SEPnet
South East Physics Network

UNIVERSITY OF Southampton

Accretion modes, environments and fuelling of radio-loud AGN

Judith Ineson

Judith Croston, University of Southampton, UK
Martin Hardcastle, University of Hertfordshire, UK
Matt Jarvis, Oxford, UK
Ralph Kraft, Daniel Evans, Harvard-Smithsonian Center for Astrophysics, USA

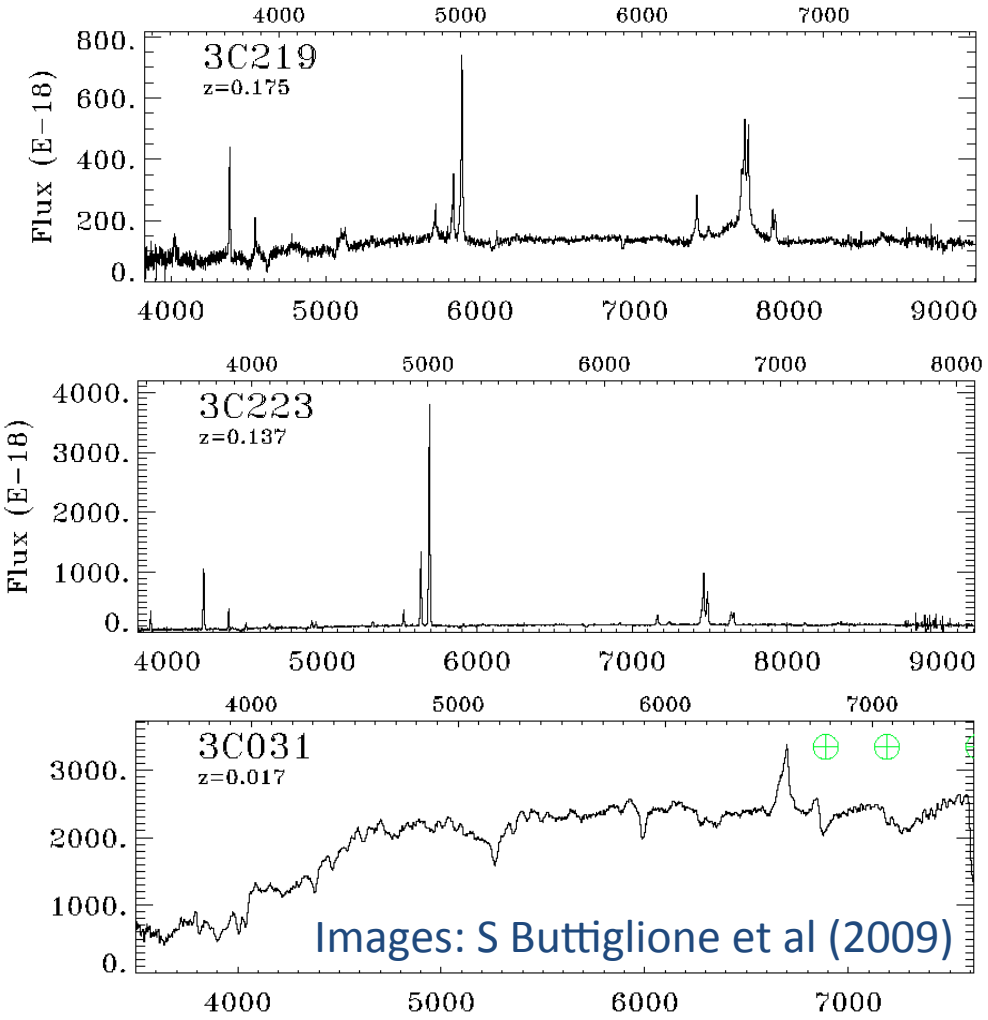
UNIVERSITY OF Southampton

Spectral classes

Broad line RG

Narrow line RG

Low excitation RG



Images: S Buttiglione et al (2009)

UNIVERSITY OF Southampton

The HERG/LERG dichotomy

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

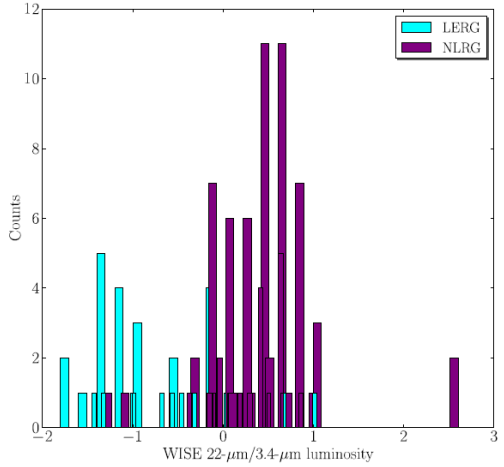
  (Best & Heckman 2012, Son et al. 2012, Mingo et al. 2014, Gürkan et al. 2014)
- Host galaxy mass
  - LERGs higher mass than HERGs

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

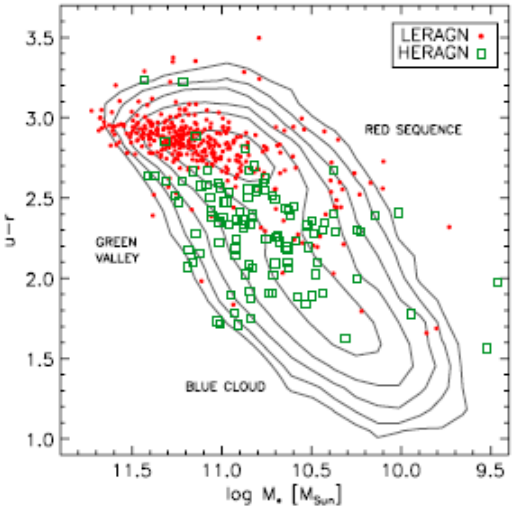
  (Smolčić 2009, Janssen et al. 2012, Herbert et al. 2010)
- Star formation rate
  - HERGs have on-going star formation

  (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 ...

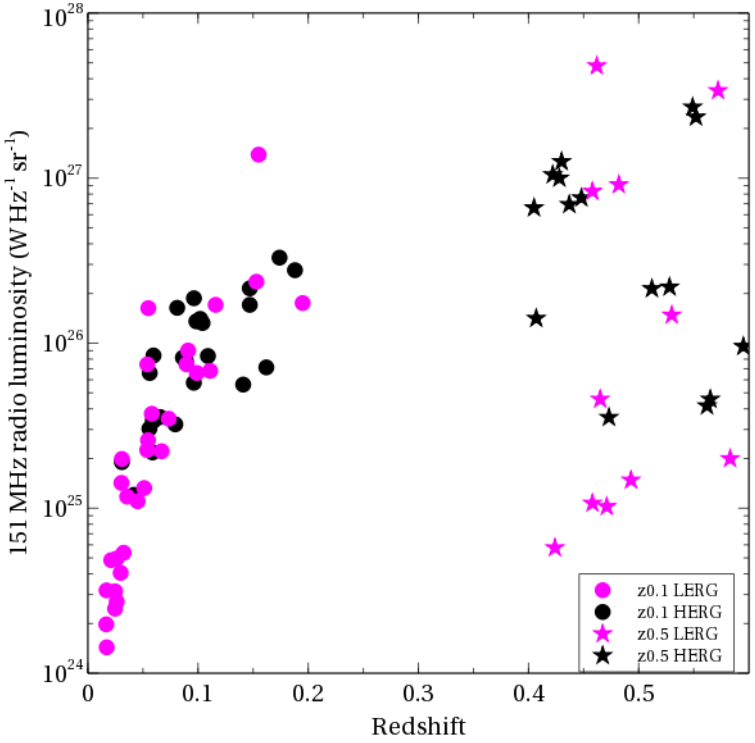
- Radio jets/lobes affect the large-scale environment
  - AGN radio jets affect the galaxy cluster environment (eg McNamara & Nulsen. 2007)
  - Radio jet heating suppresses star formation (eg Croton et al. 2006)
  - Radio jets affect galaxy formation and development
- How does the cluster environment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

UNIVERSITY OF Southampton

Samples

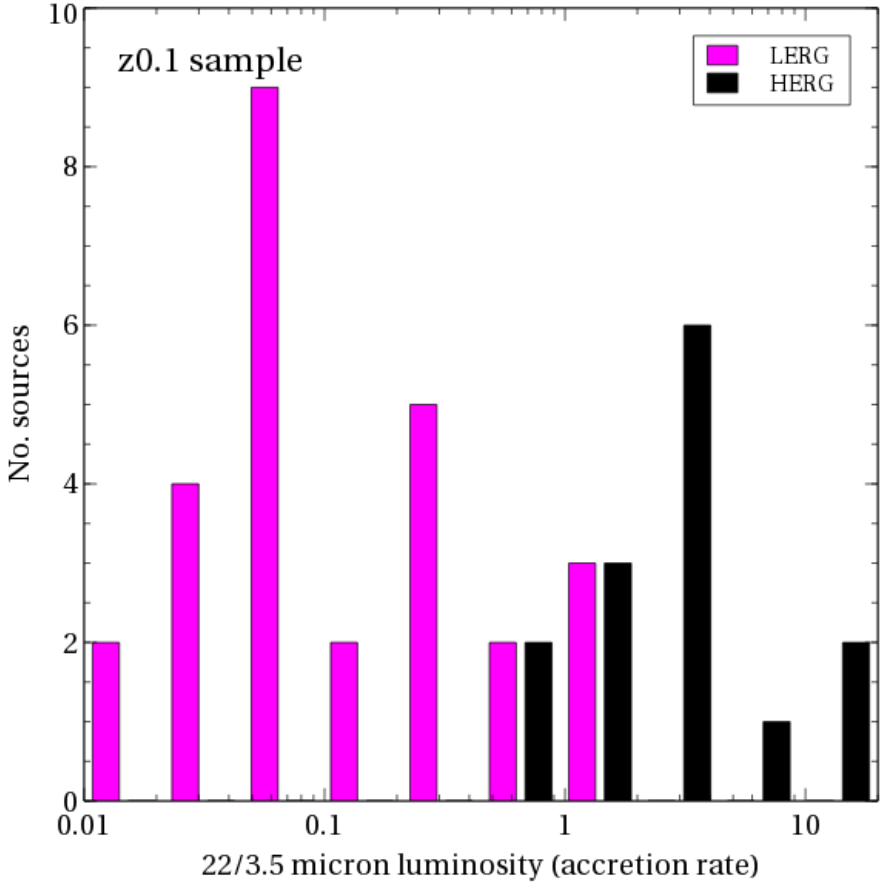
Radio luminosity vs redshift

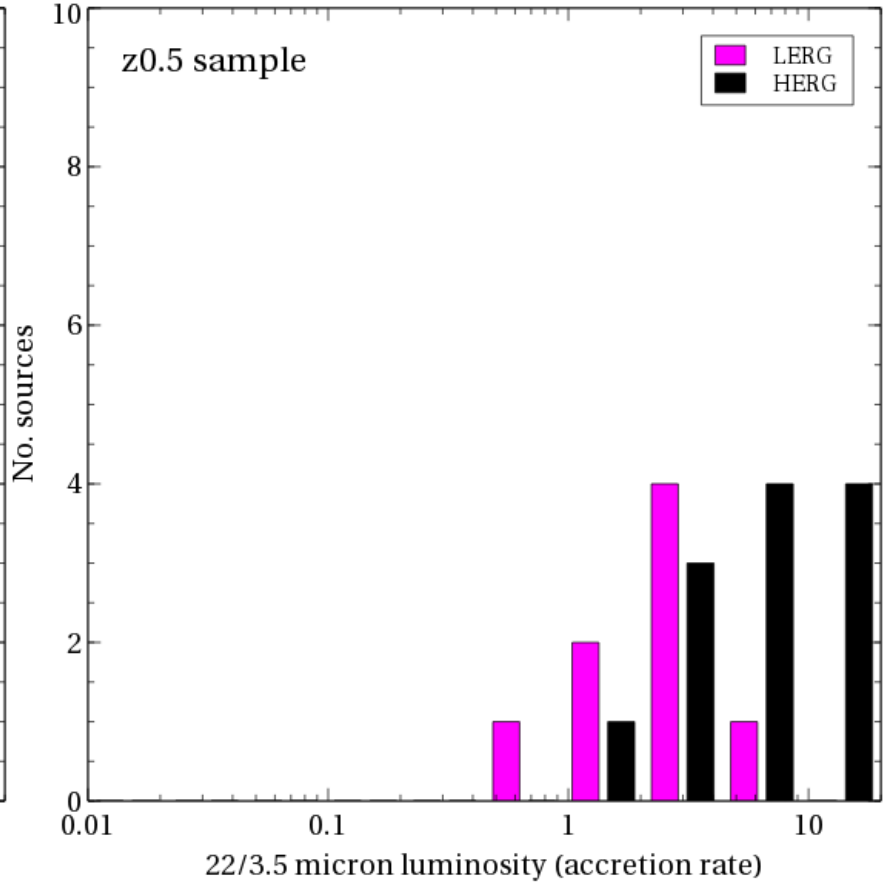
- Flux-limited samples at z~0.1 and z~0.5
- Note lack of local high luminosity sources
  - Automatic redshift dependence



UNIVERSITY OF Southampton

Sample accretion rates





IR data: Gürkan et al (2014)

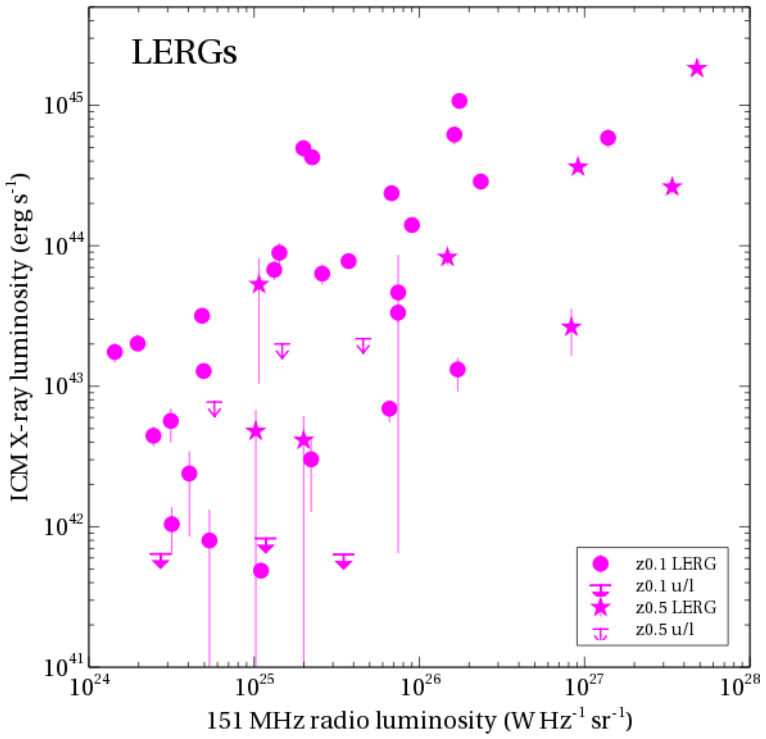
UNIVERSITY OF Southampton

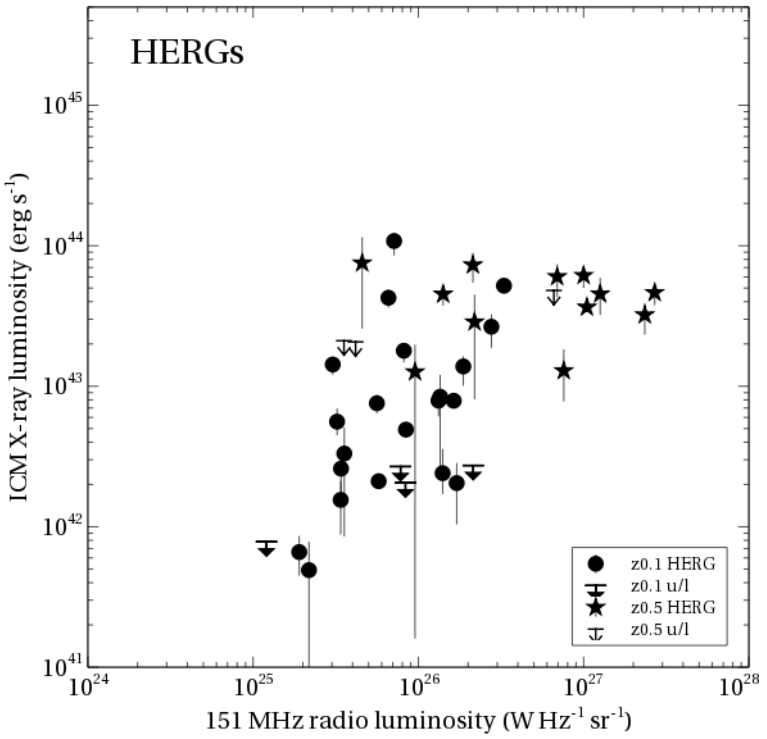
Radio luminosity vs Environment richness

- 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



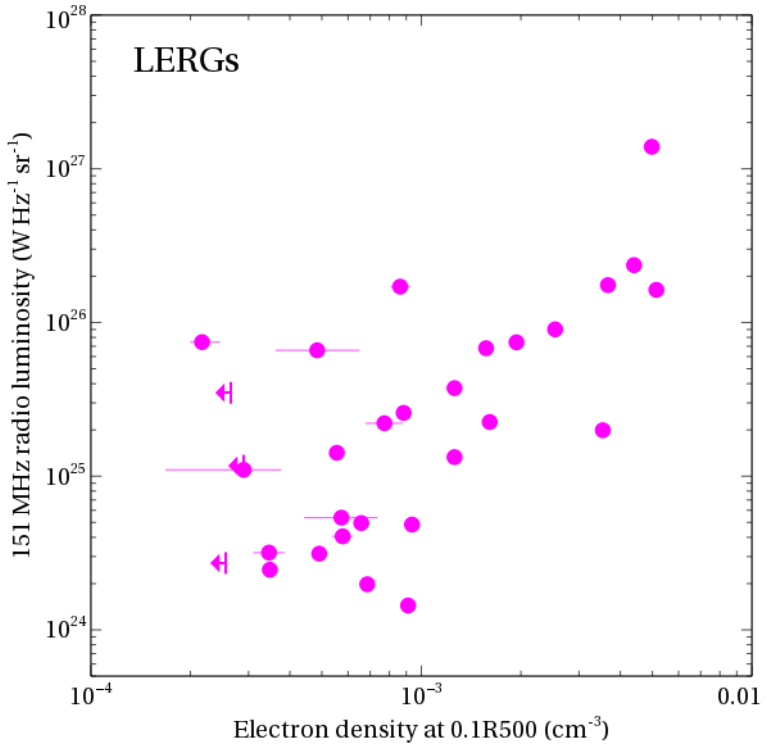


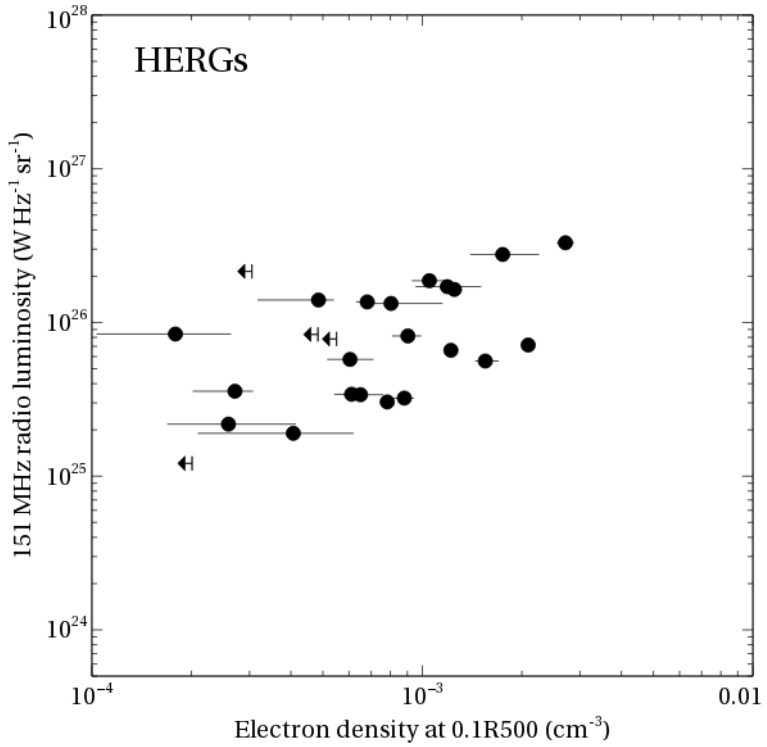
Ineson et al (2015)

UNIVERSITY OF Southampton

Central(ish) density

... looks rather like environment richness





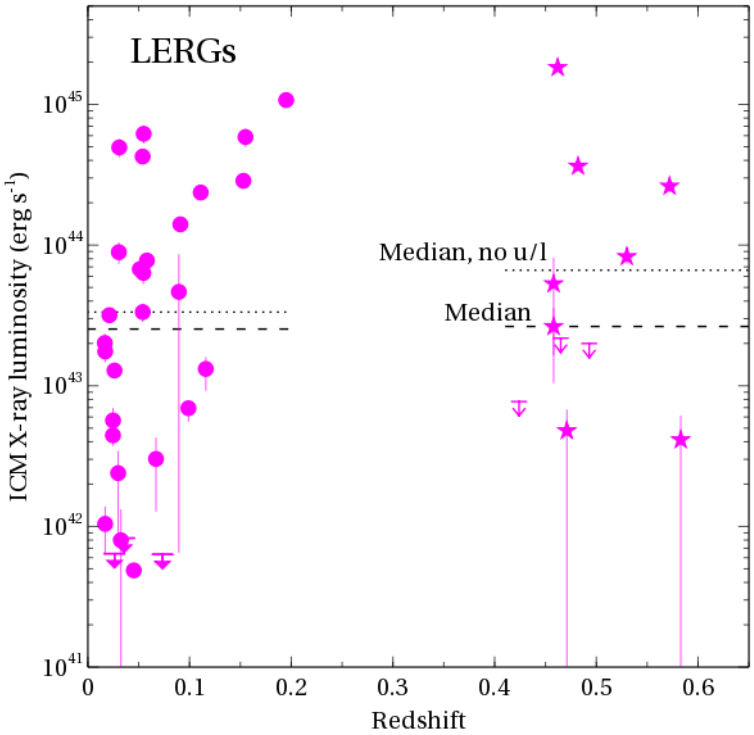
Why?

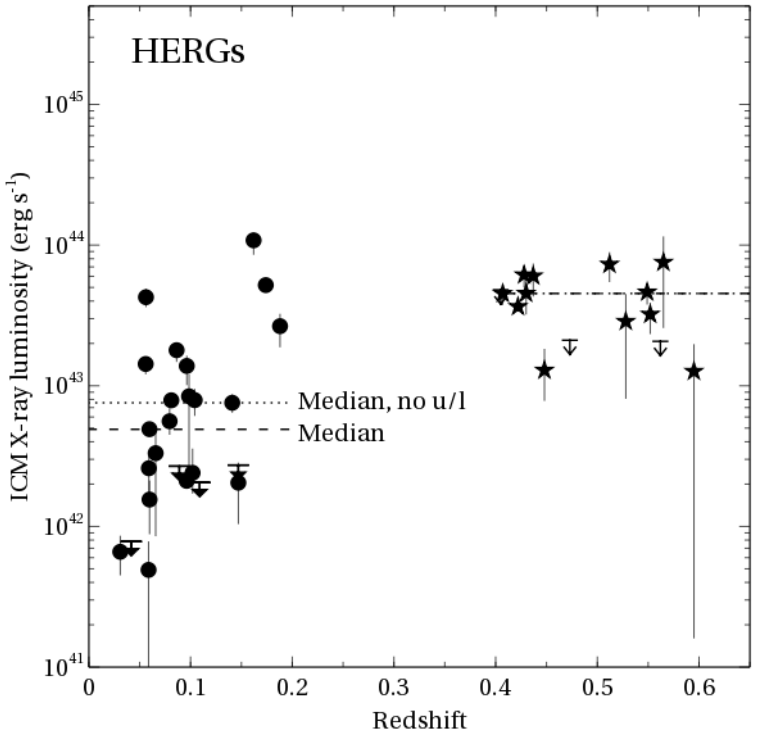
- LERG relationship between radio luminosity and environment
  - Fits with theories requiring fuel from ICM
  - Expect jet power to vary with central cycle, so would contribute to scatter
- HERG lack of relationship
  - ICM irrelevant if fuelled from local gas reservoirs

UNIVERSITY OF Southampton

Environment evolution?

Environment richness vs redshift

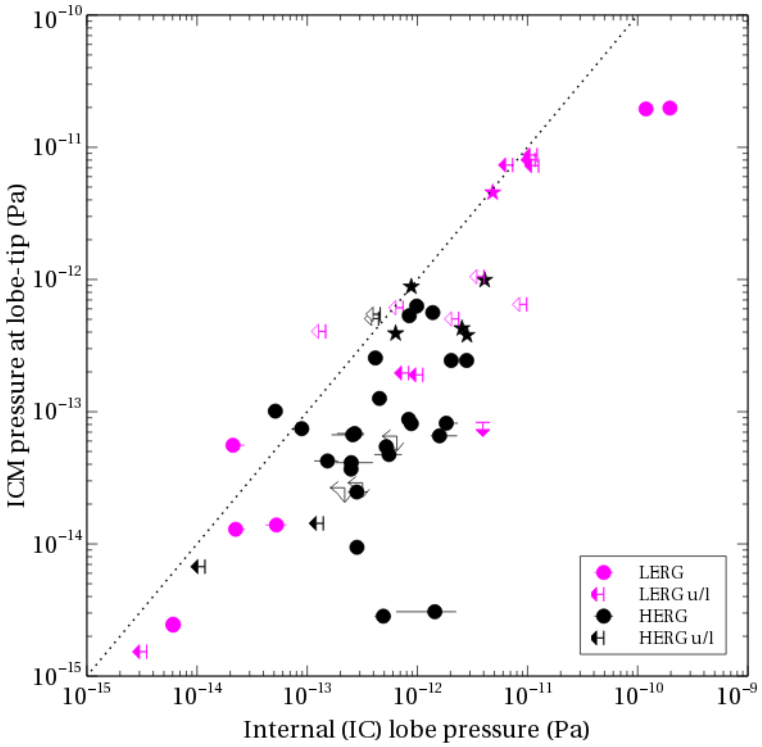




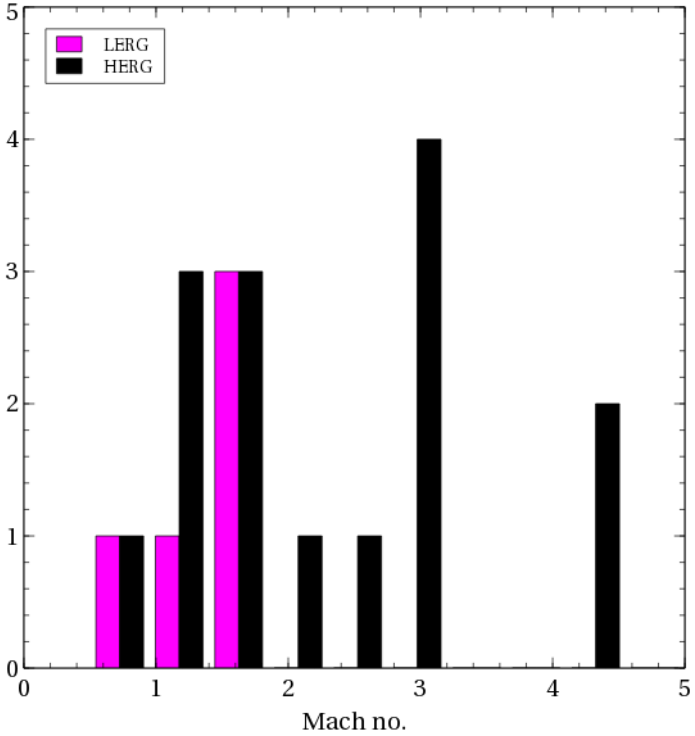
UNIVERSITY OF Southampton

Breaking news ...

FRII lobe pressure balance ...



and mach numbers



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