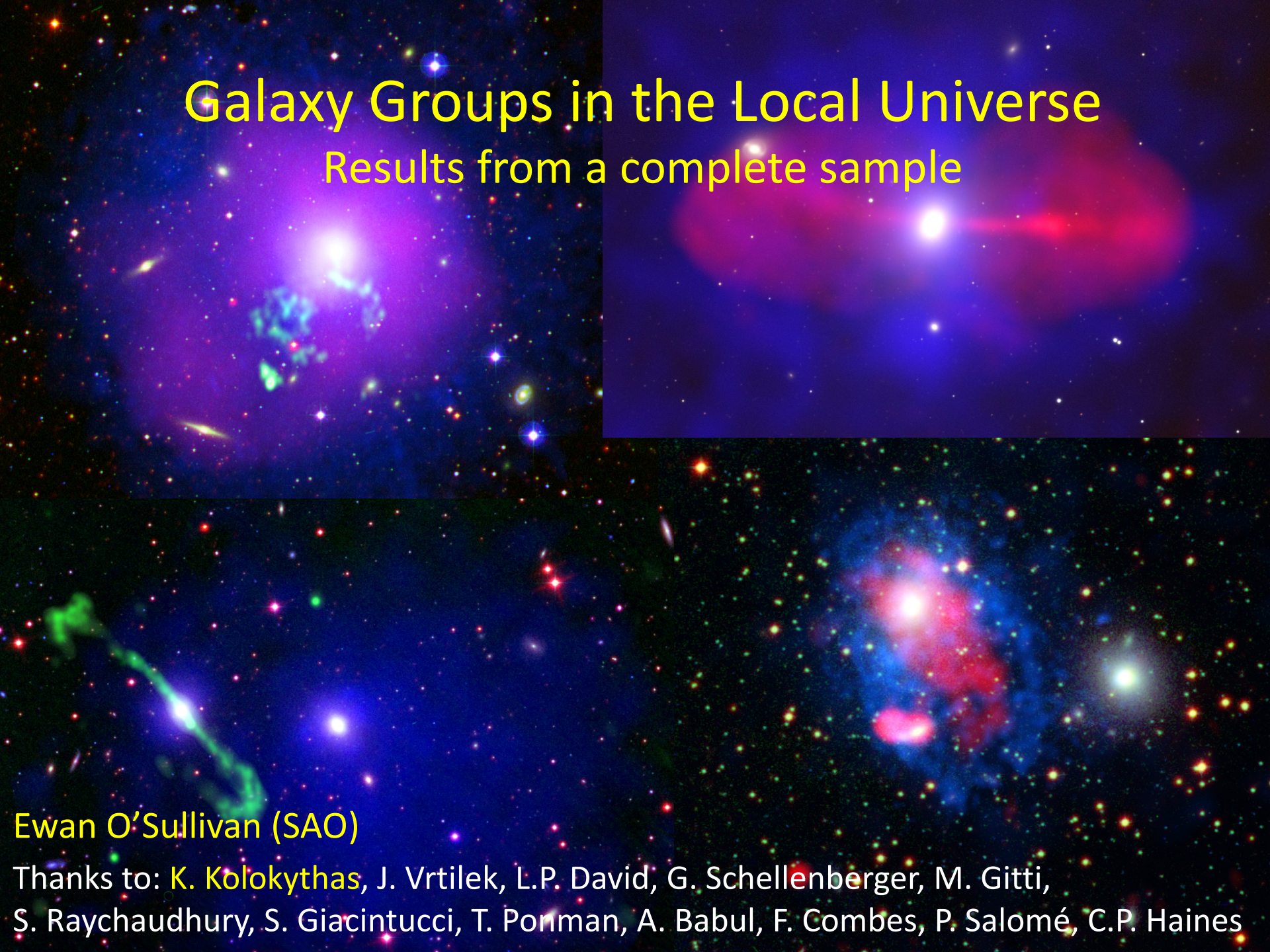


Galaxy Groups in the Local Universe

Results from a complete sample

Ewan O'Sullivan (SAO)

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 ⇒ 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.

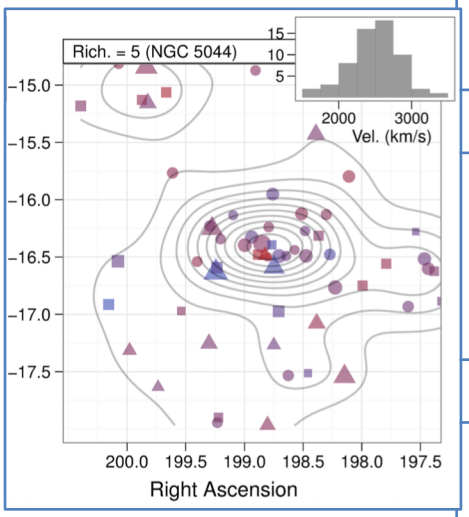
Sample selection

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

485 groups

Select from LGG list: systems with
- ≥4 members
- ≥1 early-type member with $L_B \geq 3\times10^{10} L_\odot$
- Declination >-30° (visible from GMRT and VLA)

67 groups



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

Filter on *richness* (*R* = N_{gal} with $L_B \geq 1.6\times10^{10} L_\odot$)
- Exclude known clusters: R≥10
- Exclude groups too small to characterize: R=1

53 groups

26 groups
High-richness subsample (R=4-8)

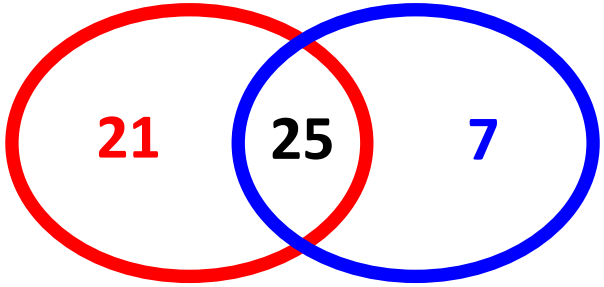
27 groups
Low-richness subsample (R=2-3)

See O'Sullivan et al. (2017)

Observational data

- **X-ray:** (O'Sullivan et al. 2017)
  - XMM-Newton and/or Chandra for all 53 groups

XMM:
27 new observations (~800ks)
19 archive observations



Chandra:
7 new observations (~360ks)
25 archive observations

  - Minimum sensitivity goal for new observations:

$L_X \geq 1.2\times10^{42}$ erg s^{-1} within R_{500}

$L_X \geq 3.9\times10^{41}$ erg s^{-1} within 65 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.

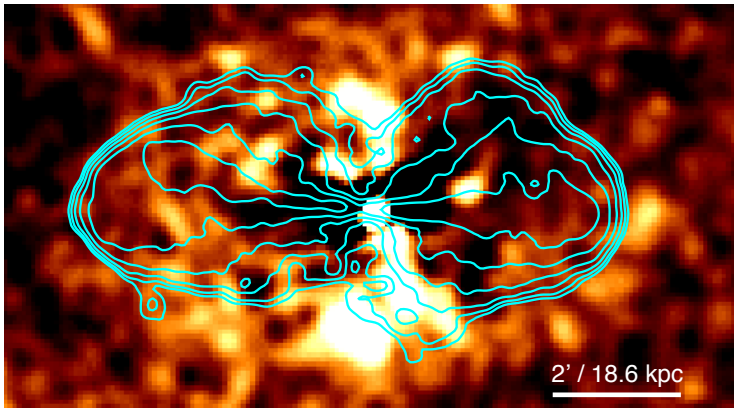
CLoGS: X-ray/Radio overview

X-ray properties:

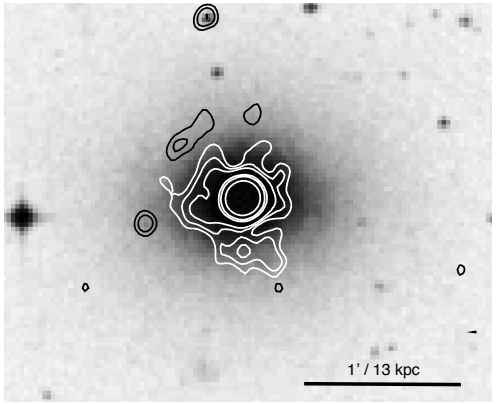
- 26/53 (~50%) have an X-ray bright IGM (extent >65 kpc, Lx>10^{41} erg/s)
  - ~1/3 dynamically active (sloshing/mergers)
  - Cool Core fraction = 65%
- 16/53 (~30%) have a galaxy-scale X-ray halo (extent < 65kpc, Lx=10^{40}-10^{41} erg/s)
- Mass range 0.5-5x10^{13} $M_\odot$

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

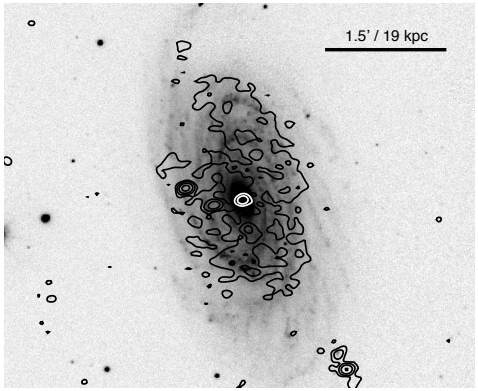


NGC 4261 (O'S 2011, Kolokythas 2015)



← 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)



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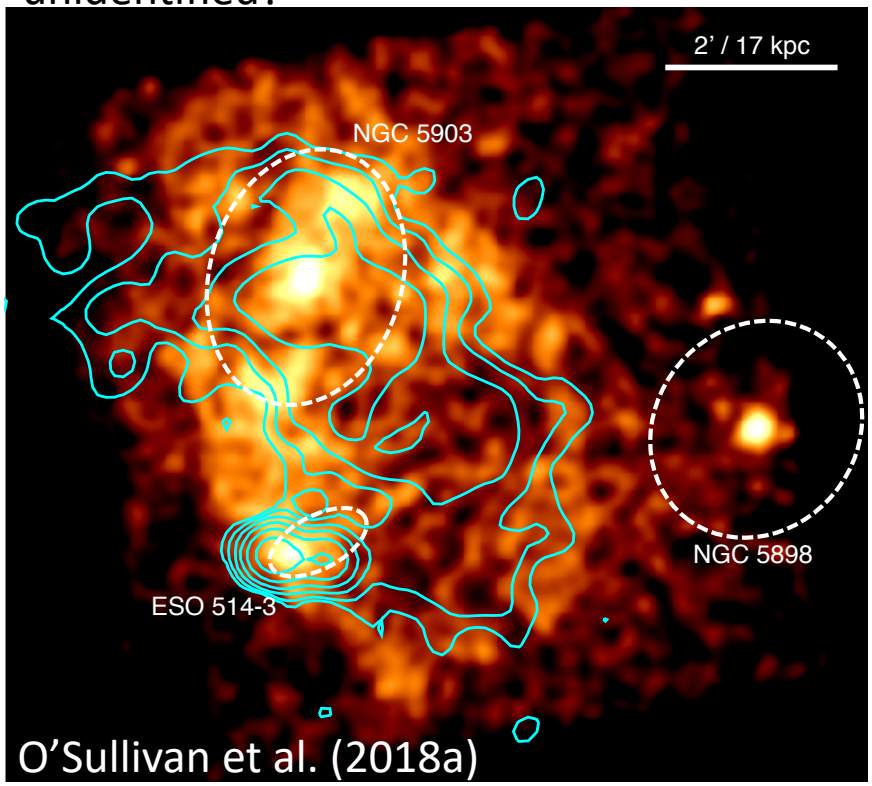
New groups

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

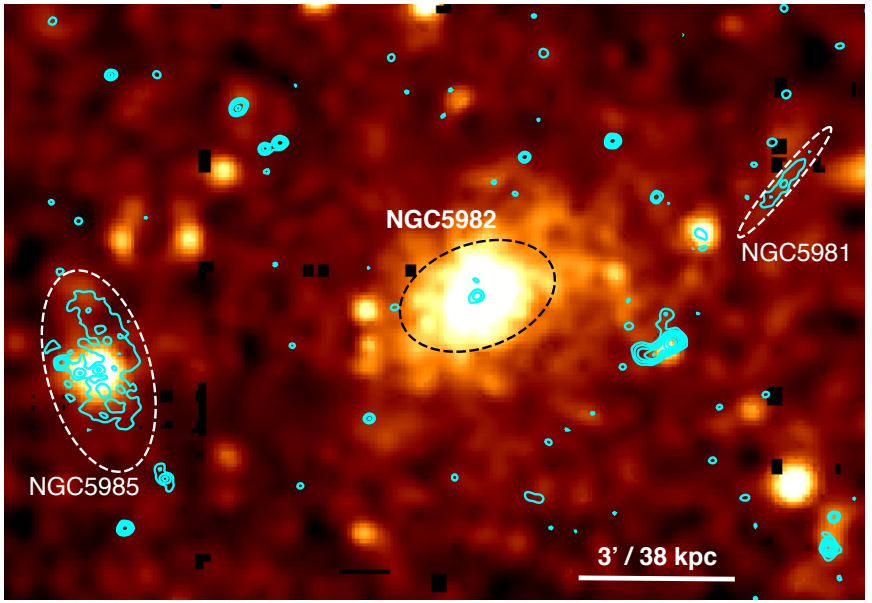
- Faint, non-cool core
- Mergers
- AGN disrupted

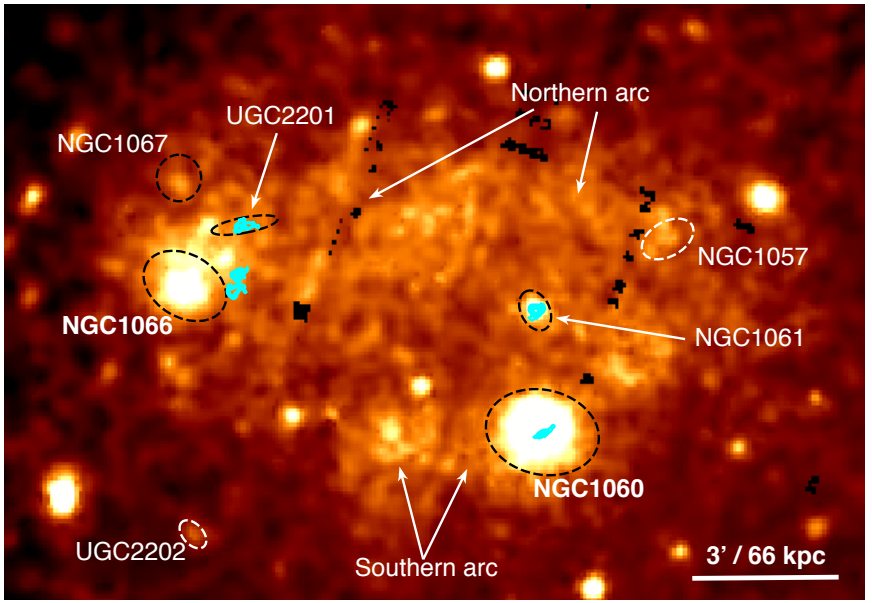
>30% of X-ray bright groups as yet unidentified?



O'Sullivan et al. (2018a)

0.5-2 keV X-ray 610 or 235 MHz radio





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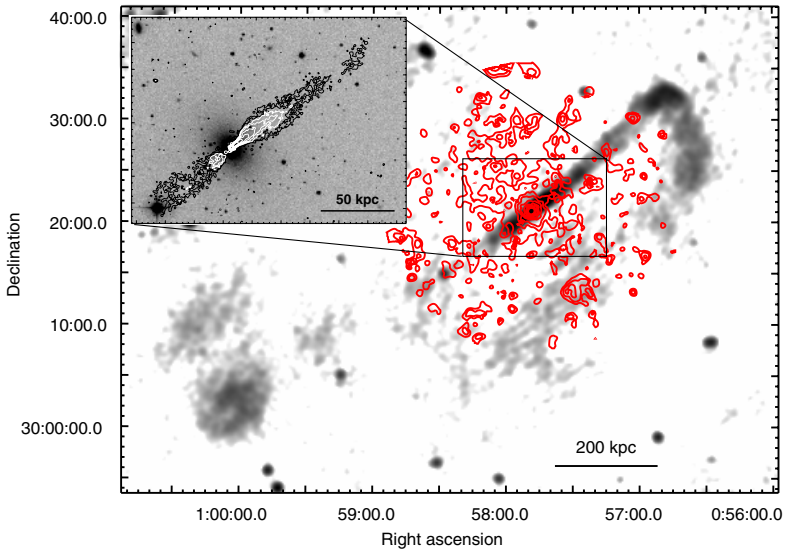
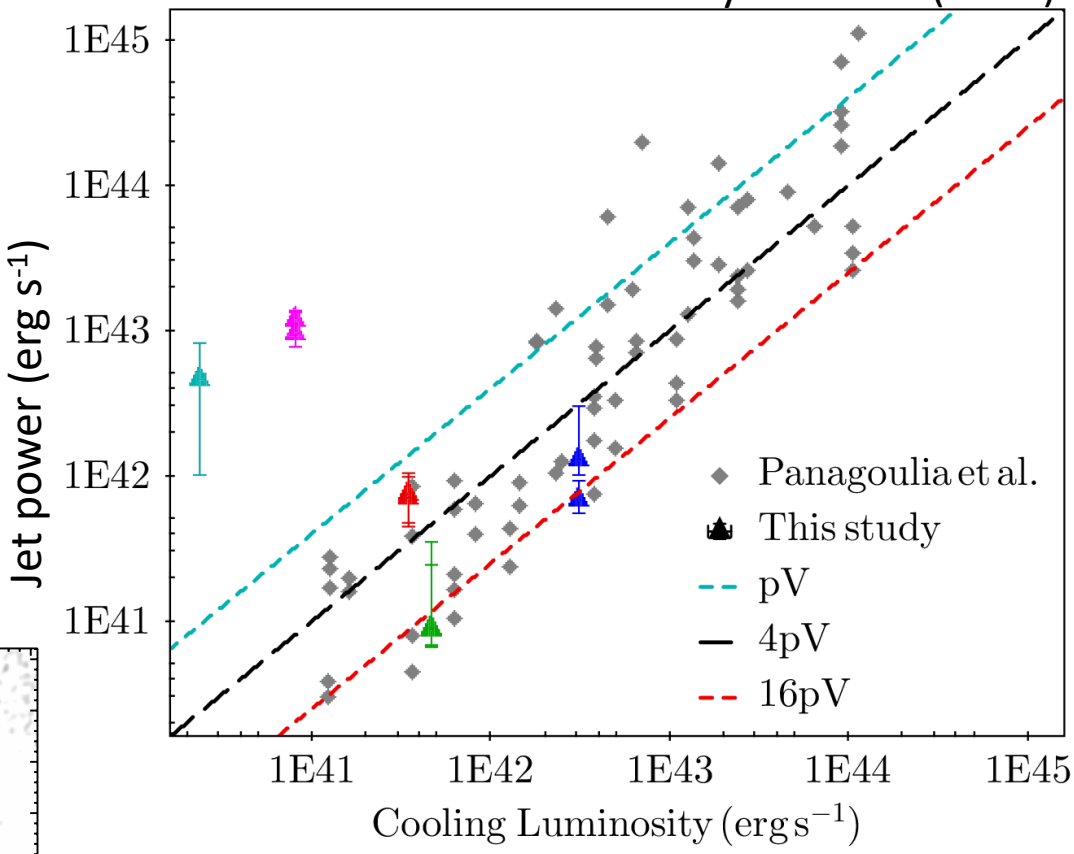
AGN Feedback: Jet Power

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



Kolokythas et al (2018)

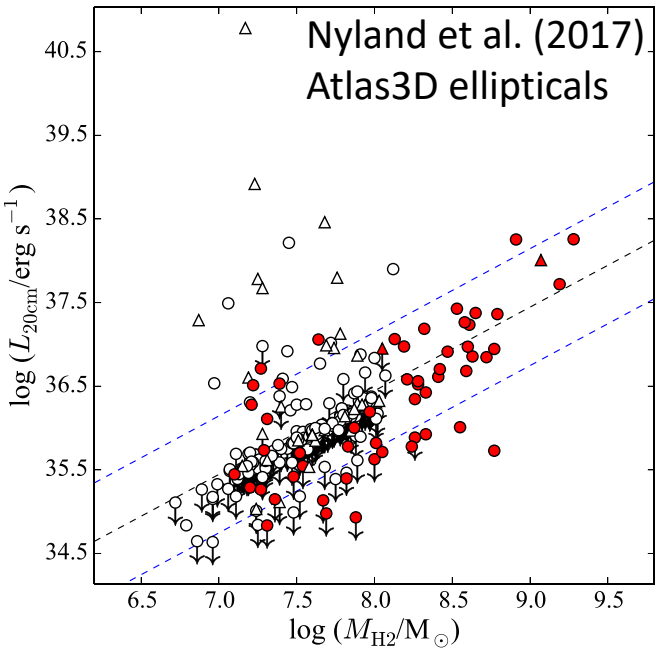


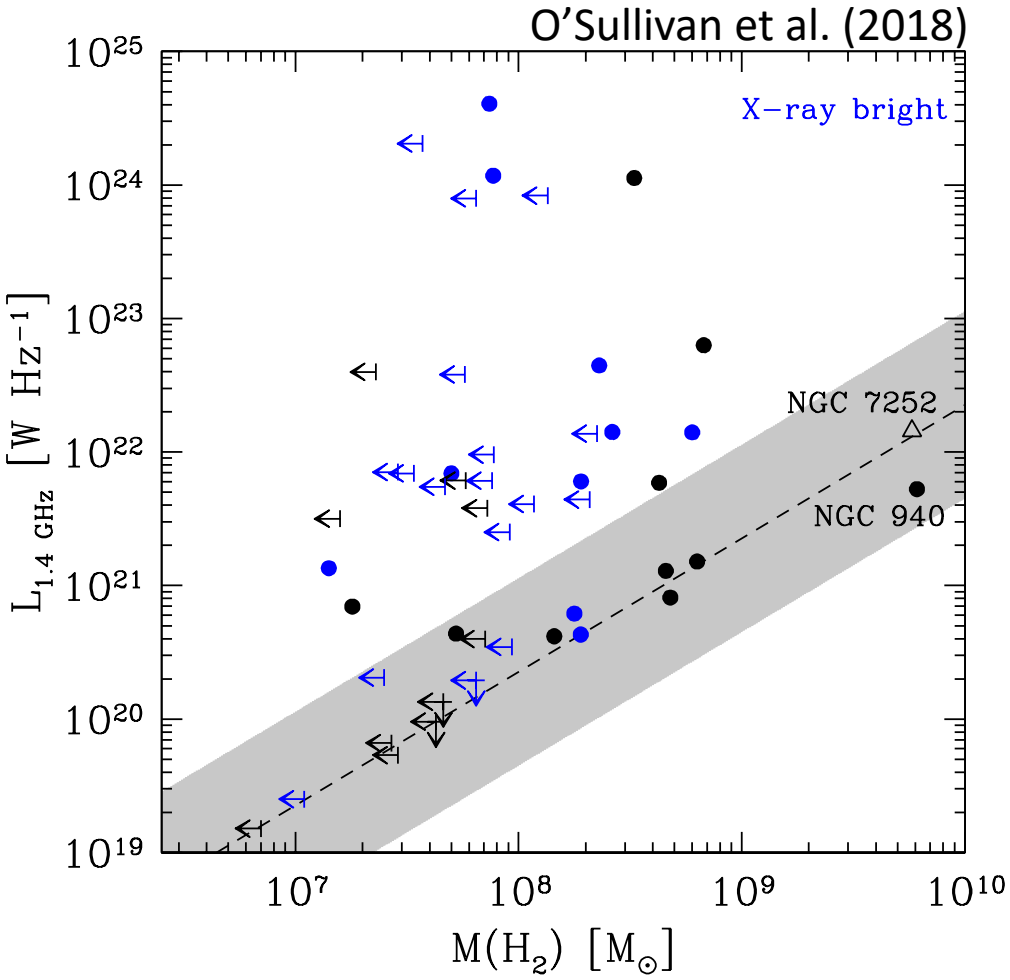
- In low-R sample, two jets depositing energy at radii >100kpc (see also Grossova et al. 2019)
  - How do such systems fit into AGN feedback models?

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.