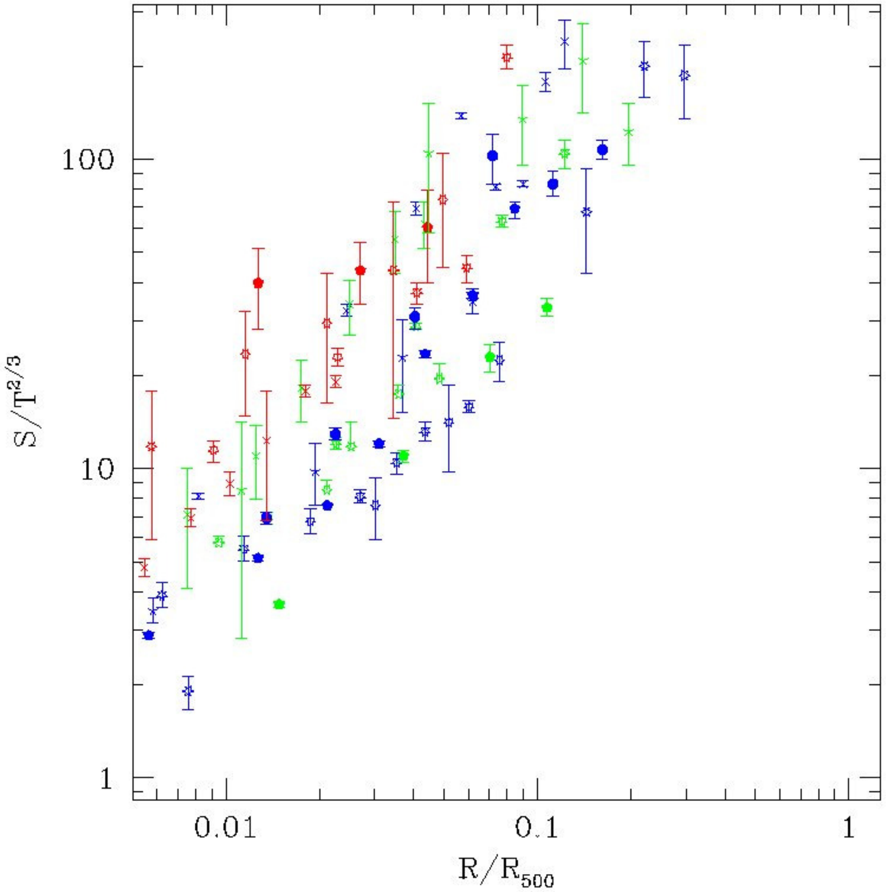
Entropy in groups

- Define entropy as

$$S(r)=T(r)n(r)^{-2/3}$$

- Entropy of a volume of gas is unaffected by moving it around.
- Entropy is affected by either energy input or radiative losses.
- Observationally, entropy is found to scale as $T^{2/3}$ for systems of different temperatures (Ponman et al 2003).

Entropy Profiles of Groups

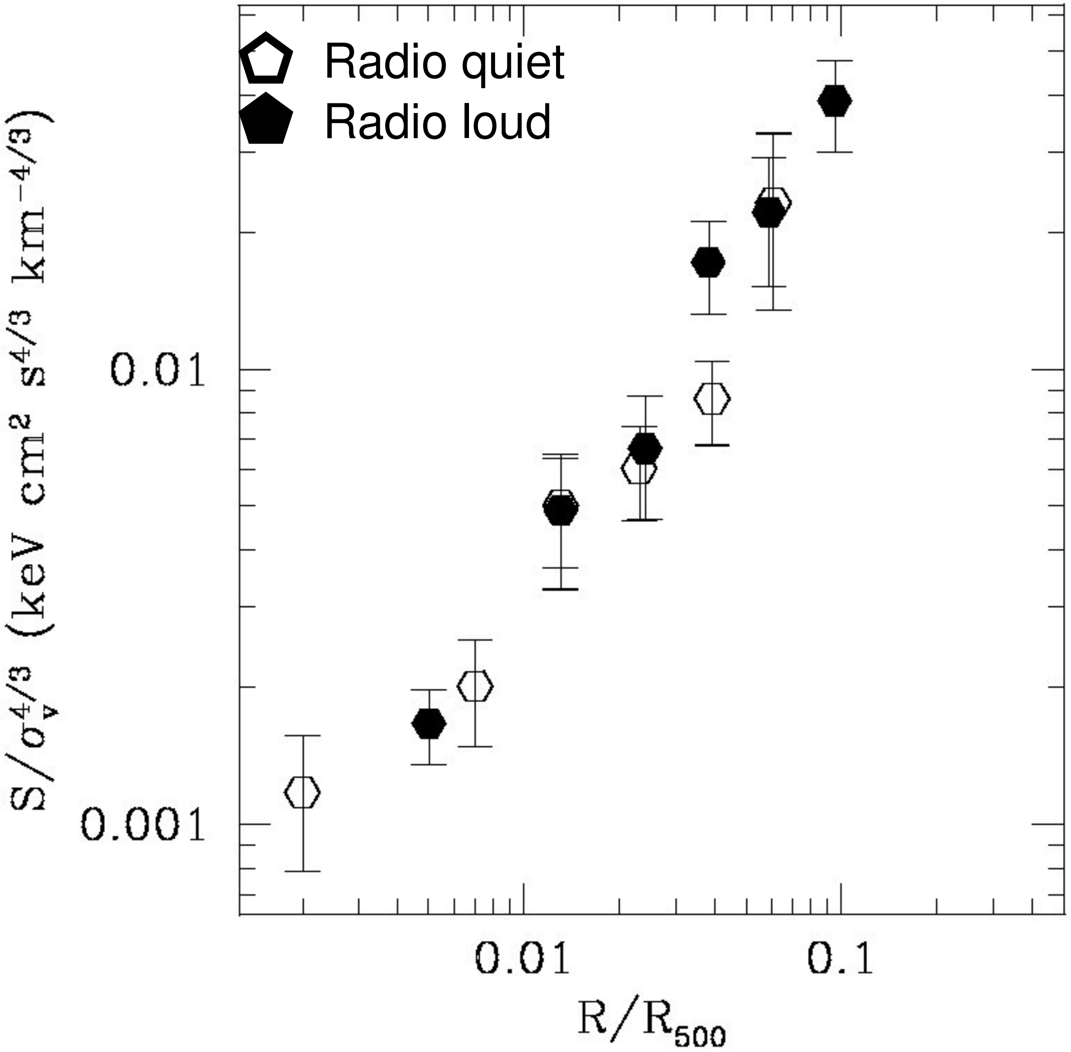


- No evidence of isentropic core.
- Slope of 1.08±0.05
- Agrees with simple shock heating model of gas
- Agrees with recent results for clusters (e.g. Piffaretti et al 2005)

Effect of AGN?

- Split sample into two.
- Radio loud – $\log(L_{1400}) \geq 21.5$.
- Scale radially by R_{500}
- σ is velocity dispersion of group, σ^2 proxy of virial temperature.
- S □ $T^{2/3}$ so scale entropy by $\sigma^{4/3}$
- Co-add radial entropy profiles for (a) radio loud and (b) radio quiet groups.

Entropy profiles – Current AGN activity



- Slope radio loud:

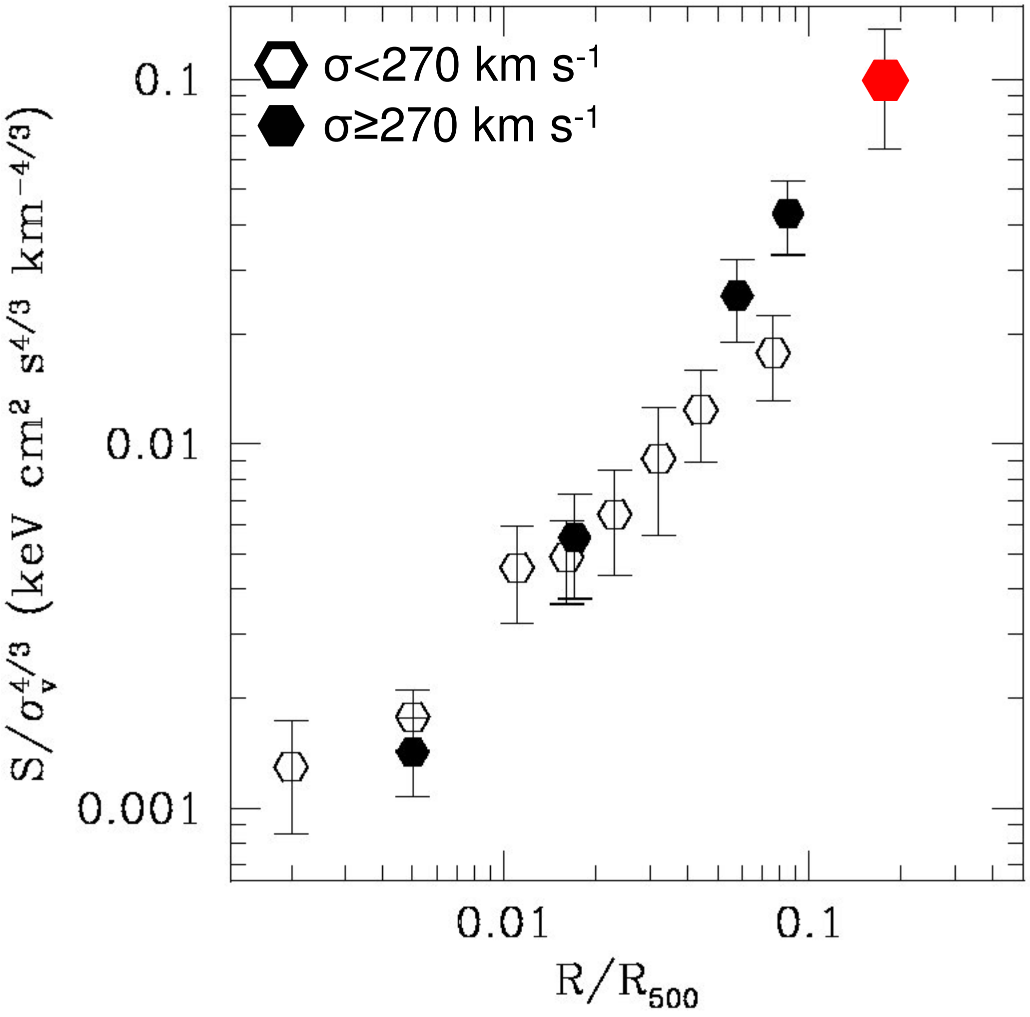
  1.04±0.05
- Slope radio quiet:

  1.00±0.08
- No significant difference.

Cumulative Effect?

- Could the effect be cumulative over repeated cycles of AGN activity?
- Larger black holes may have had more duty cycles than smaller ones.
- Use σ_{galaxy} as a proxy for M_{BH}
- Split sample at σ_{galaxy} =270 km s^{-1}

Cumulative Effects



- Slope σ≥270 km s^{-1}

  1.22±0.01

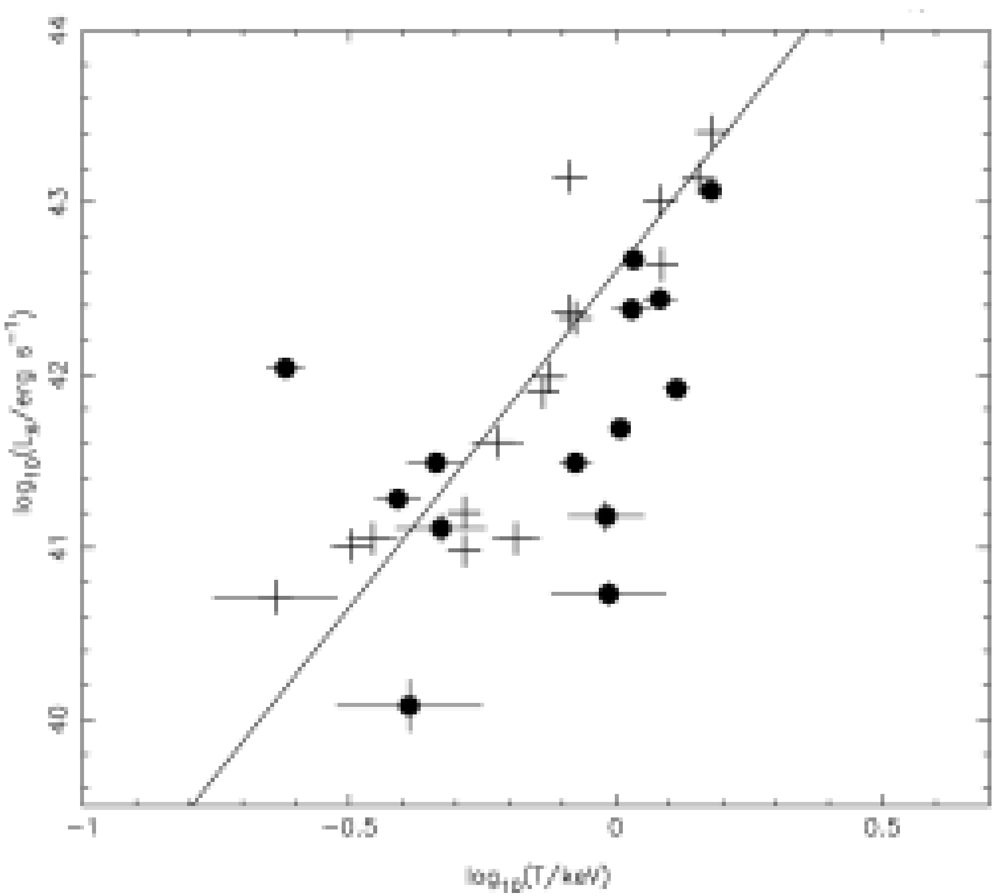
- Slope σ≤270 km s^{-1}

  0.78±0.05

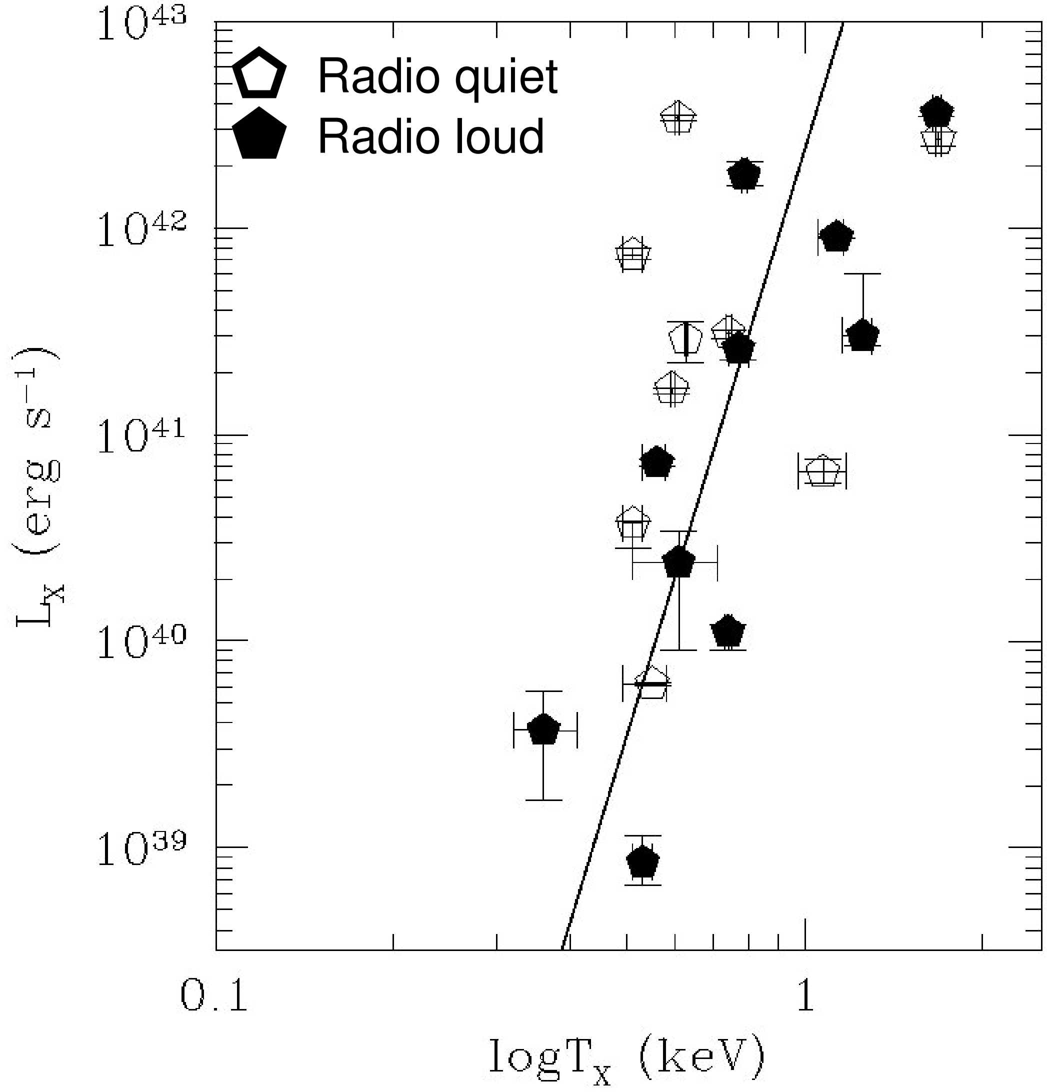
- Appears that ***repeated*** cycles of AGN activity may have an effect.

L_X:T_X relation in group cores

- Croston et al (2005) – current AGN activity and offset from L_X:T_X relation correlated.
- Interpreted as evidence of radio source heating.
- Does the effect occur in the cores also?



L_X:T_X relation in group cores



- Temperature and luminosity measured within $0.05R_{500}$
- Measure offset of points from mean fit for both radio quiet and loud sample.
- KS-Test → 20% chance of distribution of offsets arising randomly if both radio quiet and radio loud drawn from same parent population.

Possible Energy Input?

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- F

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- Im eing

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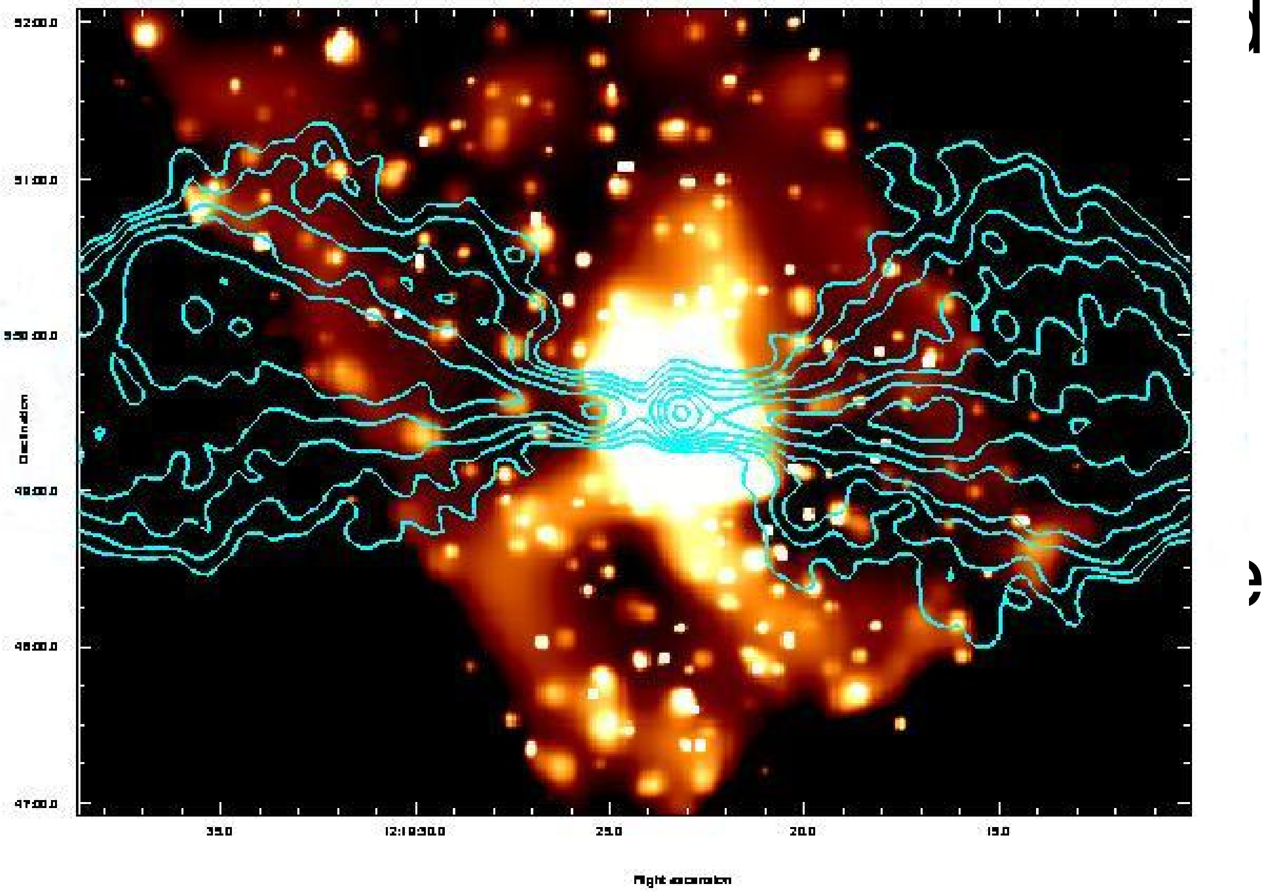
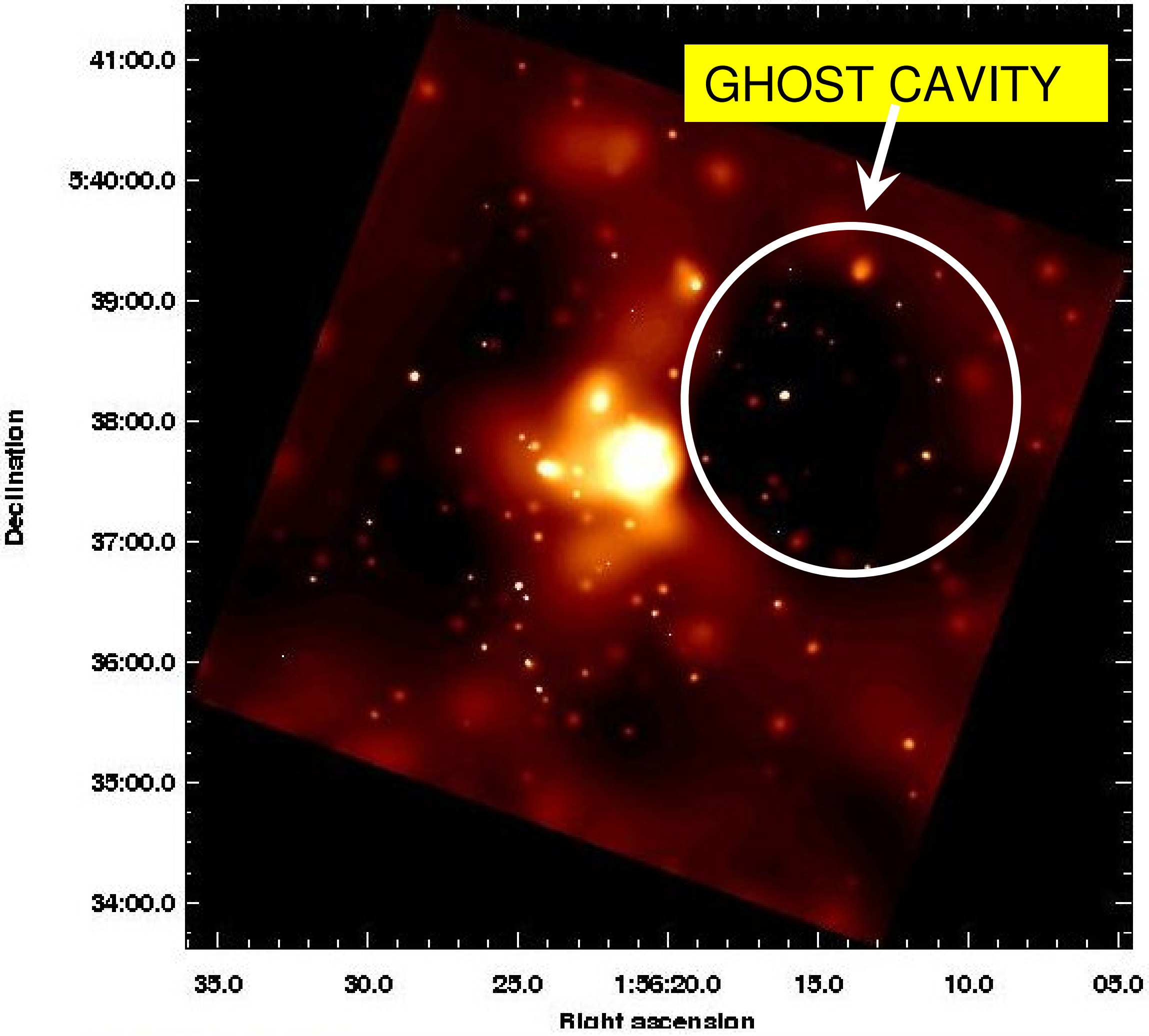


Can energy input in core stop cooling?

- $\Delta T = 0.2 \pm 0.1$keV
- Corresponds to an energy injection of $\Delta E = 2.6 \times 10^{57}$erg
- If AGN 'on' time is 10^7 years, then average power is 8×10^{42} erg s^{-1}.
- Predicted luminosity of core of 1 keV group ~3×10^{42} erg s^{-1}.
- AGN could provide enough energy to counteract cooling in cores.

An Example – NGC 741



- Can calculate PdV work done by bubble as it expands.
- Find that maximum energy input rate is ~ 1.2x10^{43} erg s^{-1}.
- Luminosity of group within 25 kpc is 1.6 x 10^{42} erg s^{-1}.

Summary

- Galaxy groups do not have isentropic cores.
- Currently active AGN appear to have little effect on the gas properties in the cores of groups.
- There is some evidence for a cumulative effect of repeated AGN outbursts.
- Large AGN outbursts could simply transport energy out to larger radii, explaining the Croston et al (2005) LT offset.
- Smaller outbursts could blow bubbles into the IGM, which counteract catastrophic cooling.