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

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CLoGS collaboration

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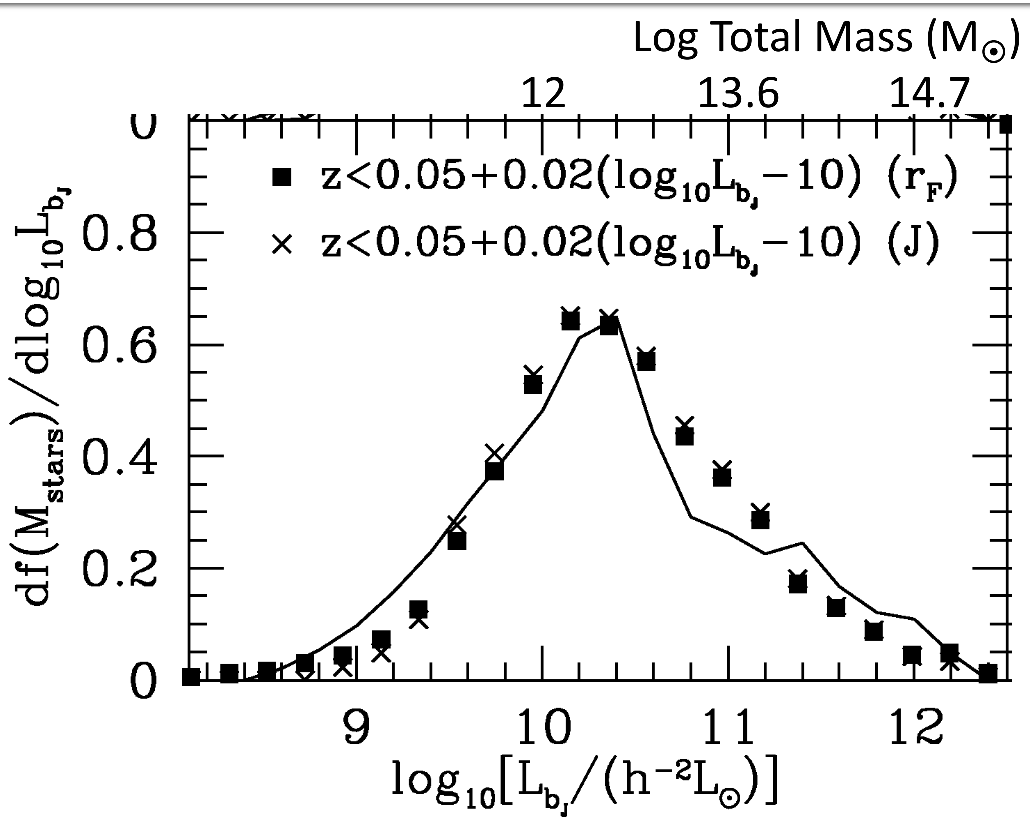
Why galaxy groups?
And why AGN feedback in groups?

- 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.



Eke et al. (2005)

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° – visible from GMRT and VLA.

Refine/expand membership, determine velocity dispersion σ.
Define Richness (R) = number of galaxies with $L_B \geq 1.6 \times 10^{10}\ L_\odot$
Exclude: groups with R≥10 – known clusters
groups with R=1 – too poor to estimate σ, f_{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, HI, 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?

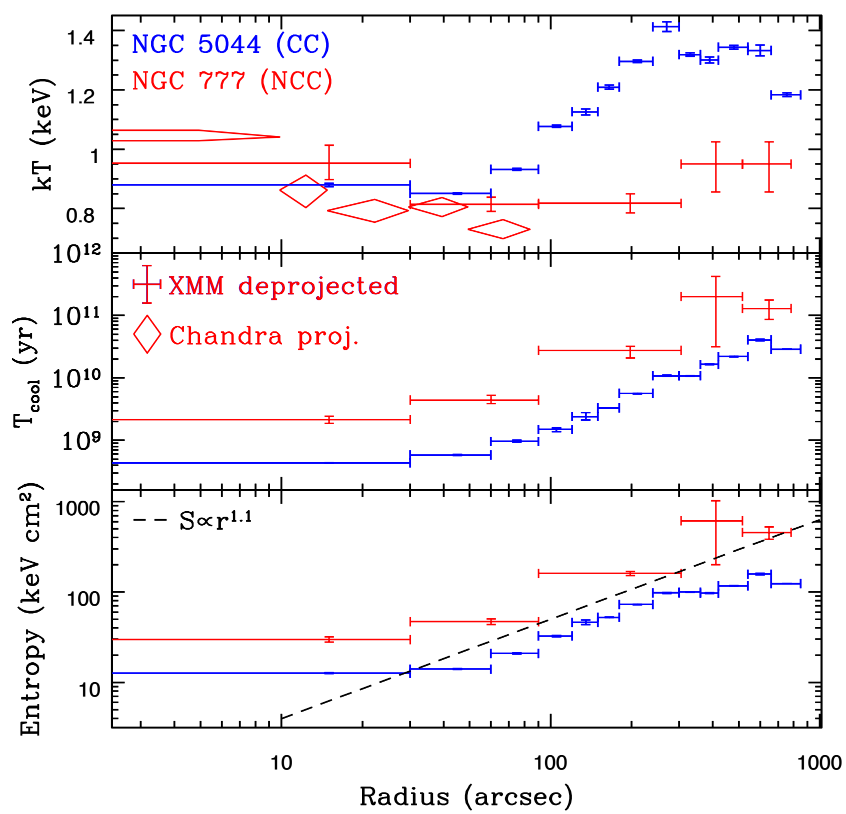
CLoGS: X-ray overview

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

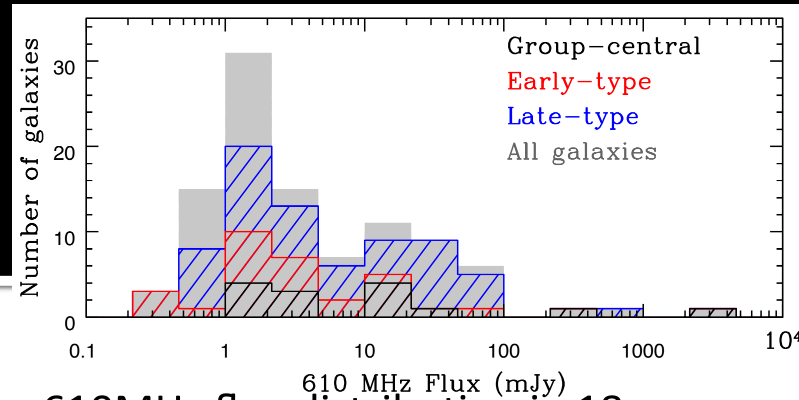
- 2/14 are group-group mergers, 2/14 "sloshing"
➔ dynamically active

- 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.



CLoGS: Radio overview



610MHz flux distribution in 18 groups

Group-central galaxies:

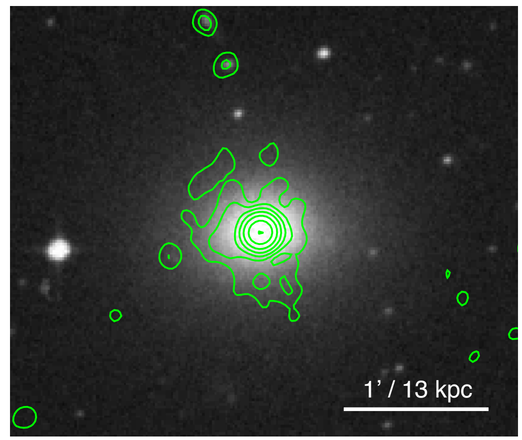
- 25/26 detected at 610 or 235 MHz
- 7 host jet sources
- 3 are diffuse, 15 unresolved

Non-central galaxies:

For 18 groups processed to date

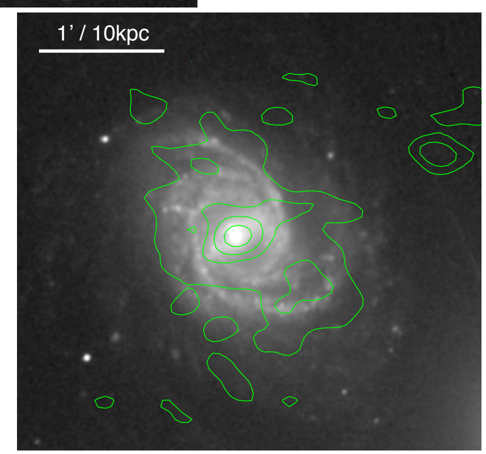
- 75/170 galaxies detected (44%)

- 43/62 late-type (69%)
- 12/45 non-central early-type (27%)
- 17/63 dwarfs/irregulars (27%)



← ESO507-25: Diffuse source 610 MHz contours at (0.4,0.8,1.6,… mJy/b)

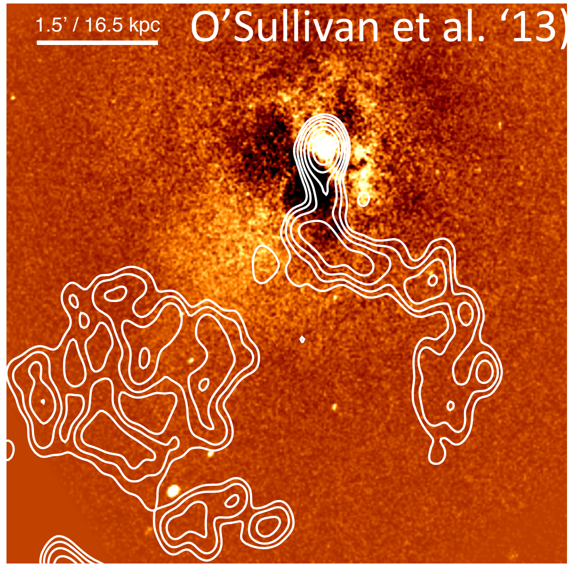
NGC 5350 → AGN+SF disk 235 MHz contours at (0.9,1.8,3.6,… mJy/b)



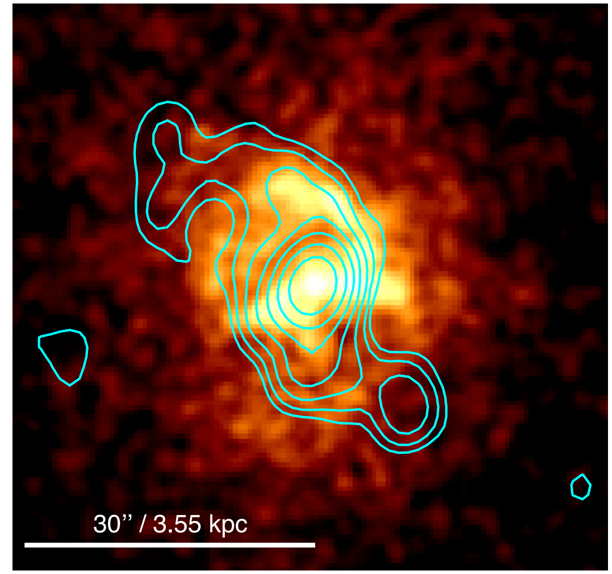
Central AGN Jets

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

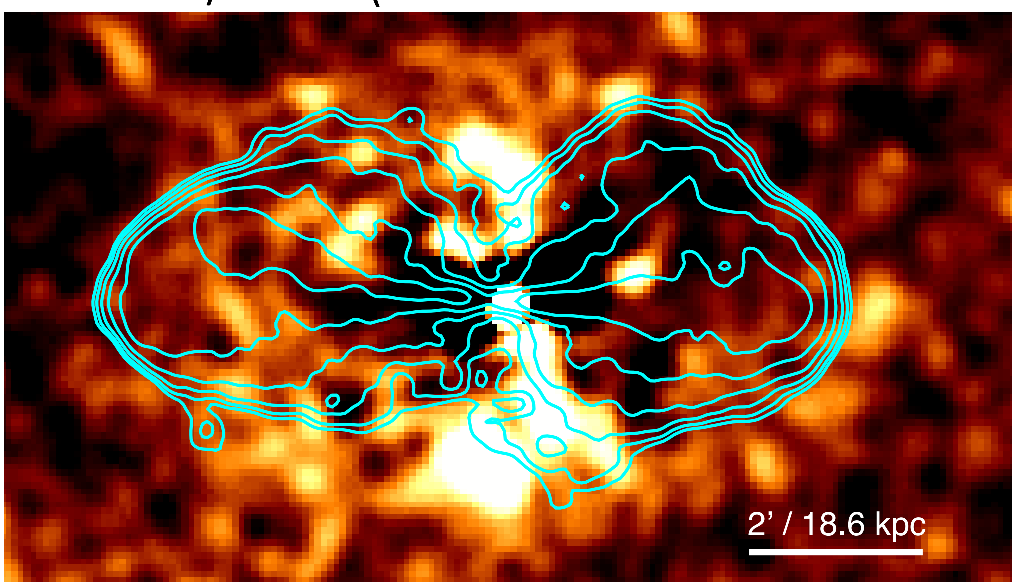
NGC 5044 (David et al. '09,'11



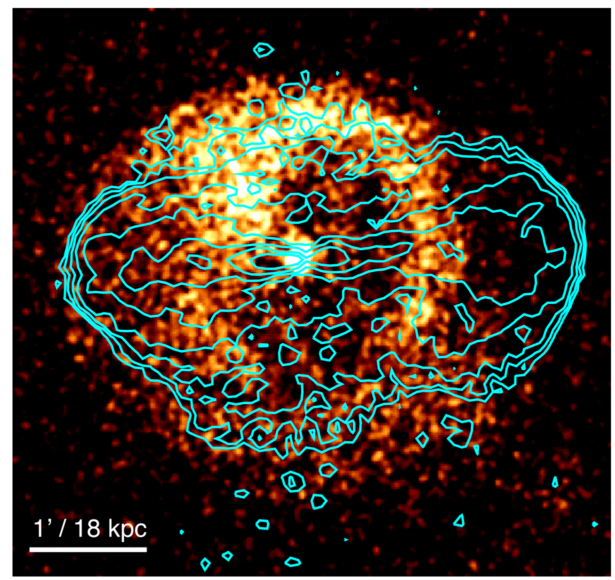
NGC 5846 (Machacek et al. '12)



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

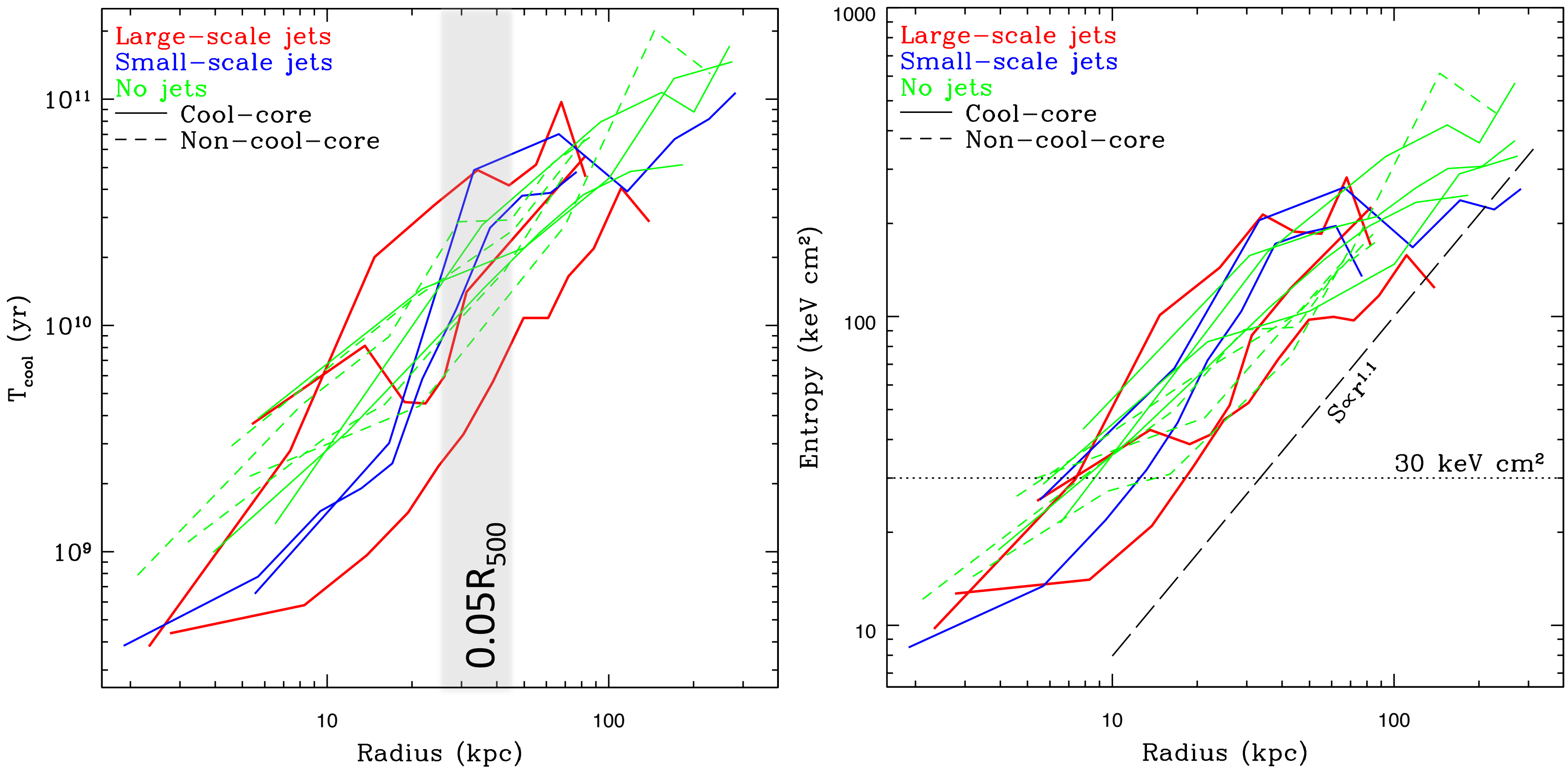


NGC 193 / 4C+03.01



GMRT contours on 0.5-2 keV X-ray

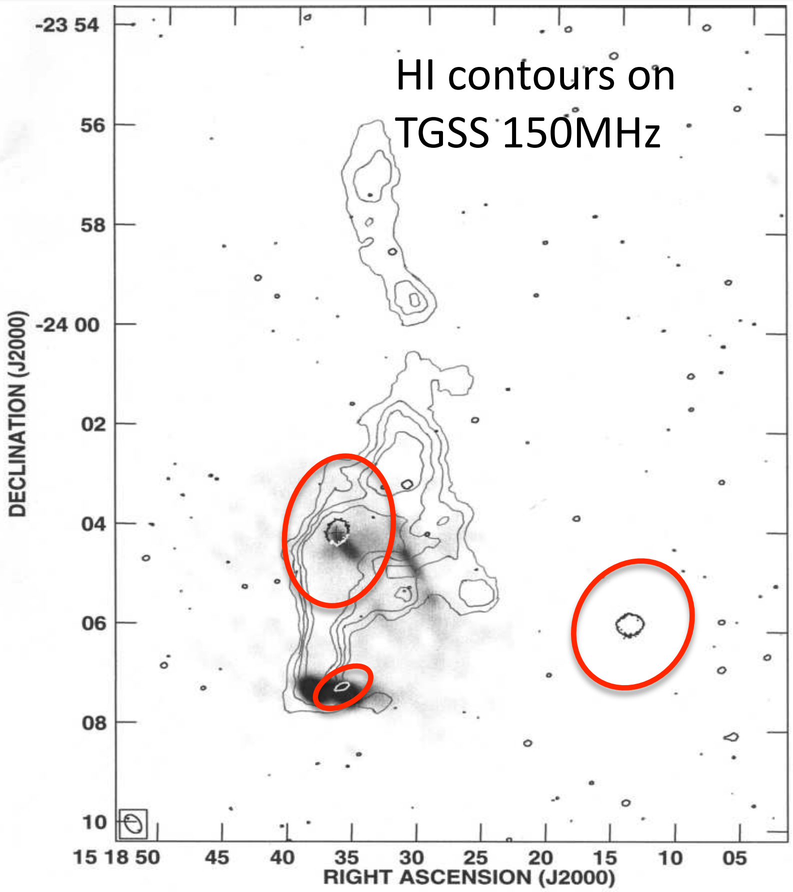
CLoGS: T_{cool} and Entropy vs AGN status

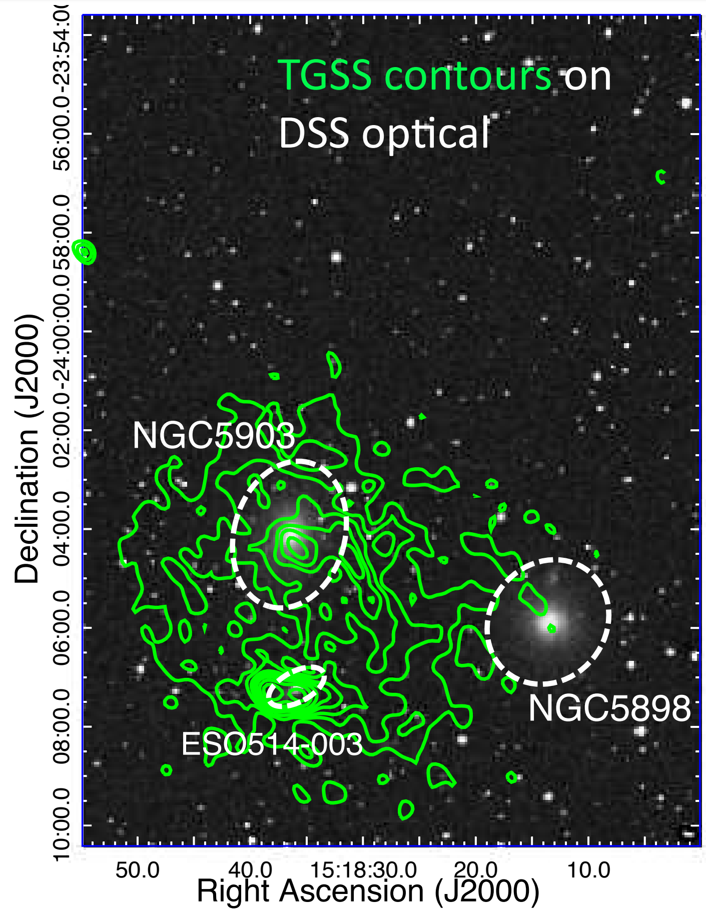


- Jet sources found only in CC as defined by declining central kT profile.
- CCs with jets fall below 30 keV cm^{-2} limit (Cavagnolo et al ’08) but so do some NCCs.
- Cooling time at fixed scale radius also poor predictor of jet activity.

NGC 5903 – An HI-rich group with diffuse radio emission

(See Gopal-Krishna et al. 2012, Poster by Mhaskey et al.)





- $3\times10^9\ M_\odot$ of HI in 100 kpc filament extending across NGC 5903 (Appleton et al. 1990)
- TGSS confirms ~7 Jy diffuse structure around NGC 5903, α=1.5±0.08

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?

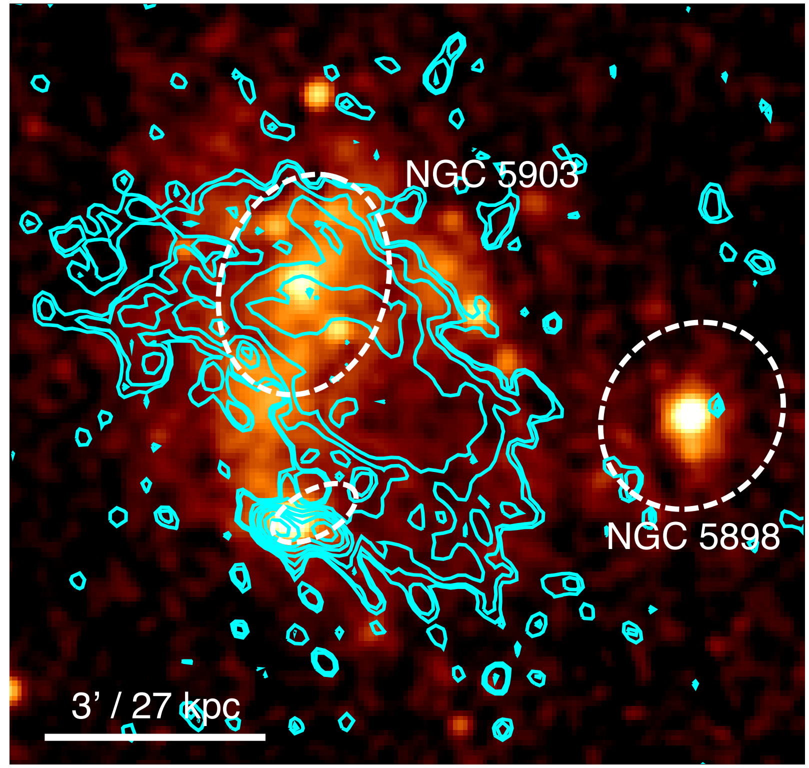
- No clear high-velocity intruder galaxy…
- In SQ radio correlated with HI and X-ray.

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.



XMM 0.3-2 keV   235 MHz contours

Summary

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 ~1-100 Myr.
- Cool-core fraction ~65%, only CC groups host jet sources.
- Sample contains interesting individual sources. NGC 5903 may be a second Stephan's Quintet-like collision shock.