The role of feedback in galaxy groups

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Observations from the "Feedback in groups" project using Chandra/XMM X-ray and GMRT 240-1400 MHz radio

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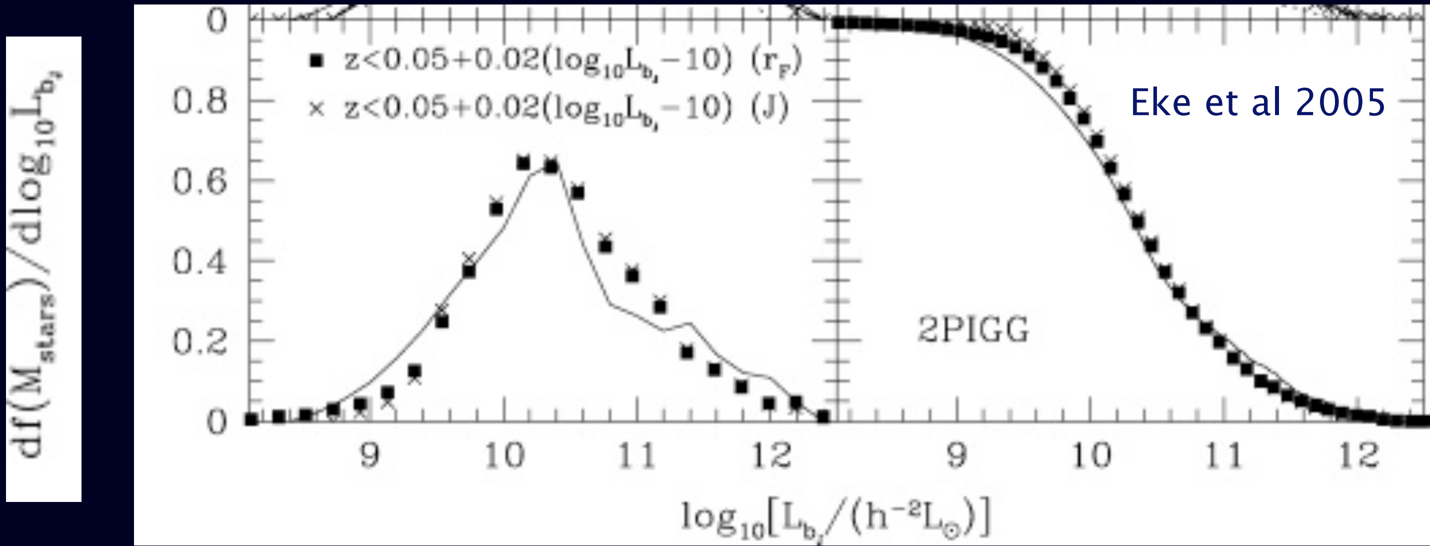
Most galaxies live in groups

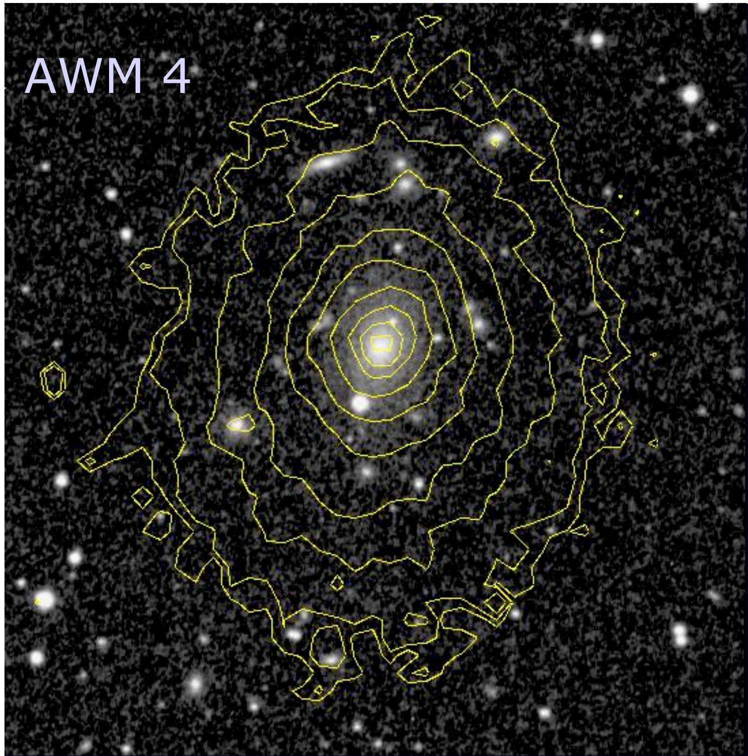


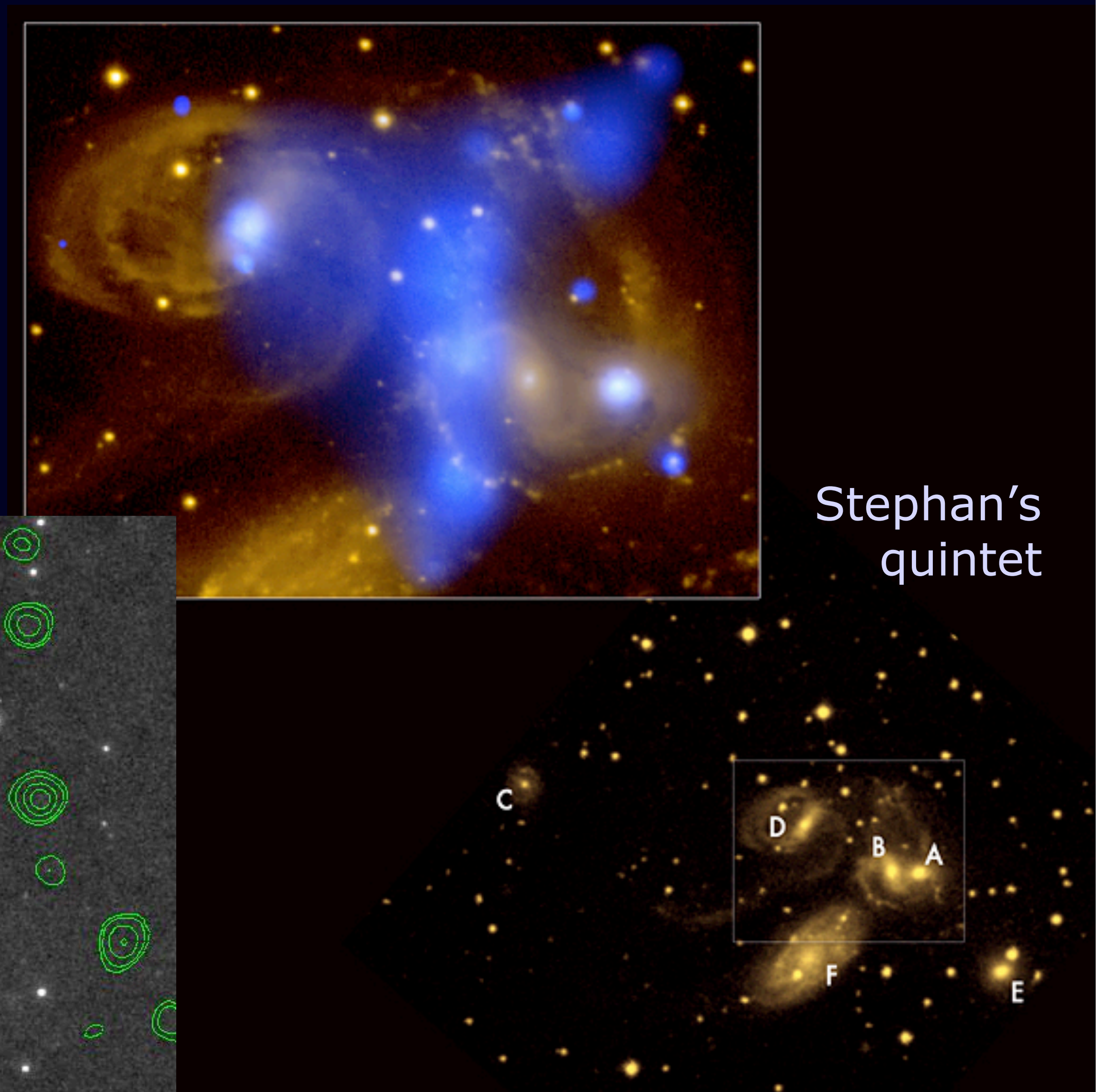
Only 2% of all stars live in clusters with $L_B/L_O > 10^{12}\ h^{-2}$ ($M/M_O > 10^{14.7}\ h^{-1}$)

Half of all stars are in systems with $L_B/L_O > 10^{10} - 10^{11}\ h^{-2}$

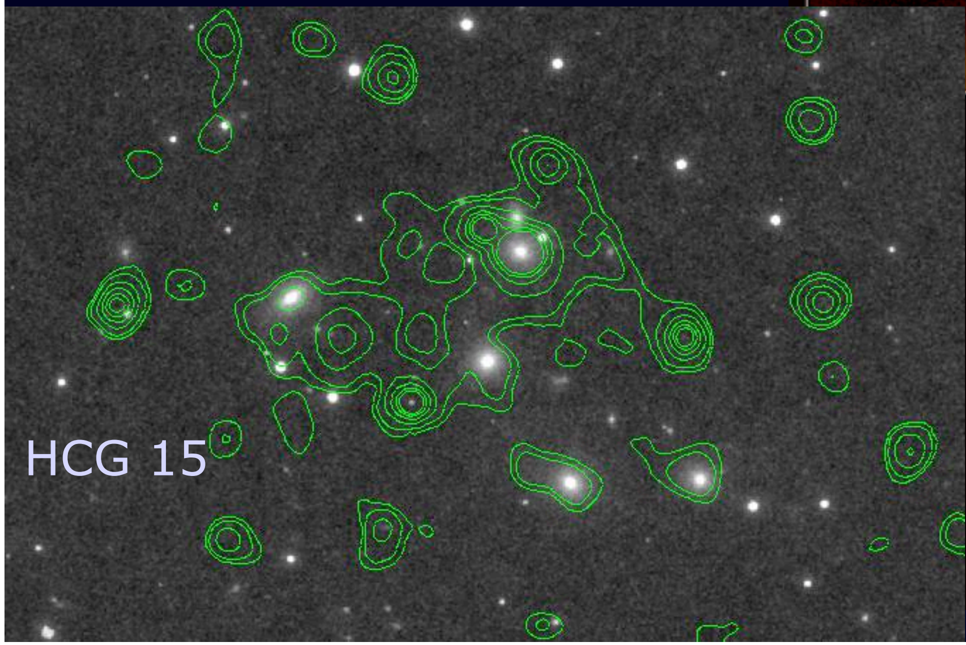
Groups are a diverse bunch

Chandra + optical





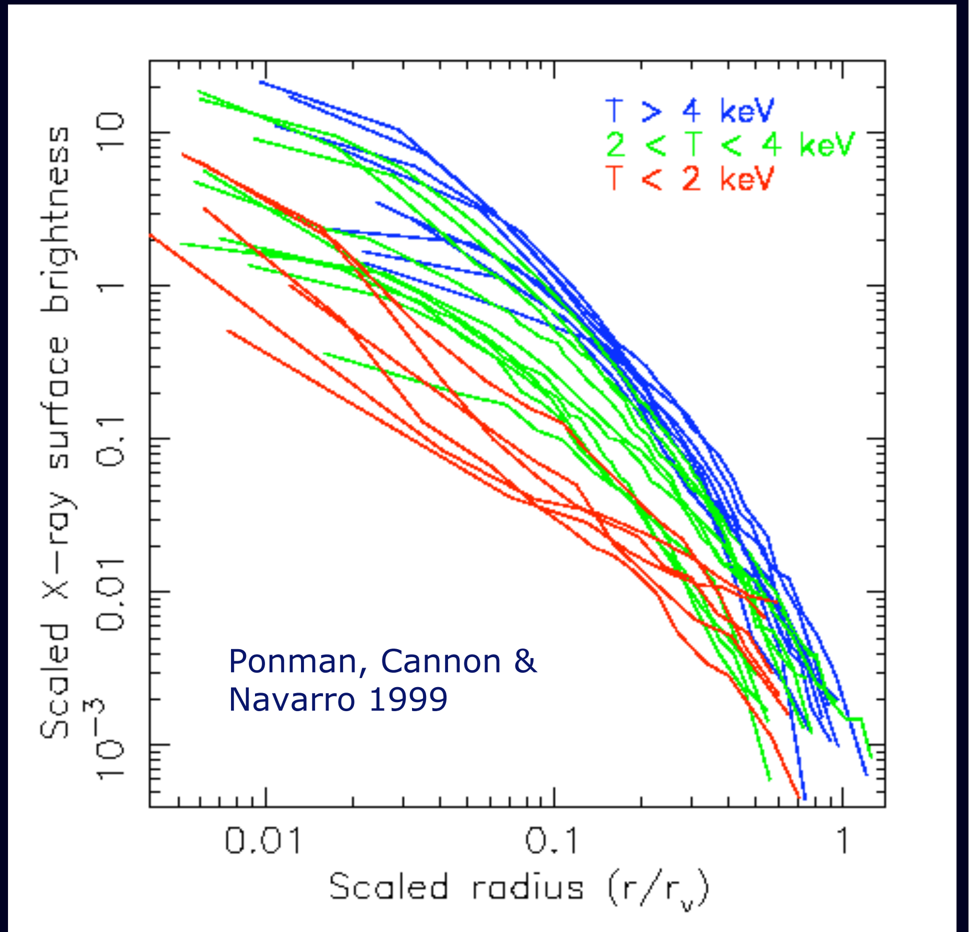
Stephan's quintet



Why feedback is needed

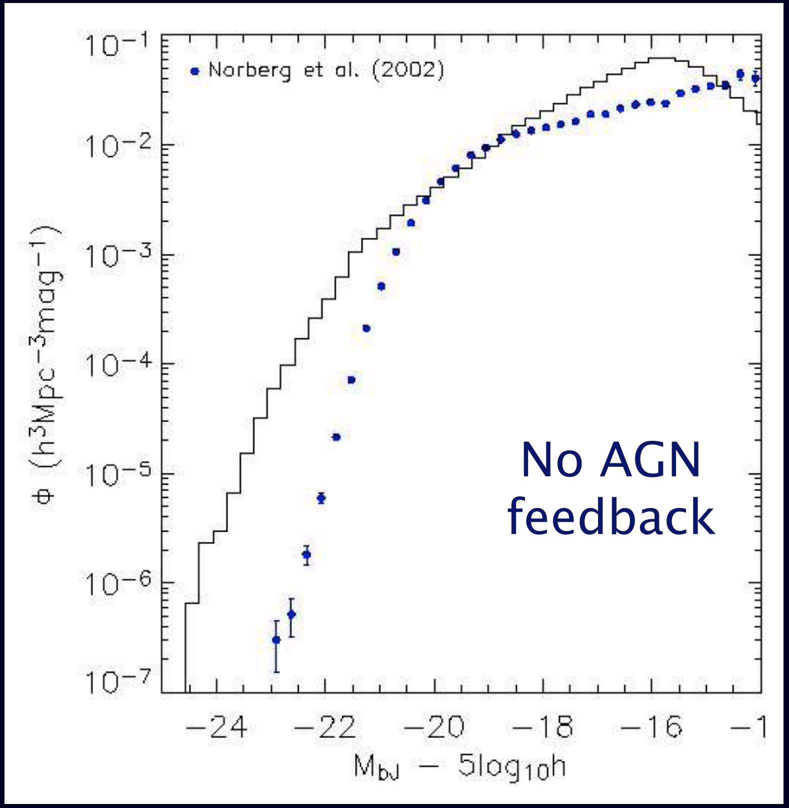
1. Not enough cooling in cluster cores
2. Similarity breaking

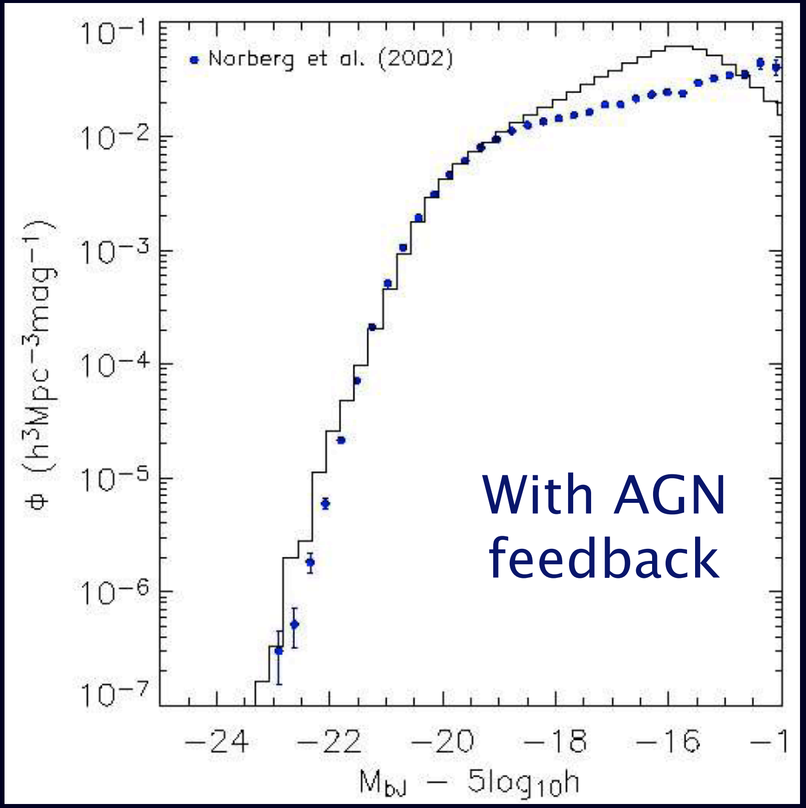
Scaled X-ray surface brightness profiles show that emissivity ($\rho_{\rm gas}$) is progressively suppressed and flattened in cool systems, relative to hot ones.



Why feedback is needed

3. AGN feedback is necessary to match the galaxy LF in semi-analytic models (Overcooling)





Croton et al 2004

Why feedback in needed

- Are we sure that AGN are responsible for #1 the lack of cool cores in clusters?
- If so, how do they do it? Why are they not effective in groups?
- Do they at the same time resolve #2 and #3 - i.e. do they cause the similarity breaking, and also solve the overcooling problem?
- What can we learn about these questions by studying galaxy groups, and comparing them with clusters?

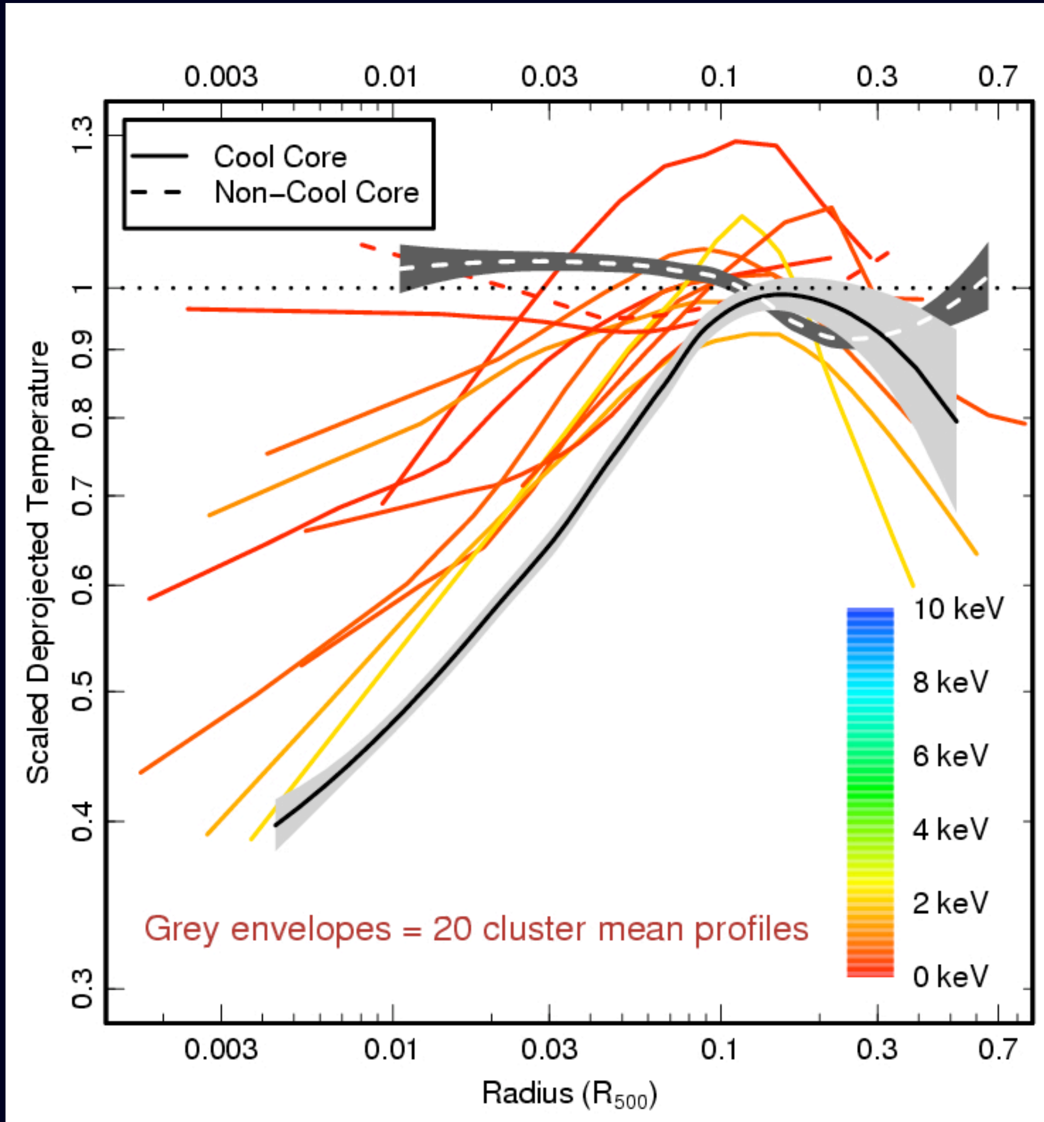
The cores of groups and clusters

A comparison of ICM temperature profiles of 20 clusters with those of 12 groups:

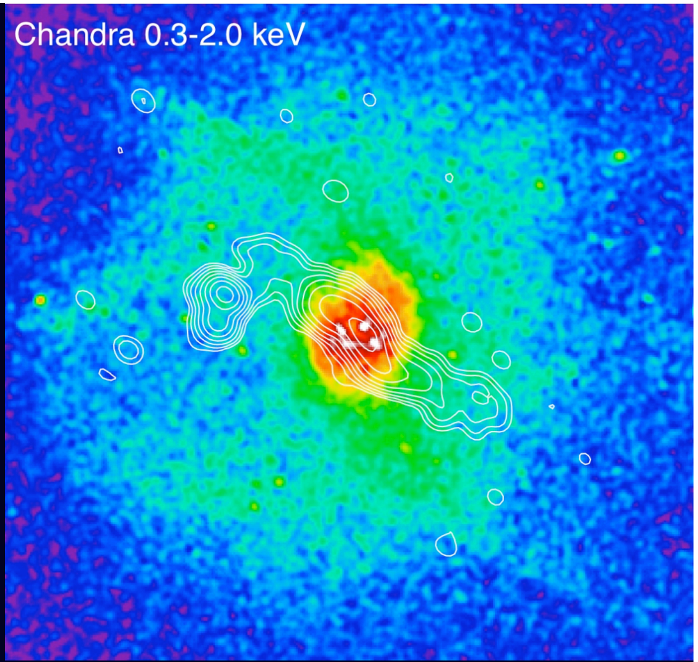
Half of the clusters are *cool core*, and the others *non cool core* (Sanderson et al 2006).

11 out of 12 groups have cool cores

Sanderson, Ponman & O'Sullivan (in prep.)



Clusters vs Groups



NGC 4636
see O'Sullivan poster

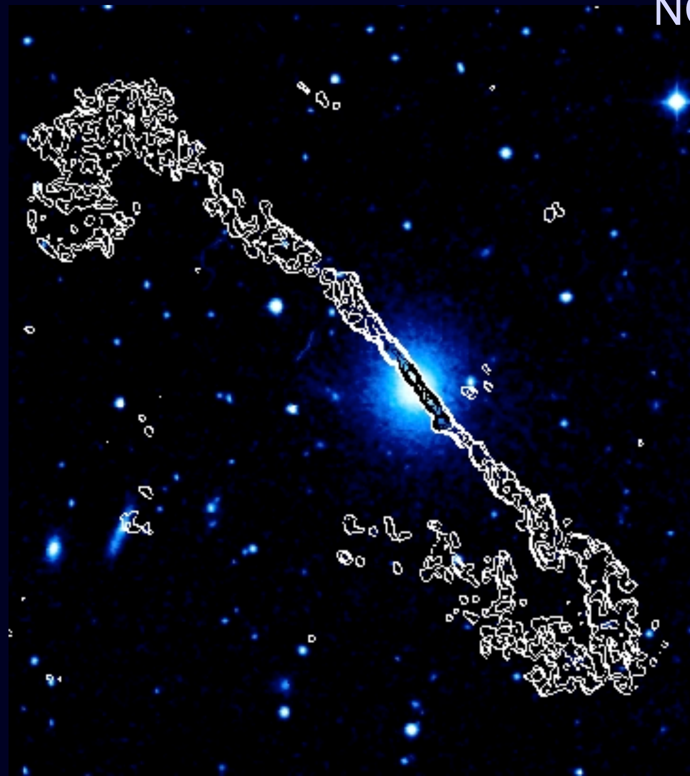
- A majority of X-ray emitting groups seem to have cool cores
- Yet we have evidence of AGN feedback in groups

- Groups don't in general have early-type BCGs
- There are far more major galaxy mergers in groups than in present-day clusters

- Galaxy-galaxy and group-group interactions are more frequent
- There are lessons one can learn from low-frequency radio observations

NGC 741

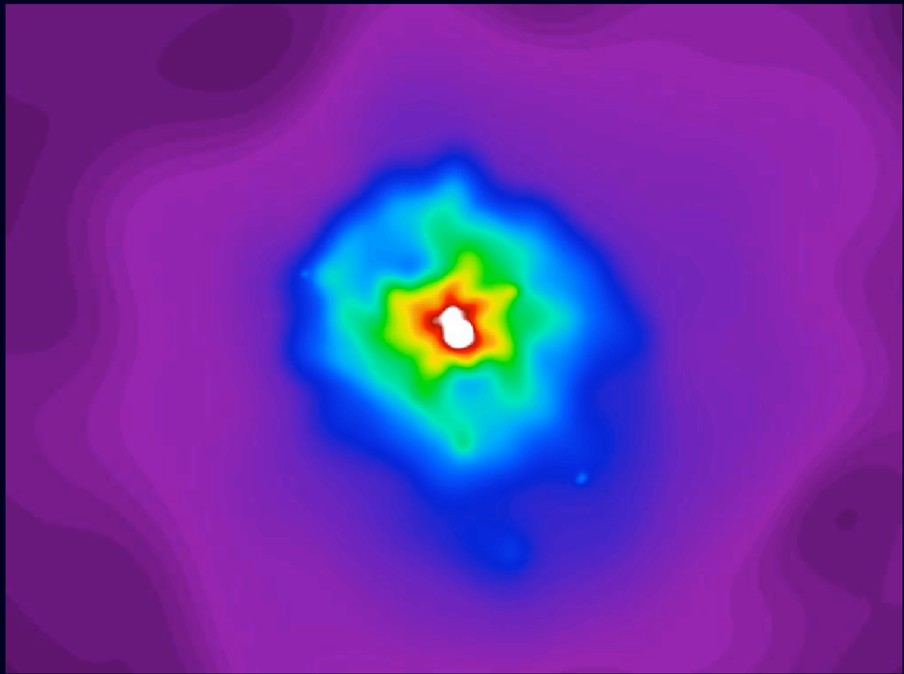
NGC 7626

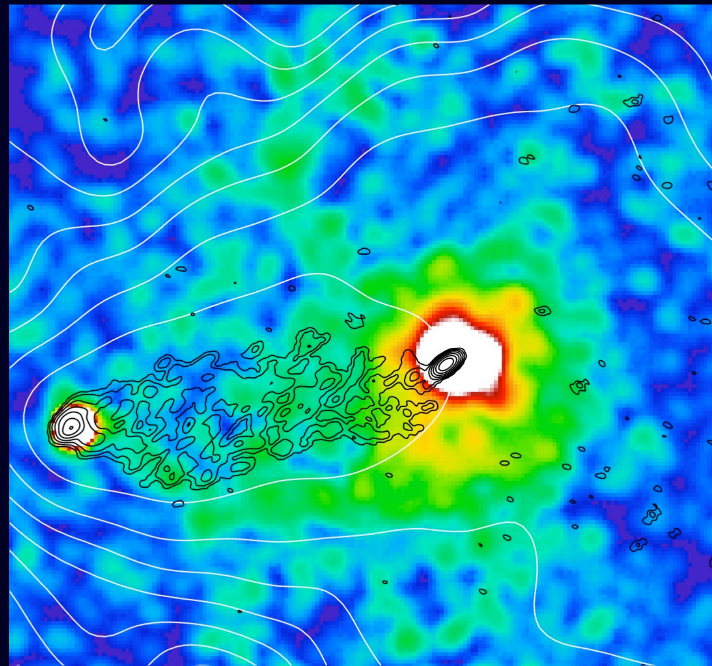


S. Giacintucci & E. O'Sullivan

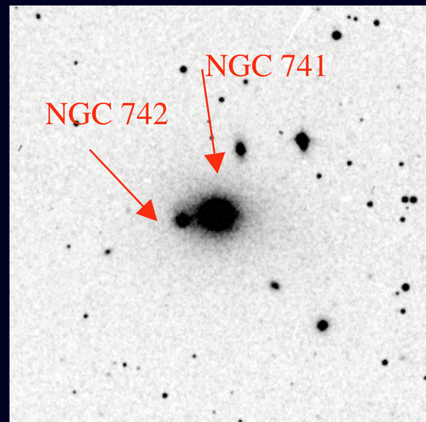
XMM+GMRT 610 MHz

Two Examples

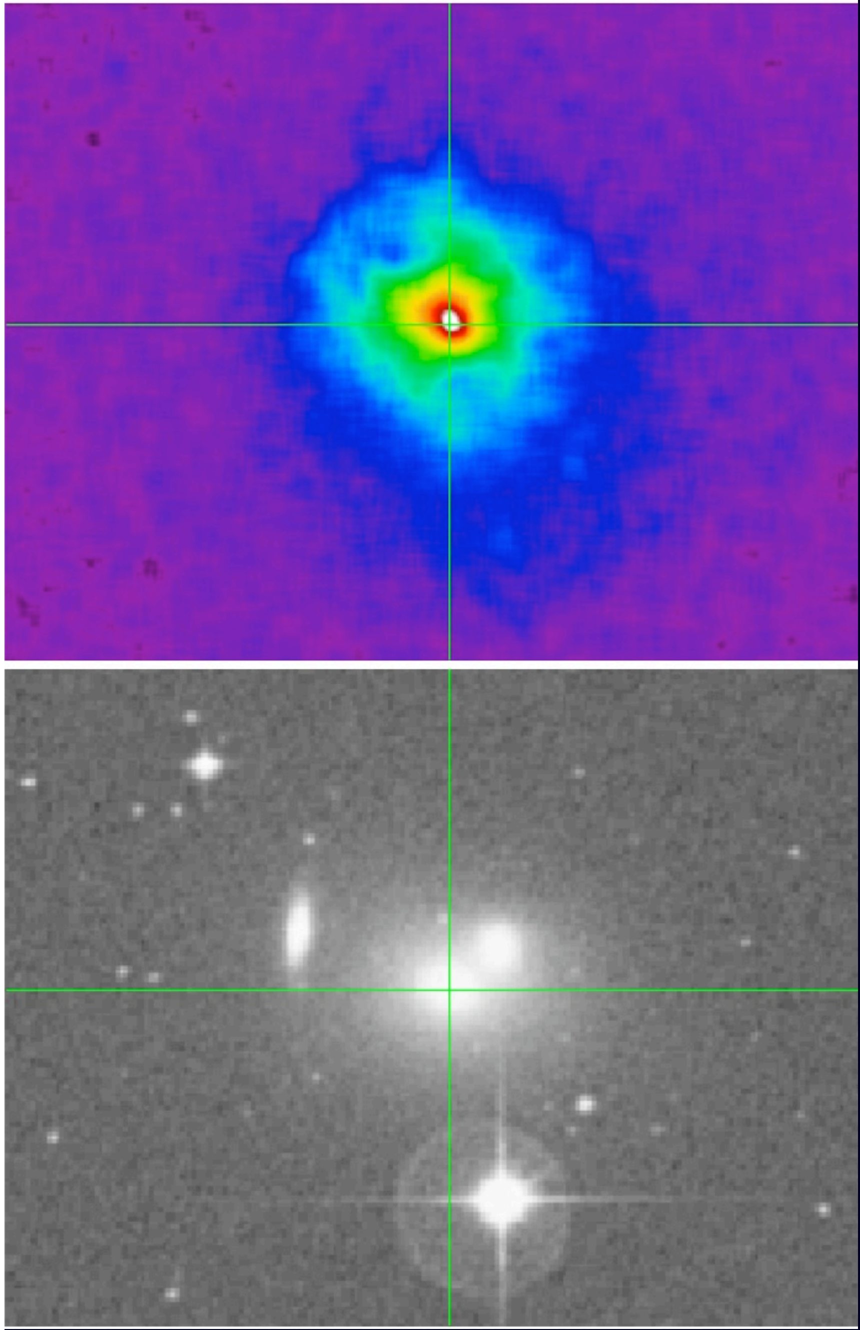




HCG 62
compact group



NGC 741
fossil group



HCG 62

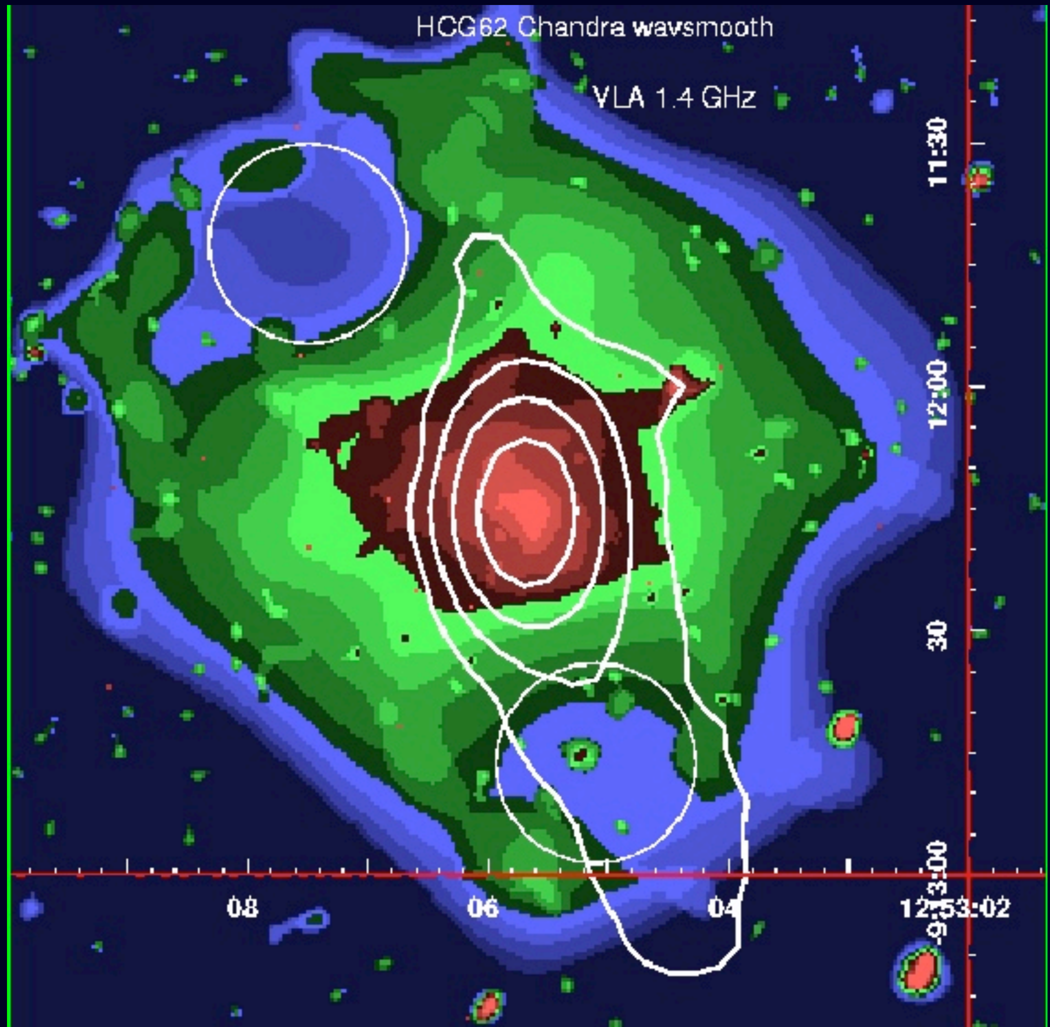
- X-ray brightest and one of the most intrinsically luminous of the 100 Hickson compact groups
  $L_x \approx 10^{43}$ erg s^{-1}

- Central galaxies: two very similar early-type galaxies (Δm ≈ 0.5);

- D=59 Mpc, giving 1′=17 kpc

- $M_{gas} \approx 10^{12}\ M_{sun}$ within ~20′

HCG 62



Vrtilek et al

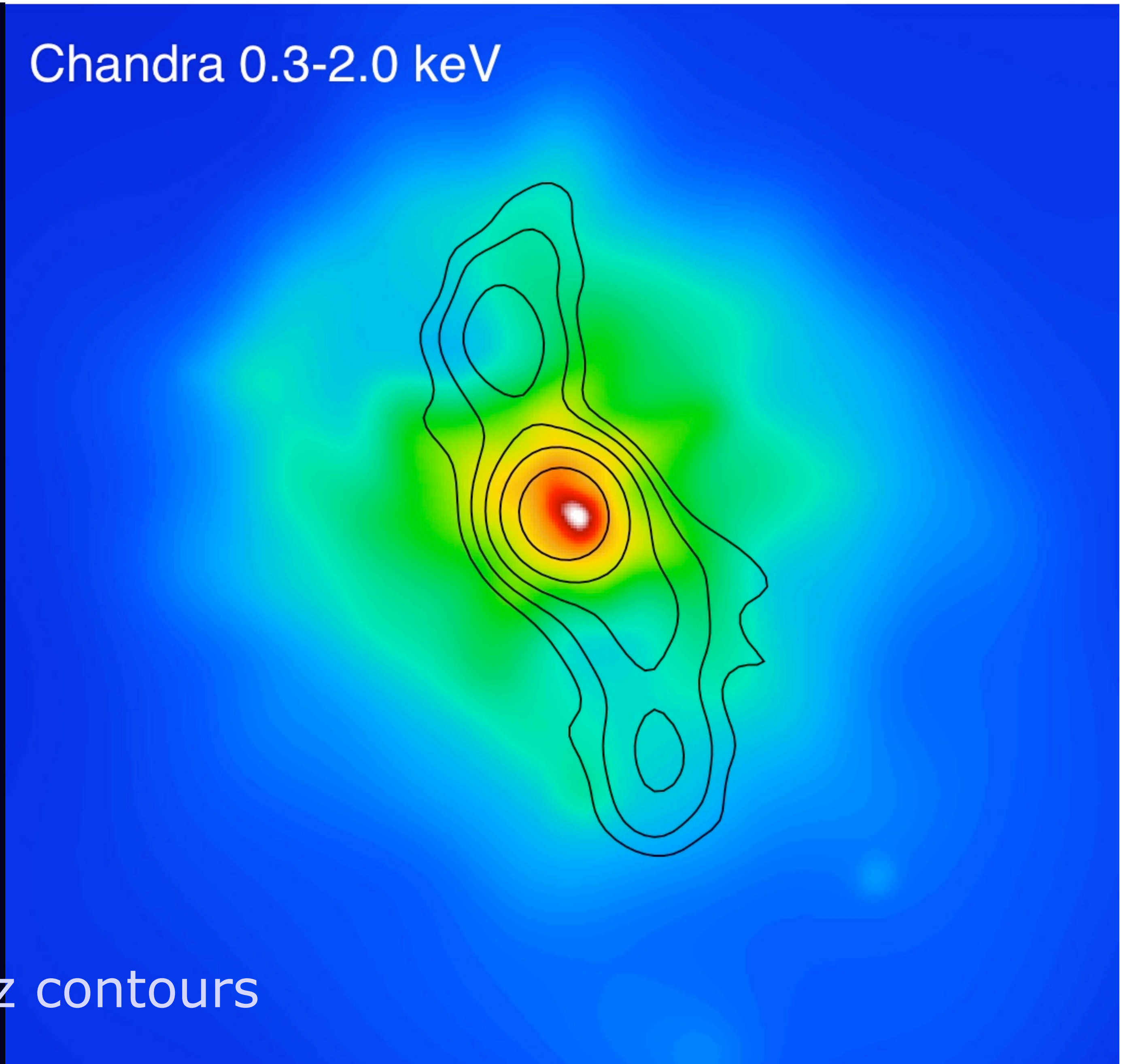
Chandra ACIS S3 50 ks

Contours: VLA 1.4 GHz

Beam 18 x 12 arcsec;
lowest contour at 0.3 mJy/beam

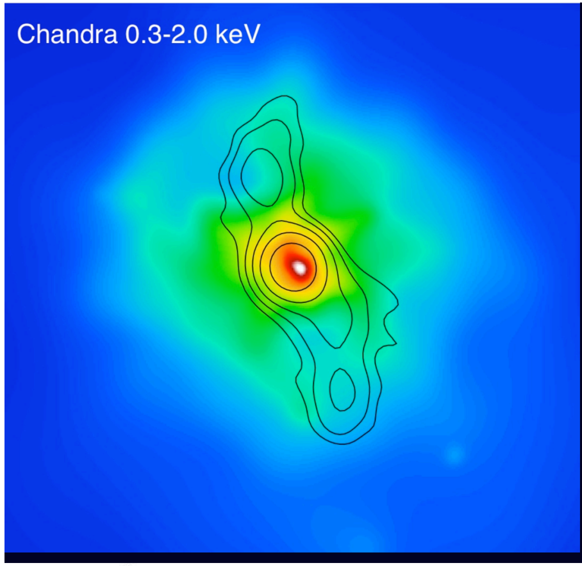
Cavities at 8 kpc - wouldn't detect them if at 50 kpc

HCG 62



GMRT 610 MHz contours

Beam 5 arcsec;
lowest contour at 0.15 mJy/beam



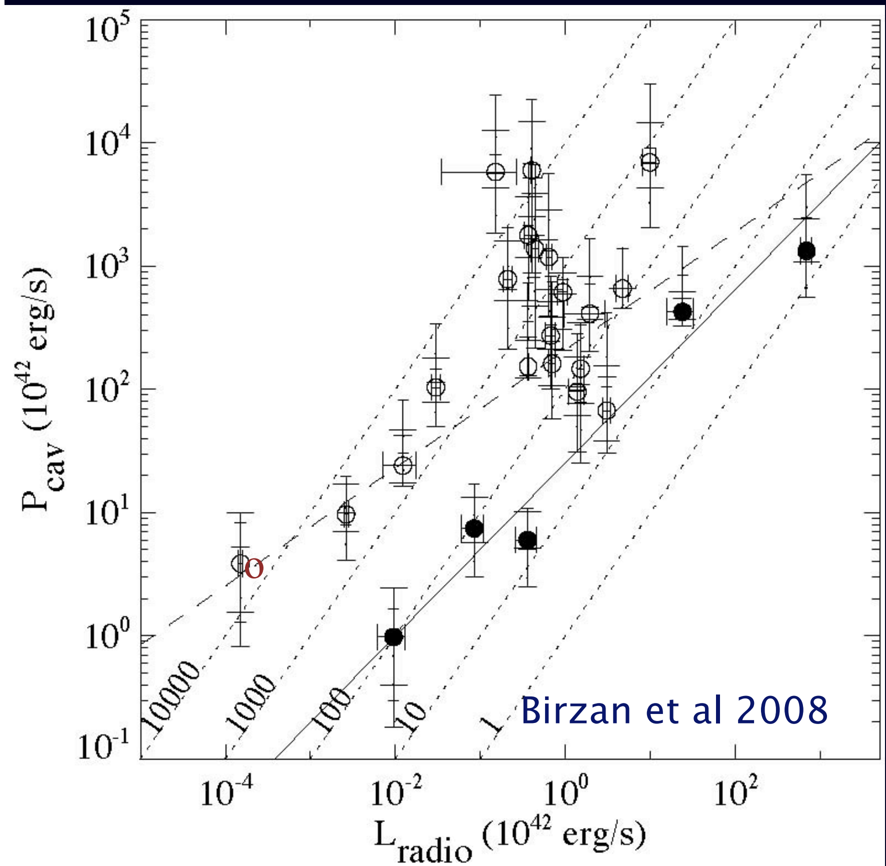
HCG 62

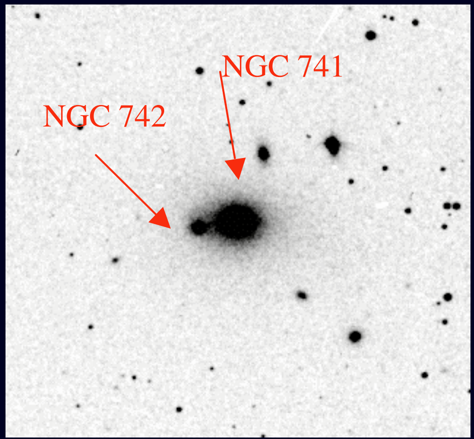
- Spectral slope based on 1400, 610 and 240 MHz of extended component

- Extended component has alpha ~ 1.3 (relatively steep)
- Compact component has alpha ~ 0.9

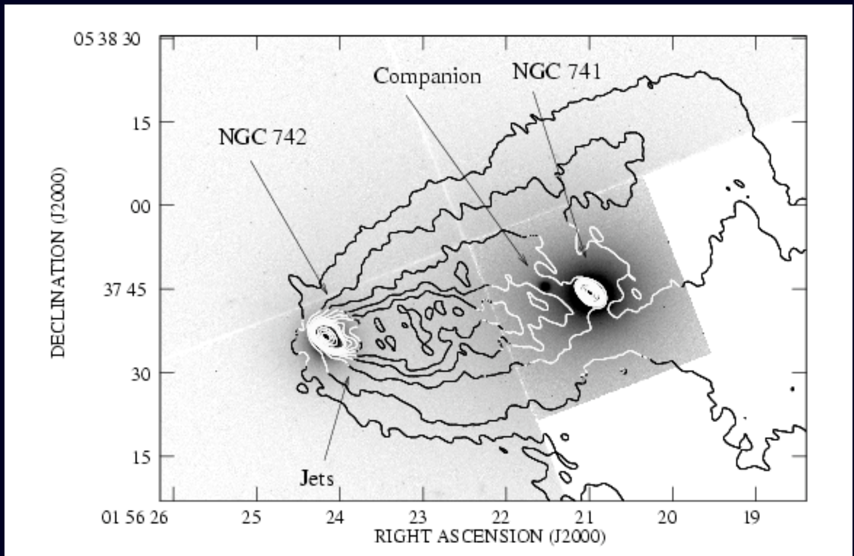
- L (10 MHz- 5 GHz) = 2.6 x 1038 erg/s

- Radio luminosity much less than mechanical power



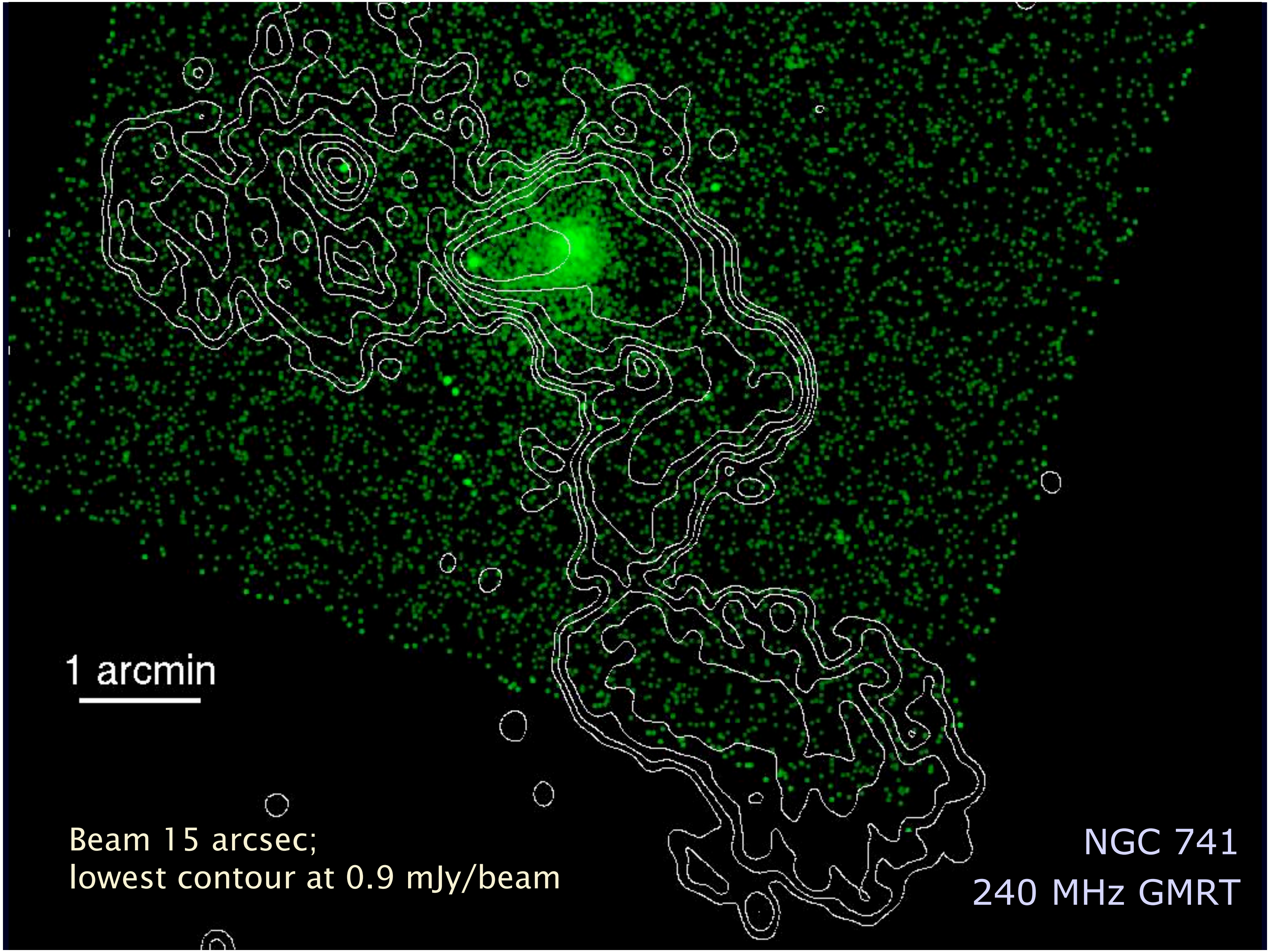


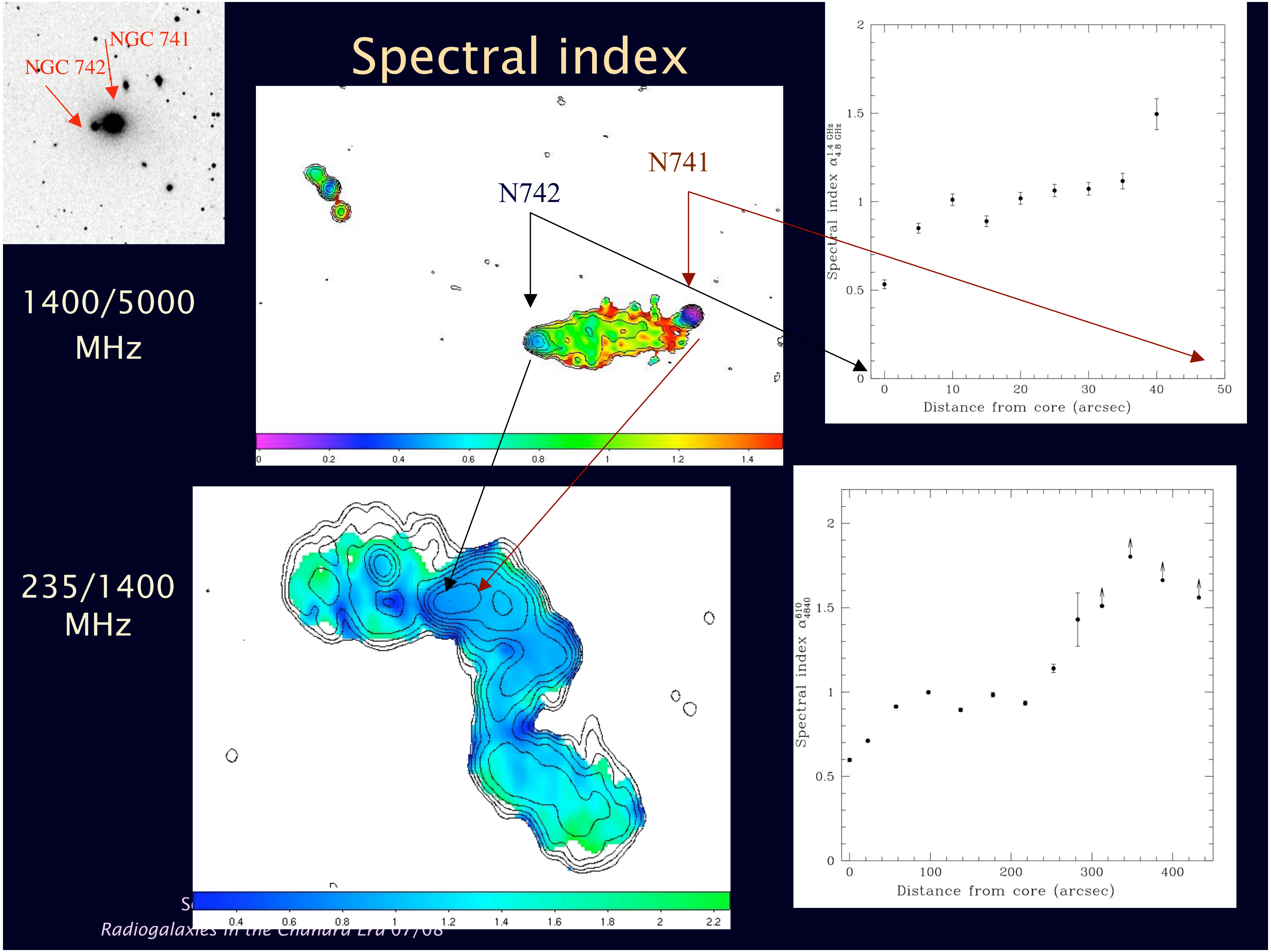
NGC 741



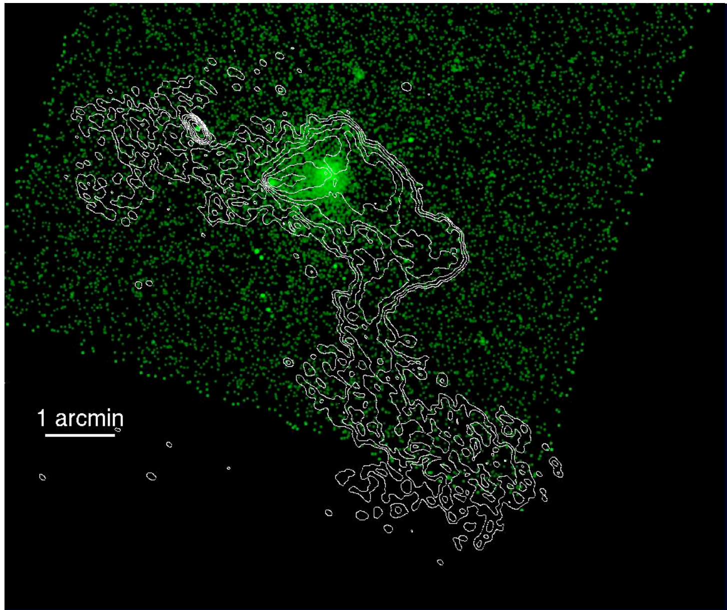
- Core of ~ 40 member group with velocity dispersion ~ 430 km s^{-1}
- Fossil group, $\Delta m \approx 2.5^m$
- Δz (741-742) = 400 km s^{-1}
- D = 81 Mpc (1' = 24 kpc)
- Narrow-angle tail radio source; bright, complex morphology

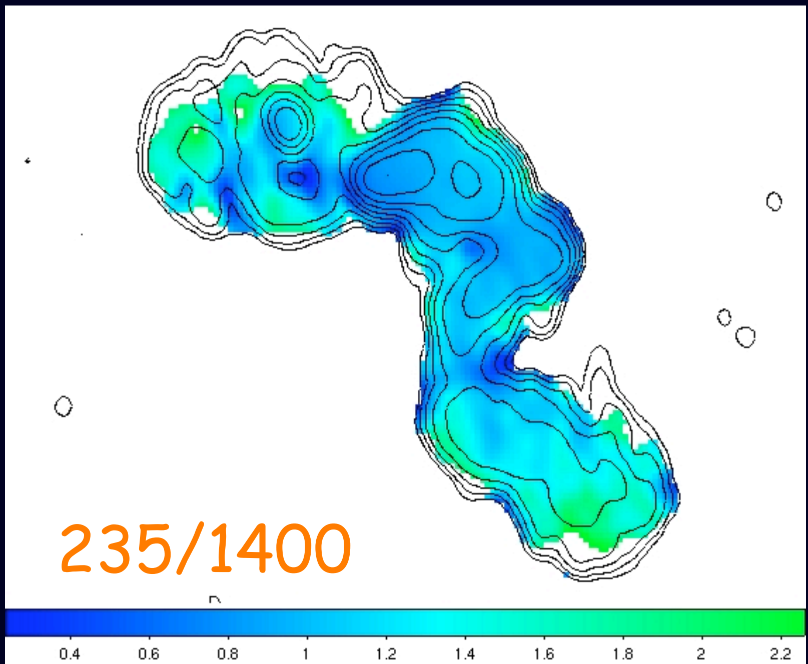
Jetha et al 2007


1 arcmin
Beam 15 arcsec;
lowest contour at 0.9 mJy/beam
NGC 741
240 MHz GMRT



Spectral index
NGC 741
NGC 742
N742
N741
1400/5000 MHz
235/1400 MHz
Spectral index $\alpha^{1.4\ GHz}_{4.8\ GHz}$
Distance from core (arcsec)
Spectral index α^{610}_{4840}
Distance from core (arcsec)





NGC 741

- Compact component has alpha~ 0.52
- Both galaxies have flat-spectrum nuclei
- NGC 741 has no jet

- L (10 MHz- 5 GHz) = 3.2 x 10^{44} erg
- There could be two outbursts superposed here
- There is a cavity to the NW caused by an earlier outburst of N741 (Jetha et al 2007)

Conclusions

- A majority of X-ray emitting groups seem to have cool cores, yet we have evidence of AGN feedback in groups

- Groups have enhanced galaxy-galaxy interaction, so the nature of AGN feeback may be different. Other modes of feedback may be important. AGN feedback is likely more inefficient in groups.

- Low frequency radio observations can provide crucial information about the history of AGN-IGM interaction.