Accretion modes, environments and fuelling of radio-loud AGN

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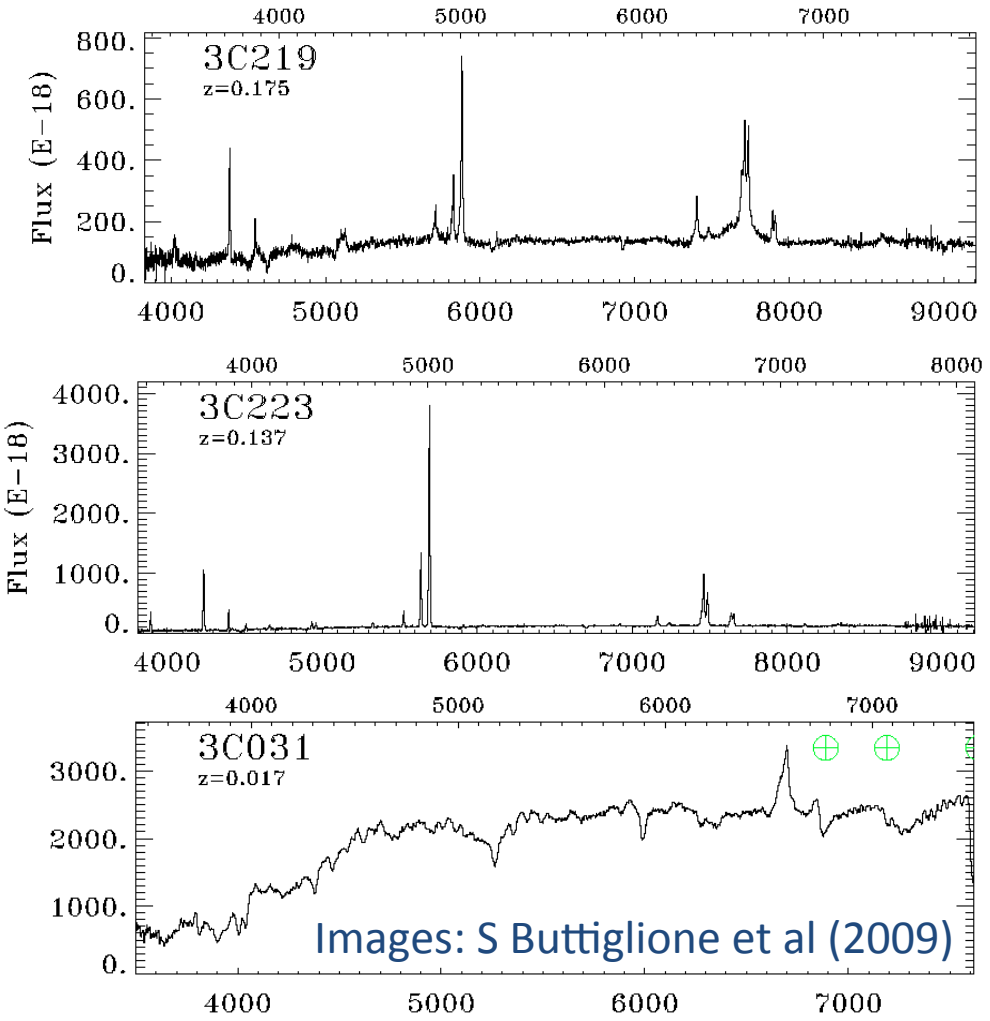
Spectral classes

Broad line RG

Narrow line RG

Low excitation RG



Images: S Buttiglione et al (2009)

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The HERG/LERG dichotomy

- Accretion rate
  - LERGs ≤ 1% Eddington rate
  - HERGs ≥ 1% Eddington rate

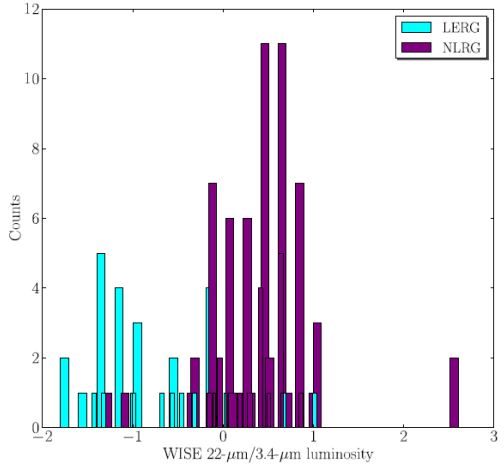
  (Best & Heckman 2012, Son et al. 2012, Mingo et al. 2014, Gürkan et al. 2014)
- Host galaxy mass
  - LERGs higher mass than HERGs

  (Tasse et al. 2008, Smolčić 2009, Best & Heckman 2012)
- Host galaxy colour
  - LERGs redder than HERGs

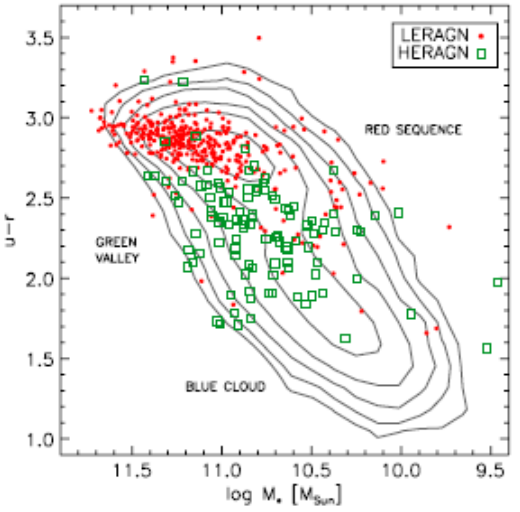
  (Smolčić 2009, Janssen et al. 2012, Herbert et al. 2010)
- Star formation rate
  - HERGs have on-going star formation

  (Hardcastle et al. 2013)
- Polarisation
  - LERGs have a wider range of integrated degrees of polarisation than HERGs

  (O'Sullivan et al. 2015)



Gürkan et al. (2014)



Smolčić (2009)

Dietary requirements

- HERGs
  - Radiatively efficient accretion
  - Standard model
  - Reservoirs of cold gas maintaining efficient accretion
  - Disturbed environments suggesting interactions important for triggering and fuelling

  (eg Hopkins et al. 2008, Ramos Almeida et al. 2012, Tadhunter et al. 2014)
- LERGs
  - Radiatively inefficient accretion
  - Bondi accretion of hot gas?

  (eg Allen et al. 2006, Hardcastle et al 2007
  - Cooling gas from ICM?
  - Matter driven out from nucleus by jets and falls back in from ICM
  - Stable cycle controlled by central entropy

  (eg Pizzolato & Soker 2005, Gaspari et al 2012, Voit & Donahue 2015)

Moving further out ...

- Radio jets/lobes affect the large-scale environment
  - AGN radio jets affect the galaxy cluster environment (eg McNamara & Nulsen. 2007)
  - Radio jet heating suppresses star formation (eg Croton et al. 2006)
  - Radio jets affect galaxy formation and development
- How does the cluster environment affect the radio properties?
- Do different types of radio galaxy occupy different cluster environments?
- Does the cluster environment change with epoch?

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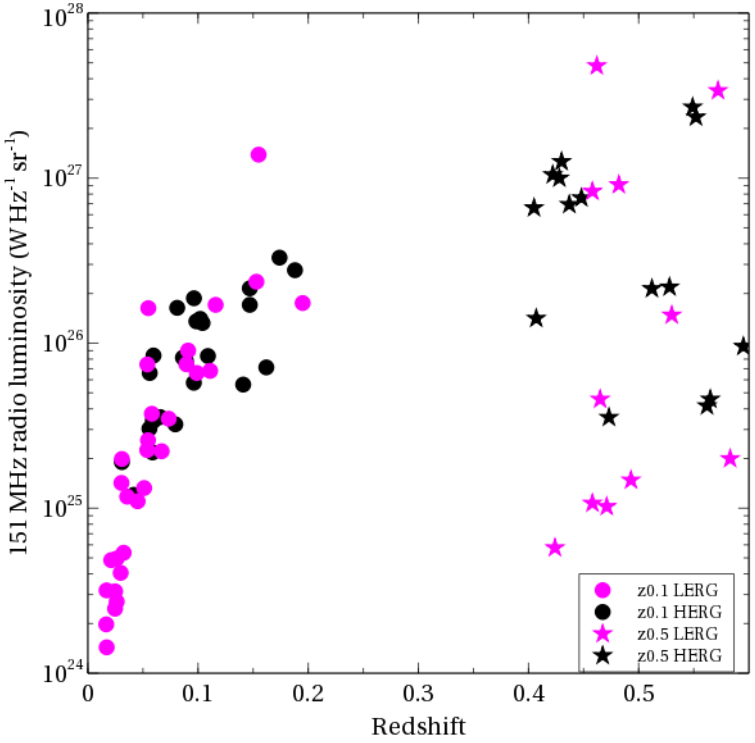
Samples

Radio luminosity vs redshift

- Flux-limited samples at z~0.1 and z~0.5
- Note lack of local high luminosity sources
  - Automatic redshift dependence



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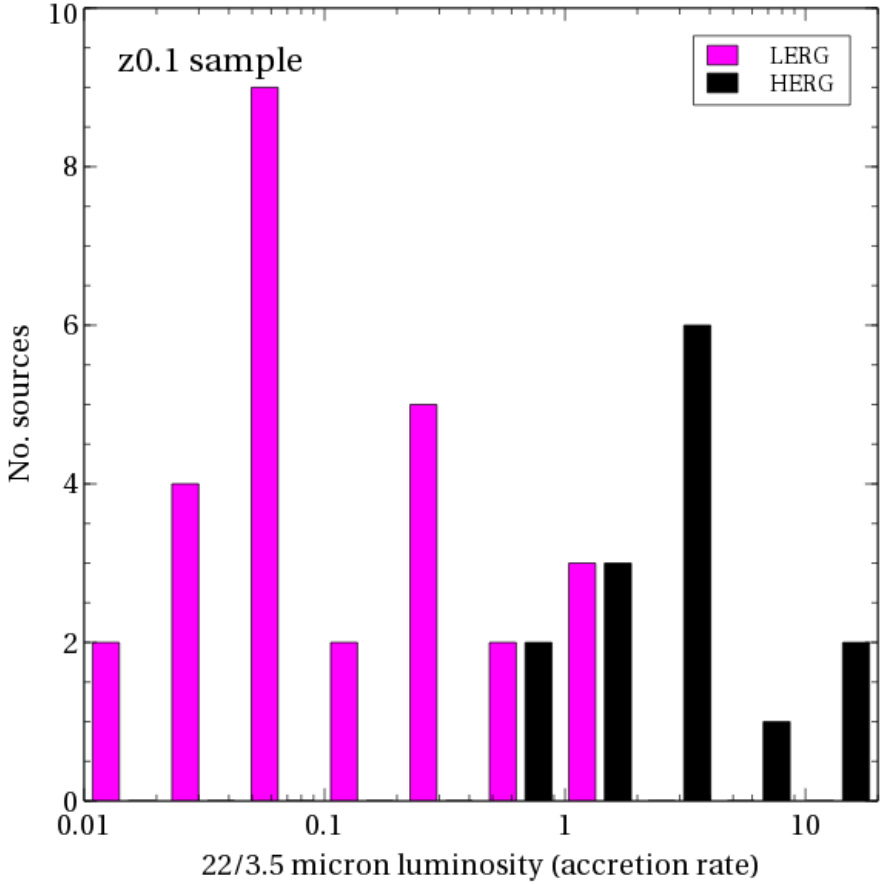
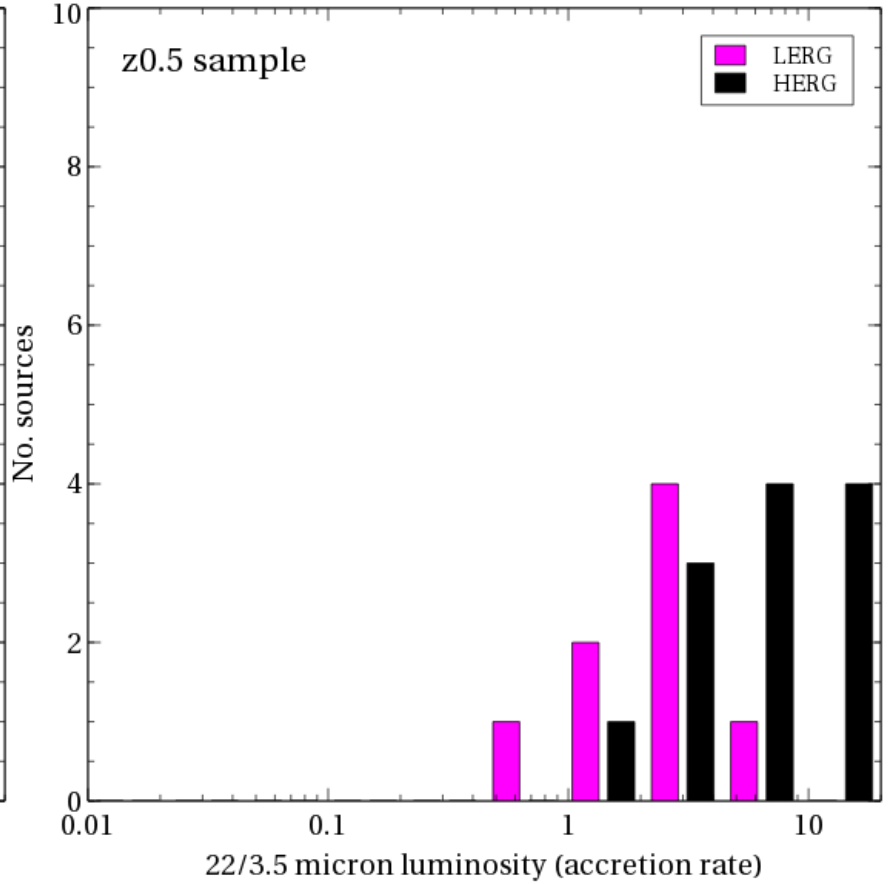
Sample accretion rates





IR data: Gürkan et al (2014)

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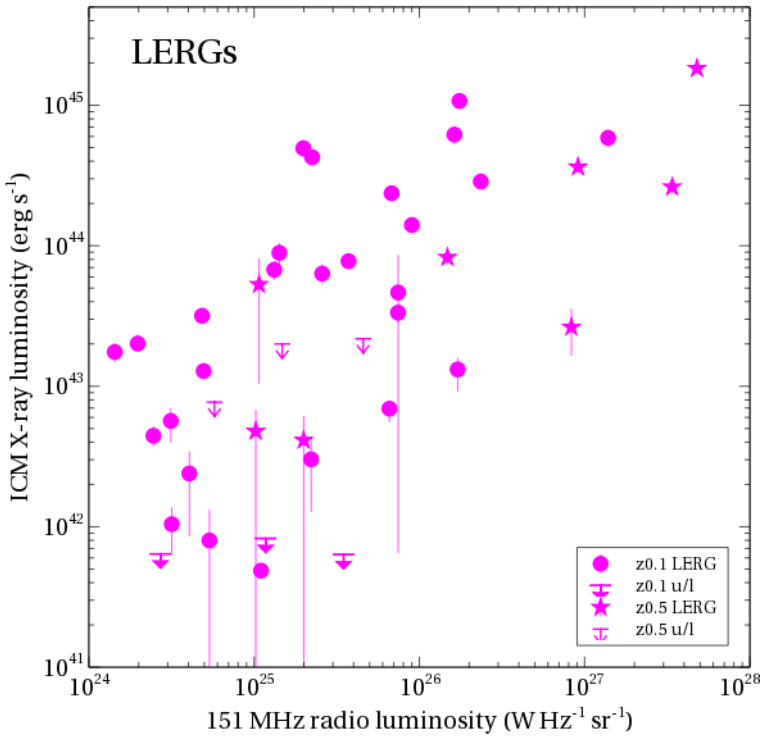
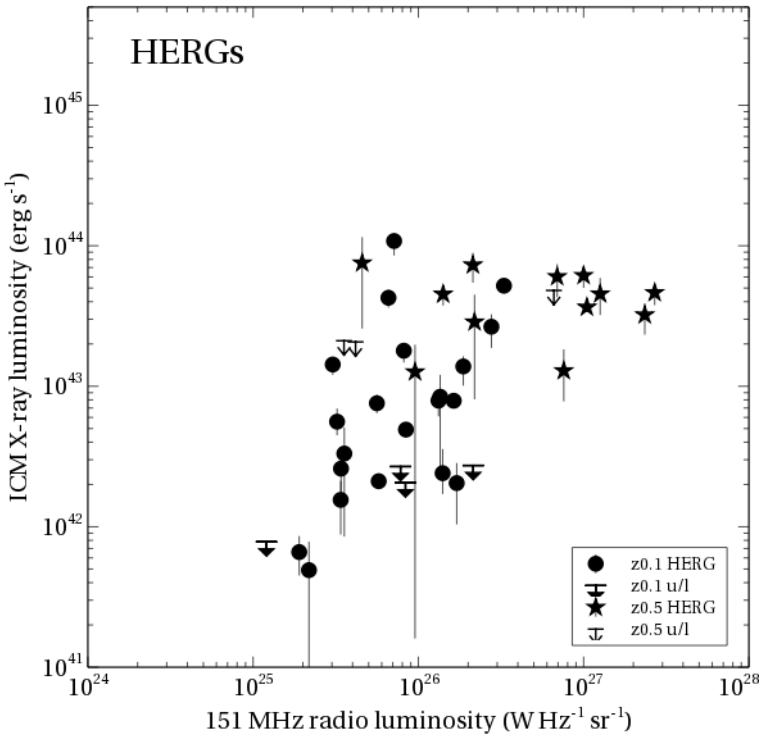
Radio luminosity vs Environment richness

- Correlation for LERGs …
  - z0.1 and z0.5 samples follow the same line …

… but not for HERGs

… z0.1 and z0.5 samples occupy different regions





Ineson et al (2015)

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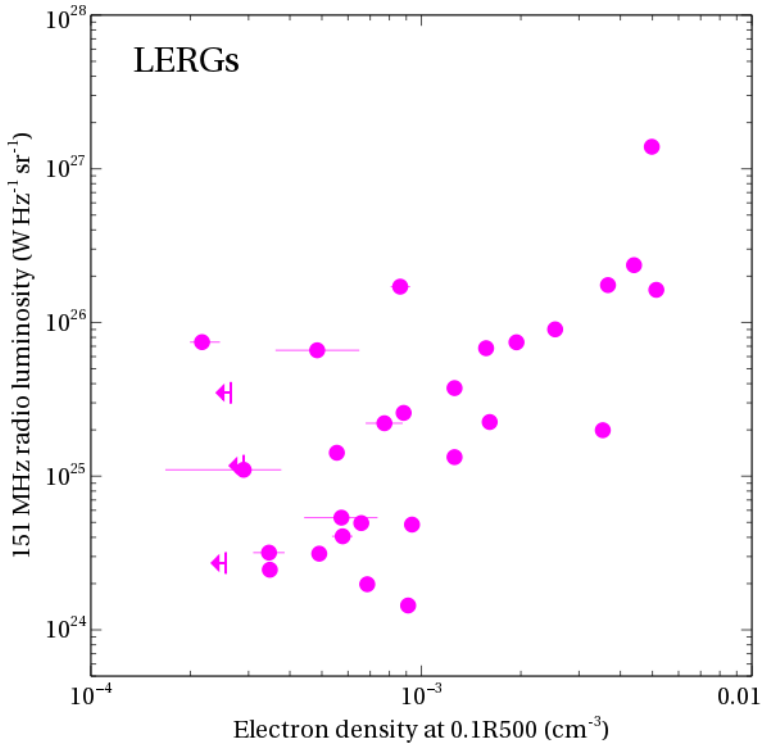
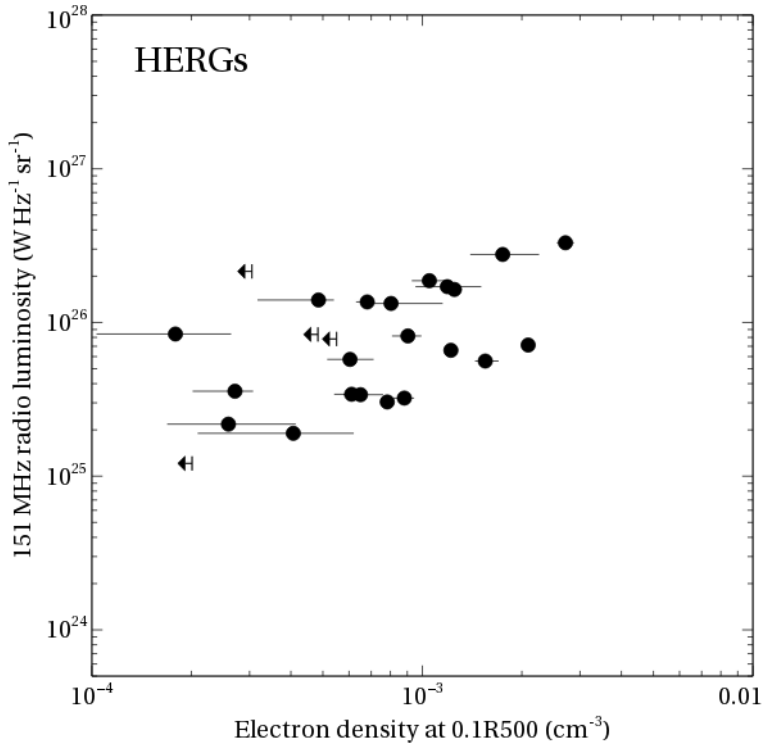
Central(ish) density

... looks rather like environment richness





Why?

- LERG relationship between radio luminosity and environment
  - Fits with theories requiring fuel from ICM
  - Expect jet power to vary with central cycle, so would contribute to scatter
- HERG lack of relationship
  - ICM irrelevant if fuelled from local gas reservoirs

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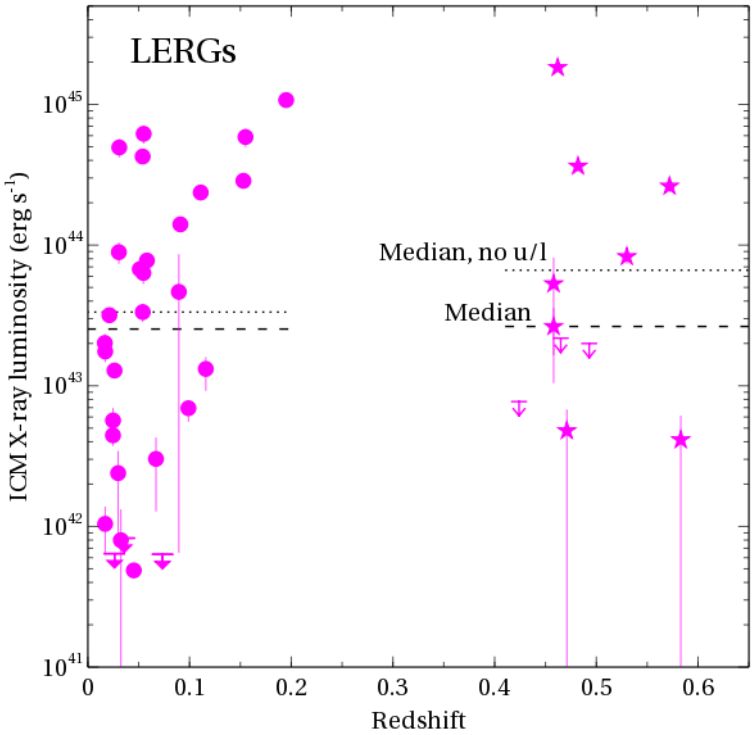
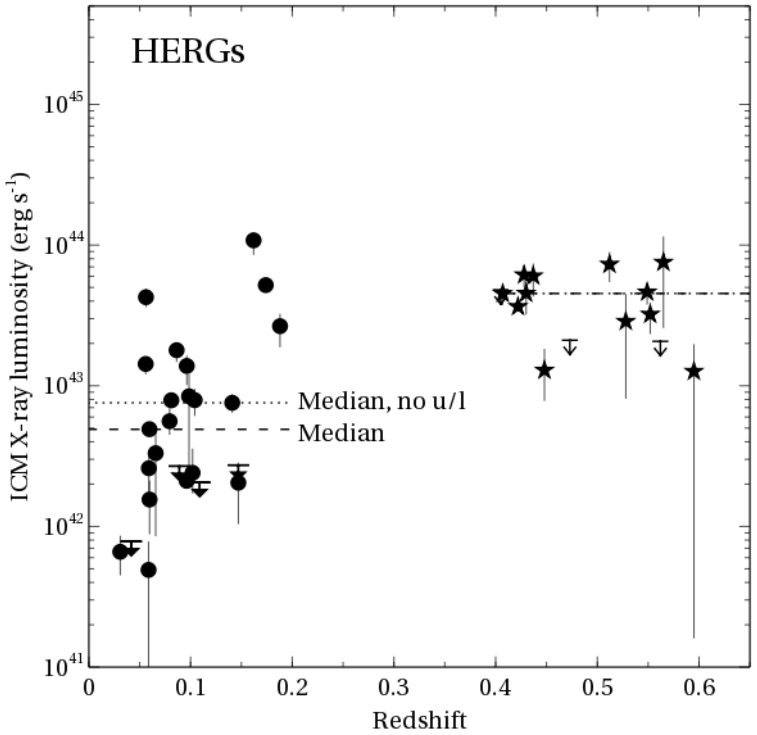
Environment evolution?

Environment richness vs redshift





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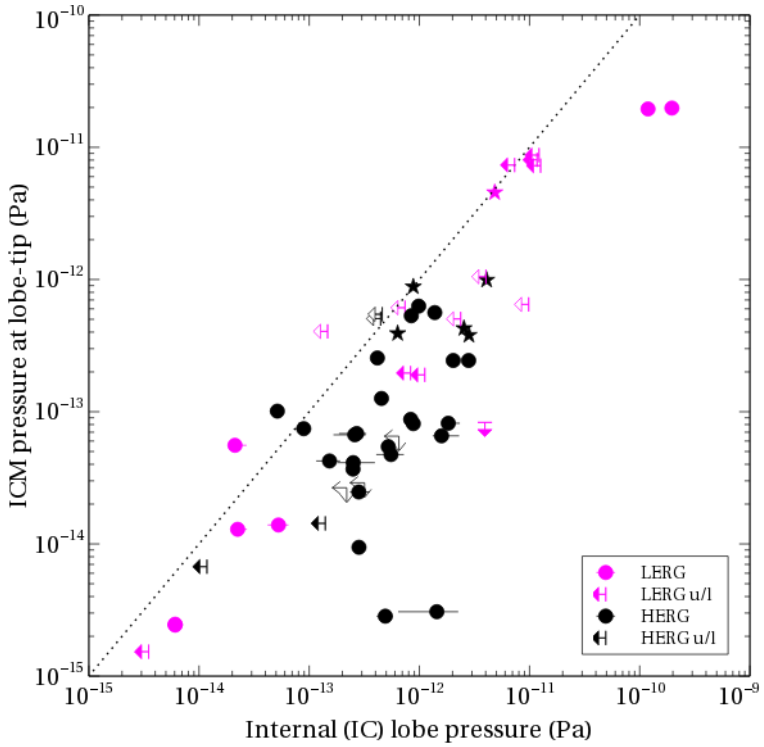
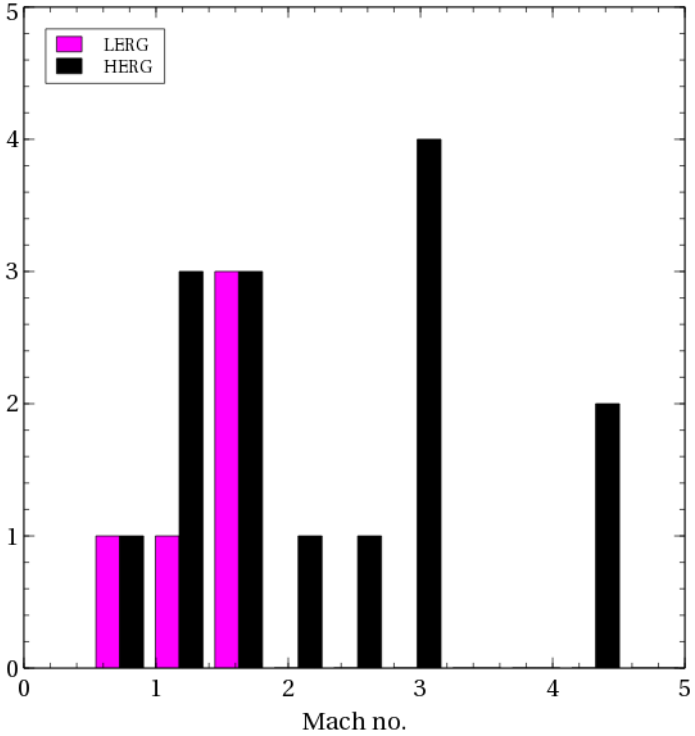
Breaking news ...

FRII lobe pressure balance ...



and mach numbers



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Summary

- Strong correlation between radio luminosity and cluster environment for LERGs, but not for HERGs
  - HERGs occupy a much narrower range of environments than LERGs
  - Supports different accretion theories for the different types of radio galaxy
- Similar correlation between radio luminosity and central density
  - Which factor drives the correlation?
- Tentative evidence of environment evolution for the HERGs
  - But need to check it is not due to sample problems
- Preliminary evidence that HERG radio lobes have a wider range of mach numbers than LERGs
  - Need to complete the analysis!
  - Also need to check result is not due to other factors