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

Stephan’s quintet

AWM 4

HCG 15

Chandra + optical
Why feedback is needed

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

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

Ponman, Cannon & Navarro 1999
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?
A comparison of ICM temperature profiles of 20 clusters with those of 12 groups:

Half of the clusters are \textit{cool core}, and the others \textit{non cool core} (Sanderson et al 2006).

\textit{11 out of 12 groups have cool cores}

Sanderson, Ponman & O’Sullivan (in prep.)
Clusters vs Groups

- 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

S. Giacintucci & E. O’Sullivan

XMM+GMRT 610 MHz
Two Examples

HCG 62 compact group

NGC 741 fossil group

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Radiogalaxies in the Chandra Era 07/08
HCG 62

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

- Central galaxies: two very similar early-type galaxies (\( \Delta m \approx 0.5 \));

- \( D = 59 \text{ Mpc}, \) giving \( 1' = 17 \text{ kpc} \)

- \( M_{\text{gas}} \approx 10^{12} M_{\text{sun}} \) within \( \sim 20' \)
HCG 62

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

Vrtilek et al

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GMRT 610 MHz contours

Chandra 0.3-2.0 keV

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 $\sim 1.3$ (relatively steep)
- Compact component has alpha $\sim 0.9$

- $L (10 \text{ MHz}- 5 \text{ GHz}) = 2.6 \times 10^{38} \text{ erg/s}$

- 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
- $\Delta z (741-742) = 400$ km s$^{-1}$
- $D = 81$ Mpc (1’ = 24 kpc)
- Narrow-angle tail radio source; bright, complex morphology

Jetha et al 2007
Beam 15 arcsec; lowest contour at 0.9 mJy/beam

NGC 741
240 MHz GMRT
Spectral index

1400/5000 MHz

235/1400 MHz

Radiogalaxies in the Chandra Era (07/08)

NGC 741
NGC 742
N742
N741
NGC 741

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

- \( L_{(10 \text{ MHz}- 5 \text{ GHz})} = 3.2 \times 10^{44} \text{ erg} \)
- 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 feedback 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.