Galaxy Groups in the Local Universe
Results from a complete sample

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Thanks to: K. Kolokythas, J. Vrtilek, L.P. David, G. Schellenberger, M. Gitti, S. Raychaudhury, S. Giacintucci, T. Ponman, A. Babul, F. Combes, P. Salomé, C.P. Haines
Background: why do we need another group sample?

- Groups are a key environment for galaxy evolution and AGN feedback
  - >50% of all galaxies reside in groups
  - Galaxy mergers and tidal interactions are common
  - Shallow potential well $\Rightarrow$ AGN, mergers have greater impact

- But we lack representative, unbiased samples
  - *Optically-selected* catalogs include false groups (chance associations, uncollapsed groups)
  - *X-ray selection* guarantees bound groups but:
    - RASS-based surveys biased toward cool core systems (e.g., Eckert et al. 2011)
    - Samples from deeper surveys tend to be at moderate redshift, tough to resolve morphology, AGN / cool core, interactions
    - *eROSITA* will determine population statistics, but again with limited detail of internal structure and properties

- CLoGS: a statistically complete sample of nearby, optically-selected groups with high-quality X-ray and radio data.
Sample selection

Begin with Lyon Galaxy Groups (Garcia 1993)
- All-sky, optically-selected, $cz<5500$ km s$^{-1}$ (D<80Mpc)

Select from LGG list: systems with
- $\geq 4$ members
- $\geq 1$ early-type member with $L_B\geq 3\times 10^{10}L_\odot$
- Declination $>-30^\circ$ (visible from GMRT and VLA)

Expand and refine membership
- Update membership from HyperLEDA
- Use isodensity maps to reject problem cases

Filter on richness ($R = N_{gal}$ with $L_B\geq 1.6\times 10^{10}L_\odot$)
- Exclude known clusters: $R\geq 10$
- Exclude groups too small to characterize: $R=1$

485 groups
- 67 groups
- 53 groups
- 26 groups (High-richness subsample $R=4-8$)
- 27 groups (Low-richness subsample $R=2-3$)

See O’Sullivan et al. (2017)
Observational data

◆ **X-ray:** (O’Sullivan et al. 2017)
  - XMM-Newton and/or Chandra for all 53 groups
  - Minimum sensitivity goal for new observations:
    \[ L_x \geq 1.2 \times 10^{42} \text{ erg s}^{-1} \text{ within } R_{500} \]
    \[ L_x \geq 3.9 \times 10^{41} \text{ erg s}^{-1} \text{ within } 65 \text{ kpc} \]

◆ **Radio:** (Kolokythas et al. 2018, 2019)
  - GMRT 235+610 MHz for all groups (192hr + archival data)
  - ~4hrs/target, rms ~0.1mJy/bm @610 MHz, ~0.6mJy/bm @ 235 MHz
  - Low frequency, >1° FoV ⇒ sensitive to range of source ages and sizes

◆ **CO:** IRAM 30m/APEX for all dominant galaxies (O’Sullivan et al. 2018b,2015)
  - 70% Hα imaging (Bok 2.3m or WIYN 0.9m), long-slit spectra, etc.
CLoGS: X-ray/Radio overview

X-ray properties:

- **26/53 (~50%)** have an X-ray bright IGM (extent >65 kpc, \( L_x > 10^{41} \) erg/s)
  - ~1/3 dynamically active (sloshing/mergers)
  - Cool Core fraction = 65%

- **16/53 (~30%)** have a galaxy-scale X-ray halo (extent < 65 kpc, \( L_x = 10^{40} - 10^{41} \) erg/s)

- Mass range 0.5-5x10^{13} M☉

Group-central galaxies:

- **46/53 (87%)** detected at 610, 235 or 1400 MHz

- 13 host jet sources ⇒ duty cycle ~1/3

- 5 are diffuse, 28 point-like

- \( L_{235} = 10^{20} - 10^{25} \) W/Hz

- + 100s non-central galaxies

NGC 4261 (O’S 2011, Kolokythas 2015)

ESO507-25: Diffuse source 610 MHz contours at (0.4, 0.8, 1.6, ...) mJy/bm

NGC 5985 AGN+SF disk 610 MHz contours at (0.8, 1.6, 3.2, ...) mJy/bm
New groups

12/26 previously not recognized as X-ray groups, 8 not found in RASS!

- Faint, non-cool core
- Mergers
- AGN disrupted

>30% of X-ray bright groups as yet unidentified?
AGN Feedback:
Jet Power

- 11/13 jet sources reside in X-ray bright groups
- 5 in high-Richness subsample
  - $P_{\text{jet}} = 0.1-100 \times L_{\text{cool}}$ (c.f. models showing variation in jet power, e.g., Li et al. 2016)

- In low-R sample, two jets depositing energy at radii >100kpc (see also Grossova et al. 2019)
  - How do such systems fit into AGN feedback models?
Molecular gas

CO Detection rate in group-dominant galaxies: 40±9%

- Compare with 22±3% in Atlas3D ellipticals (Young et al. 2013)
- >50% have HI

- CO in both X-ray bright and X-ray faint systems ⇒ cooling and merger origins?
- Large CO mass not required for AGN outburst
Summary

CLoGS is a statistically complete, optically-selected sample of 53 nearby groups with high-quality X-ray + radio coverage (+ CO for BGGs).

• 26/53 high-richness groups have X-ray bright IGM +16 galaxy-scale halos.
• 12/26 X-ray bright groups not previously identified, 8 not found by RASS ➔ ~30% of X-ray bright groups in local volume may be as yet unidentified!
• 87% of group-dominant galaxies host radio sources, 25% have jets.
• ~40% of X-ray bright groups host currently or recently active central radio jet sources ➔ duty cycle 1/3.
• In X-ray bright systems, active jets found in cool cores. Jet power can exceed cooling luminosity by a factor of 100.
• CO detection rate in group-dominant galaxies 40%, roughly double that in general population of ellipticals, but CO not correlated with AGN power.