First results from CLoGS: A Complete Local-Volume Group Sample

Ewan O’Sullivan (SAO)
CLoGS collaboration

SAO: E. O’Sullivan, J. Vrtilek, L. David, C. Jones, W. Forman
U. of Birmingham, UK: T. Ponman, K. Kolokythas, M. Gillone
Presidency U. & U. of Birmingham: S. Raychaudhury
NCRA-TIFR: N. Kantharia
U. Maryland: S. Giacintucci
U. de Chile: C. Haines
U. Alabama: N. Jetha
INAF-O.A. Bologna: M. Gitti
Johns-Hopkins: S. Murray
U. of Victoria: A. Babul

All credit for radio analysis to:
Konstantinos Kolokythas
Simona Giacintucci
Why galaxy groups?
And why AGN feedback in groups?

- Most galaxies reside in groups! ~2% in clusters, >50% in groups.
- Galaxy / gas evolution. Groups favour galaxy interactions. Small groups rich in cold gas (HI), Massive groups rich in hot gas (10^7K)
  How does this happen?
- Hot gaseous IGM requires feedback to balance cooling.

Problem: available samples of nearby groups are unreliable or biased.
Selecting a representative sample: CLoGS

From the LGG sample of groups within 80 Mpc (Garcia 1993), we select systems with:

- ≥4 member galaxies — exclude small associations with no group DM.
- ≥1 early-type member with $L_B \geq 3 \times 10^{10} L_\odot$ — spiral-only groups almost never have an IGM detectable in X-rays.
- Declination $>-30^\circ$ — visible from GMRT and VLA.

Refine/expand membership, determine velocity dispersion $\sigma$. Define Richness ($R$) = number of galaxies with $L_B \geq 1.6 \times 10^{10} L_\odot$

Exclude: groups with $R \geq 10$ — known clusters
- groups with $R=1$ — too poor to estimate $\sigma$, $f_{\text{spiral}}$, etc.

CLoGS main sample: 53 groups within 80 Mpc with $R=2-9$.
High-richness subsample: 26 groups with $R=4-9$.
Observe sample in the X-ray to confirm gravitationally bound.
CLoGS: data

- **Radio:** Full sample complete at 235 and 610 MHz
  - 192 hrs GMRT dual-freq. + archival data (Giacintucci et al. 2011)
  - 4hrs/target, rms ~0.1mJy/b @610 MHz, ~0.6mJy/b @ 235 MHz.
  - GMRT Field of view well suited to groups, diameters >1°.
  - Data for high-richness sample (almost) full reduced.

- **X-ray:** High-richness sample complete.
  - 279ks XMM-Newton + 50ks Chandra + archival data.
  - Limiting sensitivity: $L_X \geq 1.2 \times 10^{42}$ erg/s in $R < R_{500}$
    or $L_X \geq 3.9 \times 10^{41}$ erg/s in $R < 65$ kpc

- **Acquisition of data in optical, Hα, HΙ, CO has begun**
  - ~50% groups covered by SDSS, new Hα imaging for ~50% so far.
CLoGS: Goals

- Physical properties of the nearby group population:
  - What fraction of optically selected groups contain a hot IGM?
  - What is their range of mass, temperature, metal abundance, etc?
  - What fraction have cool cores? Roughly 50% of clusters are CC, but non-statistical samples of groups have up to 85% CCs (e.g. Dong et al 2010, based on Chandra archive).

- Central AGN as a group-scale feedback mechanism:
  - Do group-central AGN balance cooling? What is duty cycle, power?
  - How are central AGN affected by environment? Cool cores, entropy?

- Impact of group environment on member galaxies:
  - Is star formation rate affected by group environment?
  - What fraction of member galaxies host AGN? Radio, X-ray, optical?
**CLOGS: X-ray overview**

- Fraction of X-ray bright groups (extent >65 kpc) = 14/26 (~55%)
  - 7/26 have galaxy-scale emission, 5/26 only point sources

- 2/14 are group-group mergers, 2/14 “sloshing”
  ➔ dynamically active

- Typical kT ≈ 0.5-1.6 keV
  ➔ \( M_{500} \approx 8 \times 10^{12} – 6 \times 10^{13} M_\odot \)

- Fraction of Cool Cores = 65%
  - 9/14 have declining central kT
  - Compare to ~50% in clusters.
Group-central galaxies:
• 25/26 detected at 610 or 235 MHz
• 7 host jet sources
• 3 are diffuse, 15 unresolved

Non-central galaxies:
For 18 groups processed to date
• 75/170 galaxies detected (44%)
• 43/62 late-type (69%)
• 12/45 non-central early-type (27%)
• 17/63 dwarfs/irregulars (27%)

NGC 5350 ➔ AGN+SF disk
235 MHz contours at (0.9, 1.8, 3.6,... mJy/b)

ESO507-25:
Diffuse source
610 MHz contours at (0.4, 0.8, 1.6,... mJy/b)
Central AGN Jets

- **6/14 X-ray confirmed groups host jet source**
- Variety of Radio, X-ray morphologies
- Age: 1-100 Myr
- Enthalpy: $10^{55-59}$ erg

NGC 4261 / 3C270 (O’Sullivan et al. ’11 and next talk!)

GMRT contours on 0.5-2 keV X-ray

NGC 5044 (David et al. ‘09,’11)

NGC 5846 (Machacek et al. ‘12)

NGC 193 / 4C+03.01

The Metrewavelength Sky
Jet sources found only in CC as defined by declining central kT profile.
CCs with jets fall below 30 keV cm$^{-2}$ limit (Cavagnolo et al ’08) but so do some NCCs.
Cooling time at fixed scale radius also poor predictor of jet activity.
NGC 5903 – An H\textsc{i}-rich group with diffuse radio emission

- 3x10^9 M_☉ of HI in 100 kpc filament extending across NGC 5903 (Appleton et al. 1990)
- TGSS confirms ~7 Jy diffuse structure around NGC 5903, \(\alpha=1.5\pm0.08\)

(See Gopal-Krishna et al. 2012, Poster by Mhaskey et al.)
NGC 5903: collision shock?

- ~40 ks XMM, low-level flaring throughout
- Disturbed 0.7 keV IGM correlated with HI!
- Hot gas mass ≈ HI deficit \((3 \times 10^{10} \, M_\odot)\)

Similar to collision shock in Stephan’s Quintet?
- No clear high-velocity intruder galaxy...
- In SQ radio correlated with HI and X-ray. Here we only see a hint of this in NW ridge – age?

Plans:
New HI observations to get high-res. velocity maps.
Hα imaging proposed to trace moderate temperature gas.
CLoGS: An optically-selected, statistically complete sample of 53 groups within 80 Mpc, observed in radio and X-ray.

- **Full sample** completely observed at 610 and 235 MHz.
- **High-richness sample** of 26-groups complete in X-ray.
- 14/26 groups confirmed as gravitationally bound with X-ray bright IGM, typical $kT = 0.5-1.6$ keV.
- 6/14 have central jet sources, enthalpies = $10^{55}$-$10^{59}$ erg, source ages $\sim$1-100 Myr.
- Cool-core fraction $\sim$65%, only CC groups host jet sources.
- Sample contains interesting individual sources. NGC 5903 may be a second Stephan’s Quintet-like collision shock.