A Combined X-ray/Low-Frequency Radio View of
AGN Feedback in Galaxy Groups

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With thanks to:

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The GMRT Groups project

• Galaxy groups contain >50% of galaxies in the Universe
➔ most common environment of AGN feedback.
• No useful statistical sample of nearby groups available!
• Our sample – 18 groups with Chandra/XMM X-ray data and GMRT low-frequency radio observations, covering a wide range of group and radio galaxy properties.

X-ray provides –
1) Location/properties of most baryons.
2) Estimation of energy in cavities, shocks, conduction & cooling rates.
3) Dynamical limits of age of structures.

Radio provides –
1) Timescales via Synchrotron aging.
2) Constraints on source geometry.
3) Direct view of AGN/gas interactions.

Why GMRT? - low-frequency

- Older structures easier to see at lower frequencies.
- Broader spectrum gives better estimate of total power.
- Break frequency allows age to be estimated.

GMRT sensitivity (for 2-3hr obs.):

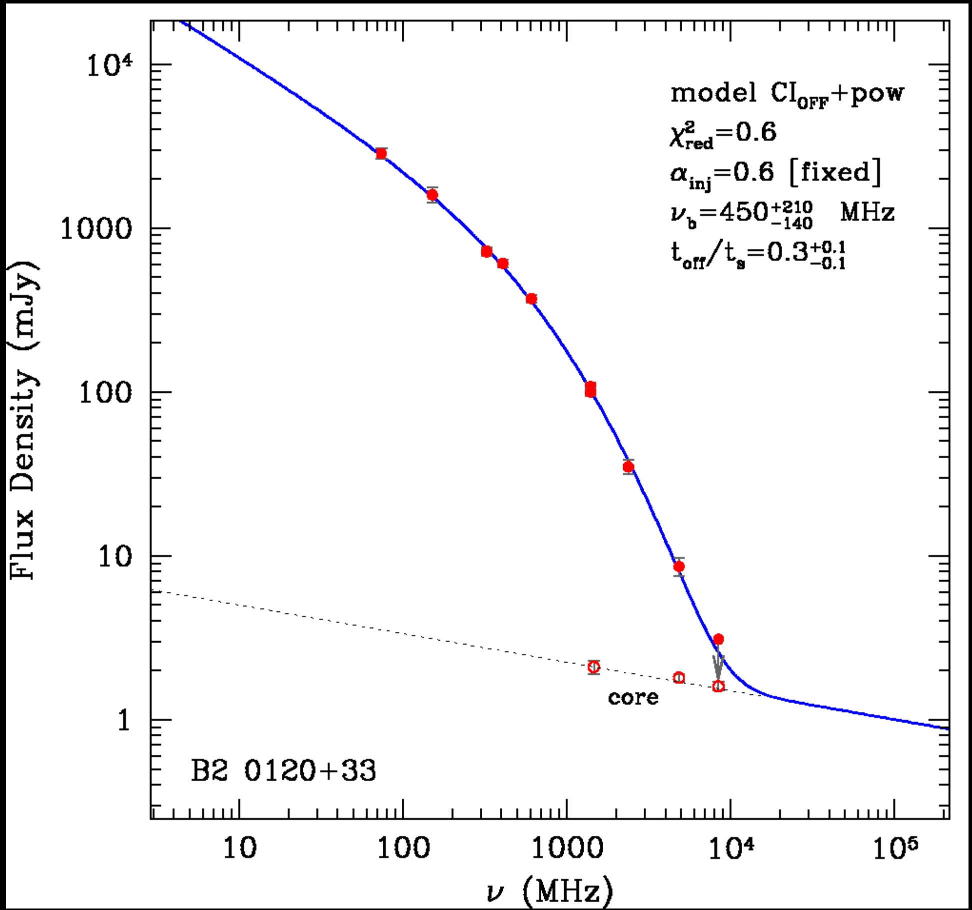
rms ≈ 50-100 μJy/b @ 610 MHz

rms ≈ 300-500 μJy/b @ 235 MHz

Resolution:

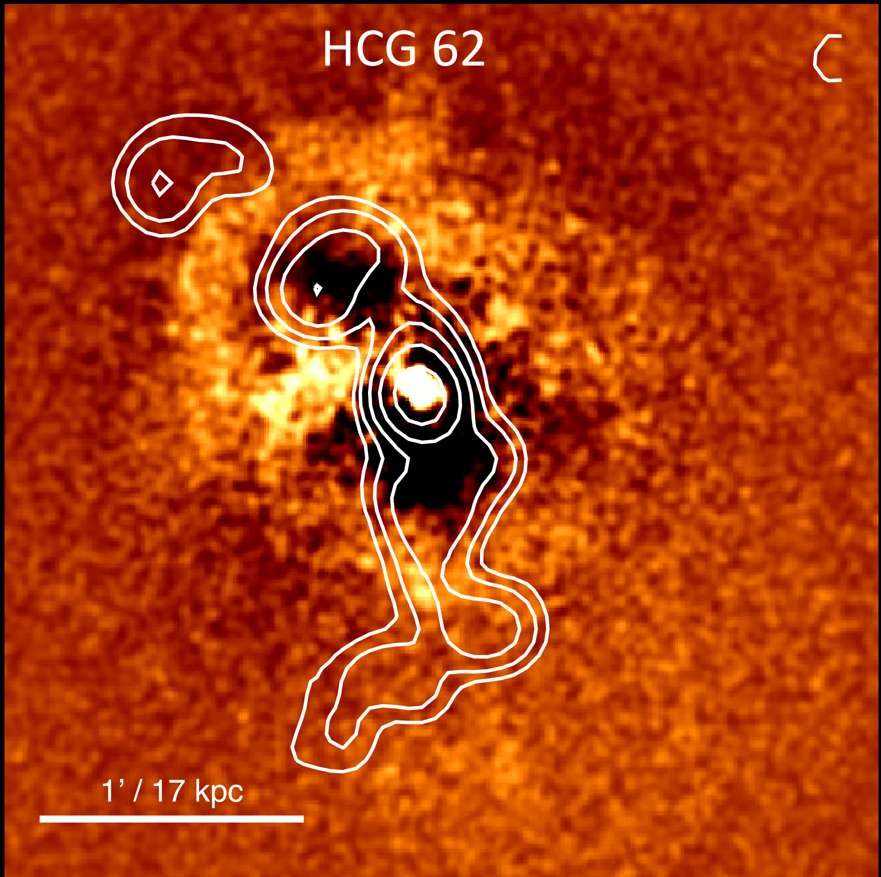
5” @ 610 MHz (HPBW)

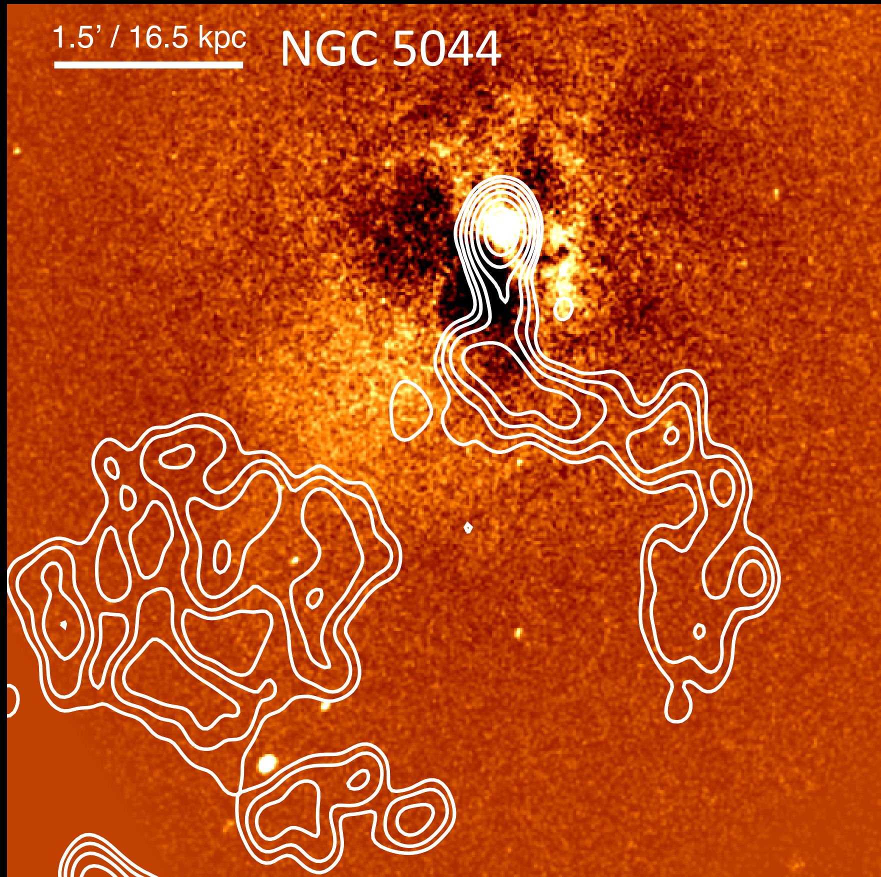
12” @ 235 MHz



NGC 507 (Murgia et al. in prep.)

Benefits of low-frequency radio data





Smoothed Chandra 0.3-2 keV residual images

1.4 GHz VLA contours / 235 MHz GMRT contours

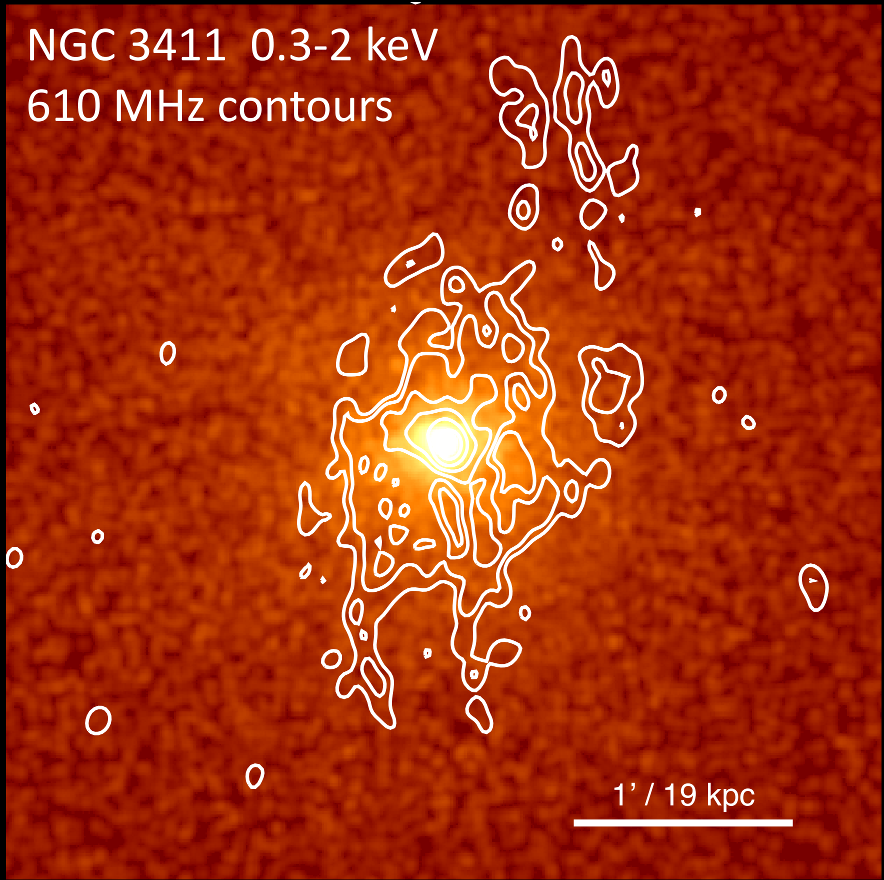
HCG62 cavities are paired, NGC5044 cavities isotropically distributed by gas motions.

GMRT Groups sample

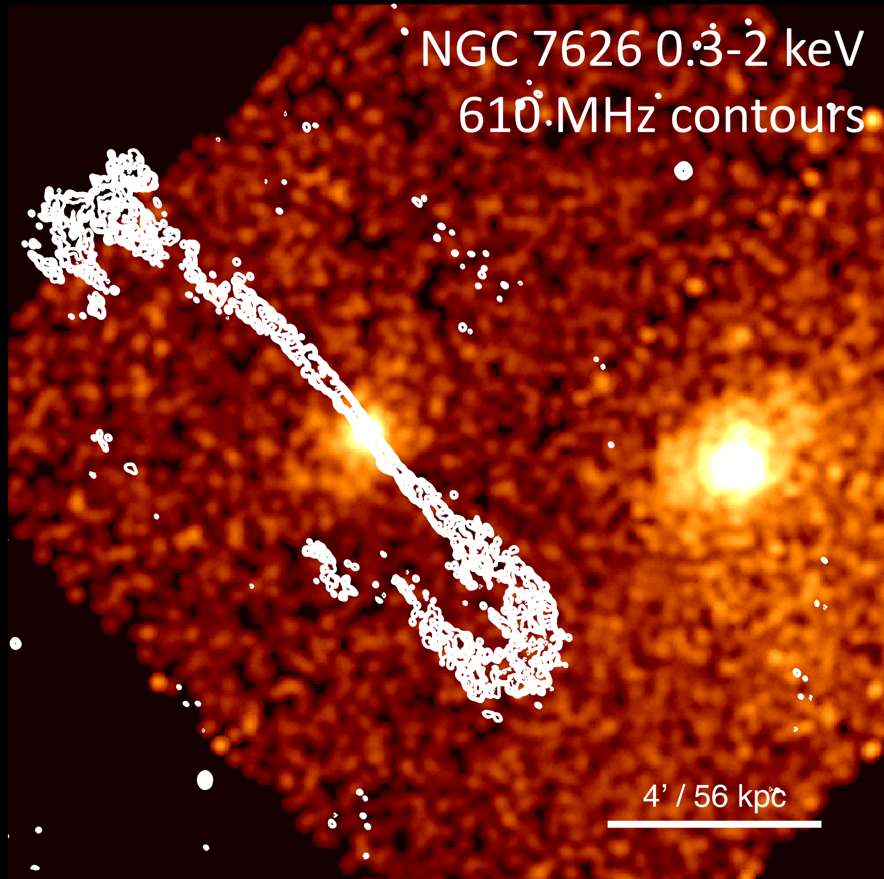
GROUP	z	Chandra	XMM	150 MHz	235 MHz	327 MHz	610MHz	Papers?
UGC 408	0.0147	✓		✓	✓		✓	CfA in prep…
NGC 315	0.0165	✓	✓		✓		✓	
NGC 383	0.0170	✓	✓		✓		✓	
NGC 507	0.0165	✓	✓		✓		✓	
NGC 741	0.0185	✓	✓		✓		✓	Jetha 08 +…
HCG 15	0.0208		✓		✓	✓	✓	
NGC 1407	0.0059	✓	✓		✓	✓	✓	
NGC 1587	0.0123	✓			✓		✓	
MKW 2	0.0368		✓		✓		✓	
NGC 3411	0.0153	✓	✓		✓		✓	O'S 07
NGC 4636	0.0031	✓	✓		✓		✓	O'S 05 + Baldi 09
HCG 62	0.0137	✓	✓		✓	✓	✓	Gitti 10
NGC 5044	0.0090	✓	✓	✓	✓	✓	✓	David 09 +…
NGC 5813	0.0066	✓	✓	✓	✓			Randall 10
NGC 5846	0.0057	✓	✓				✓	
AWM4	0.0318	✓	✓		✓	✓	✓	SG 08+2xO'S 10
NGC 6269	0.0348	✓			✓		✓	Baldi 09
NGC 7626	0.0114	✓	✓	✓	✓		✓	Randall 09

Small clear cavities   Giant or poorly confined   Amorphous/Core-halo

Core-halo and poorly-confined sources

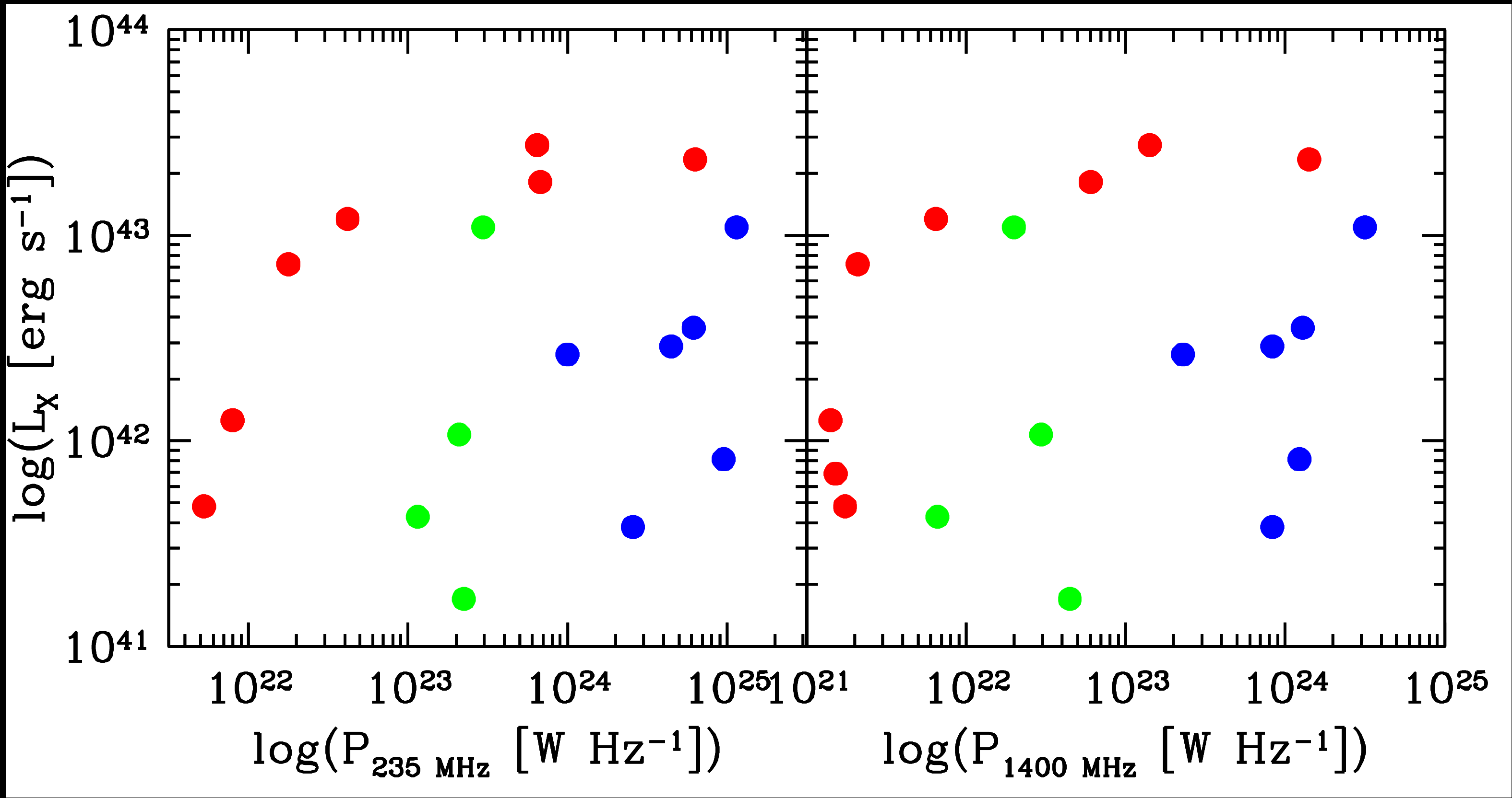


No clear jets/lobes/cavities/shocks
Hot core ➔ 2×10^{57} erg heating
(O'Sullivan et al. 2007)



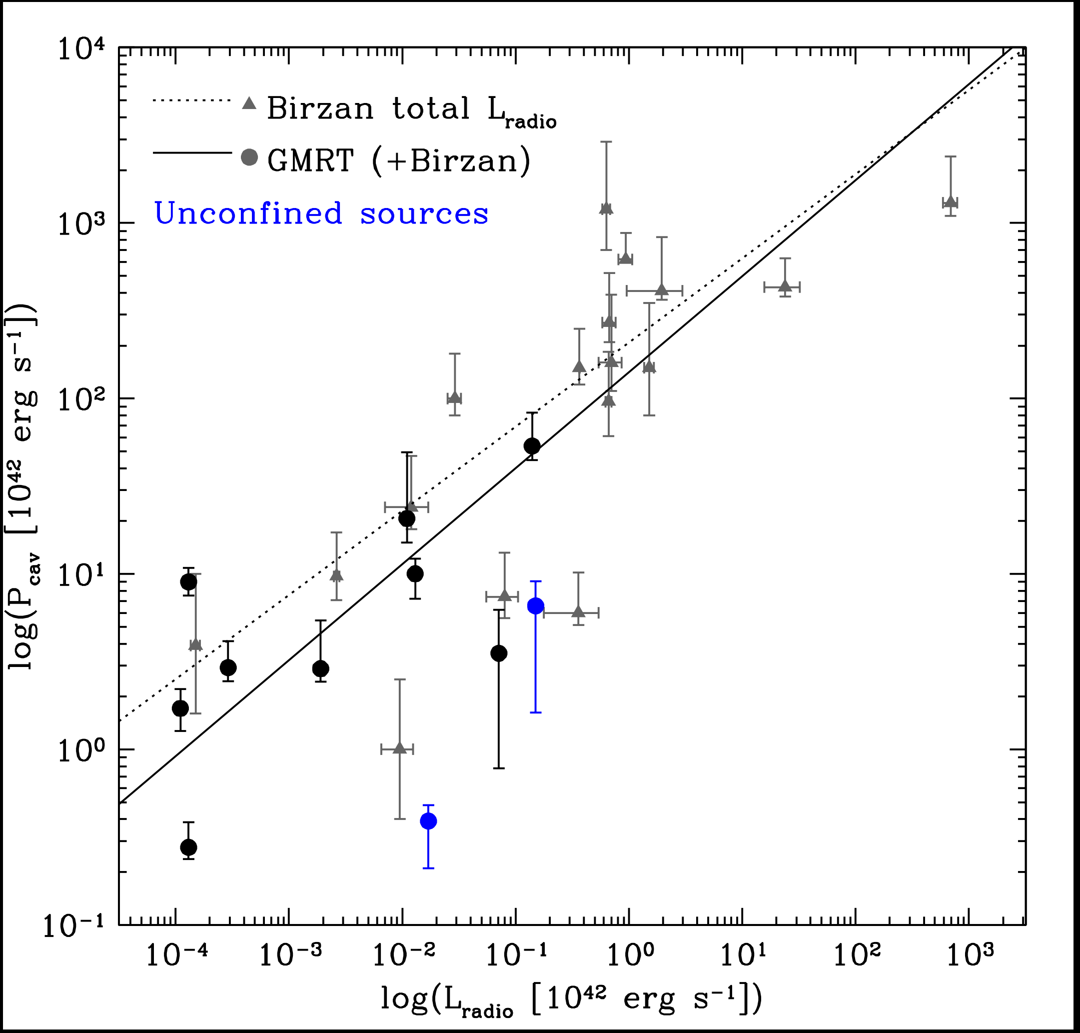
Large double source in merging group
T map suggests cavity (Randall et al '08)
Difficult to assess mass, temperature

Classifying the radio sources



- Red = small, well-confined, identifiable cavities.
- Blue = Giant sources extending beyond group, or very over-pressured
- Green = Amorphous/Core-halo sources, may still affect environment

Cavity power vs radio power – 10MHz-10GHz



Work in progress!

Uses 610-235MHz spectral index, not model fit.

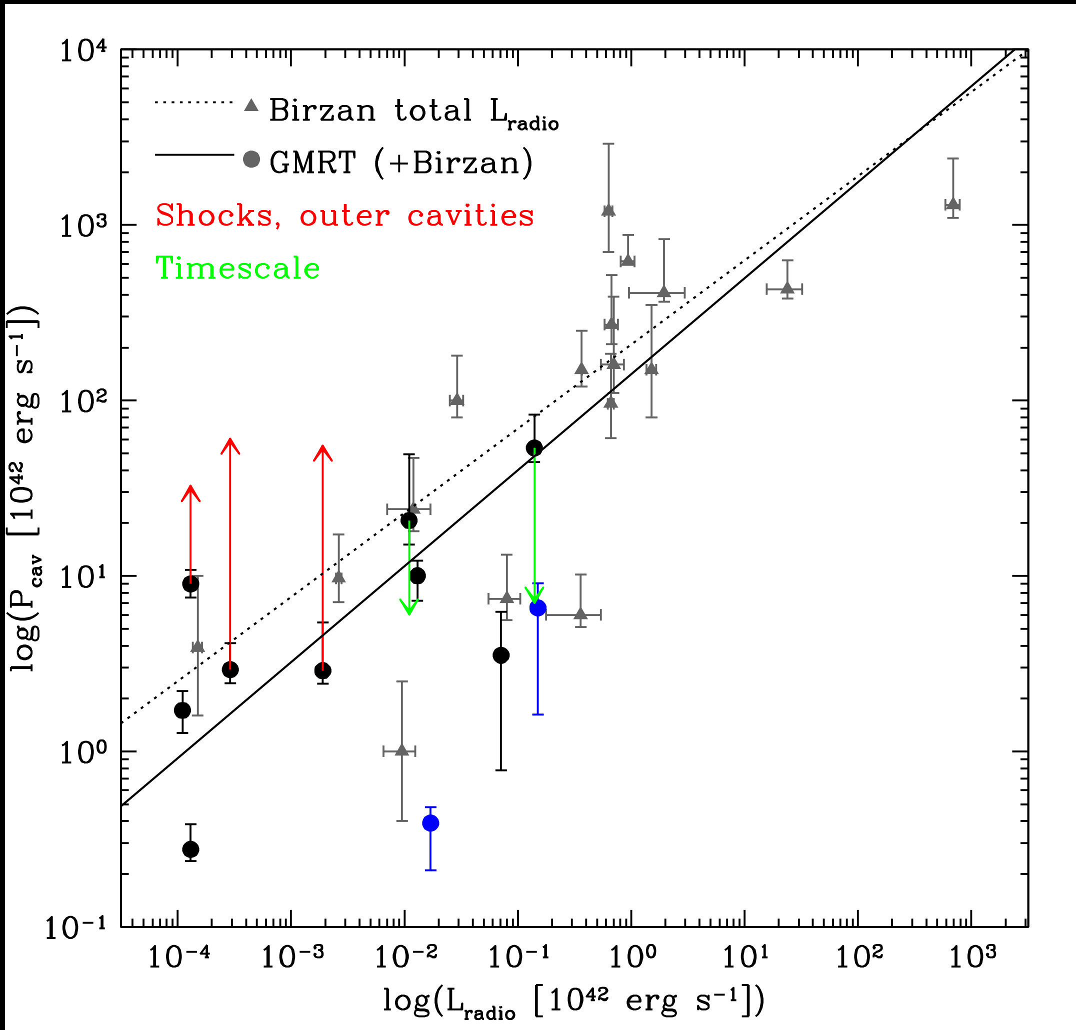
Integrated L_{radio} for source, not lobe luminosity.

BCES best fit:

Log P_{cav}=(0.55±0.08) Log L_{radio} +(2.15±0.15)

Similar to Birzan 0.59±0.08

Cavity power vs radio power - Caveats



Uncertainties on true power output very large

- Shocks add factor of:
  - ~3 in HCG 62
  - ~10 in NGC 5813
- Outer cavity adds factor
  - ~10 in NGC 5044
- Age > buoyancy time subtracts factor of:
  - ~6 in AWM4
  - ~2 in NGC507

Summary

- We are studying AGN feedback in a sample of 18 groups.
- Our combined X-ray / low-frequency radio dataset is a particularly powerful tool for this study.
  - Low-frequency data significantly improves our ability to detect old/faint radio structures (vs VLA 1.4 GHz).
  - Multi-frequency coverage allows radiative age estimates as well as dynamical estimates from X-ray.
- Cavity power vs radio power estimates coming soon!
  - Only a subset of systems form cavities.
  - Energy in cavities may be < energy in shocks.
  - Buoyancy timescale not always representative of true age.
- We have a lot more planned for this dataset!