Hot and cold mode accretion

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Outline

- 1. Rationale
- 2. New spectroscopic radio galaxy surveys
- 3. First results
- 4. The future, connecting wide field surveys: eROSITA, EMU …

1. Rationale: The importance of feedback

› There is a non-linear mapping of halo mass function to galaxy stellar mass function.

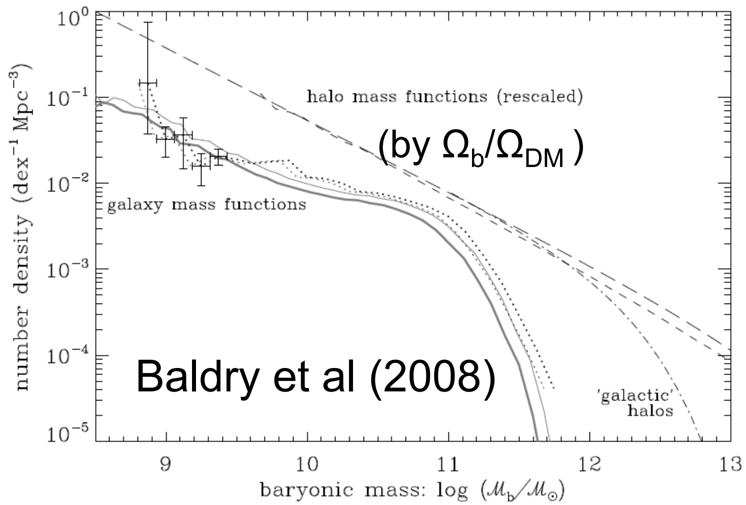
› Driven by a range of physical processes.

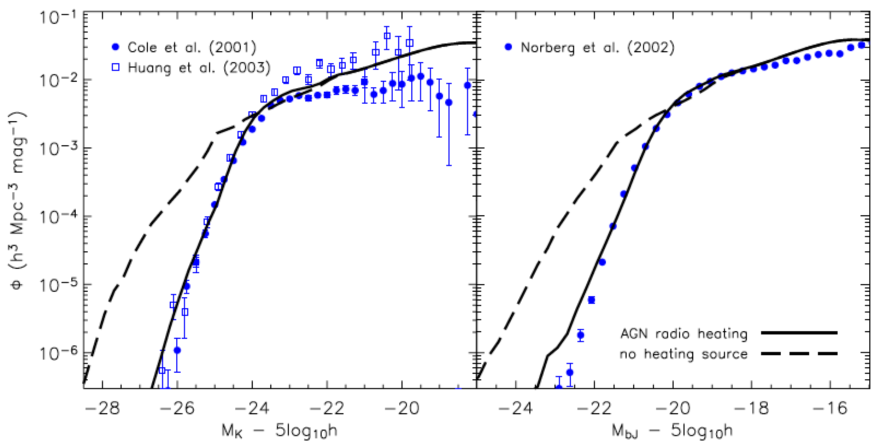
› At high mass SF is not sufficient.

› The physics needs to:

- Reduce the number of massive galaxies
- Suppress ongoing star formation at late times.

› AGN, and in particular ***radio-mode*** AGN provide a solution (e.g. Bower et al. 2006, Croton et al. 2006).





Croton et al (2006)

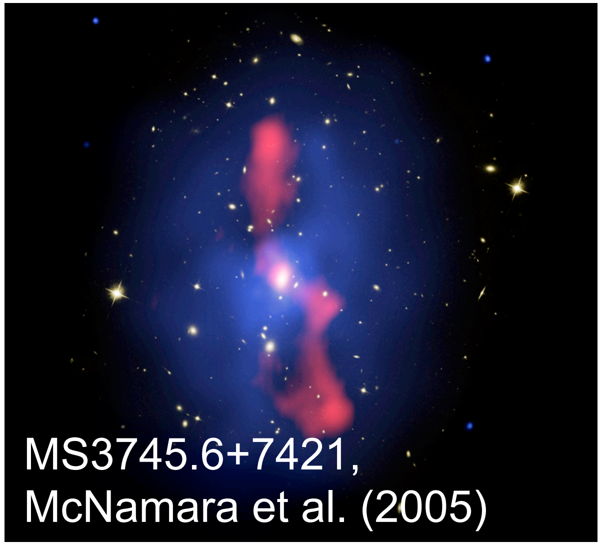
1. Rationale: The radio-mode

› Good observational evidence for radio mode feedback in clusters (see other talks today).

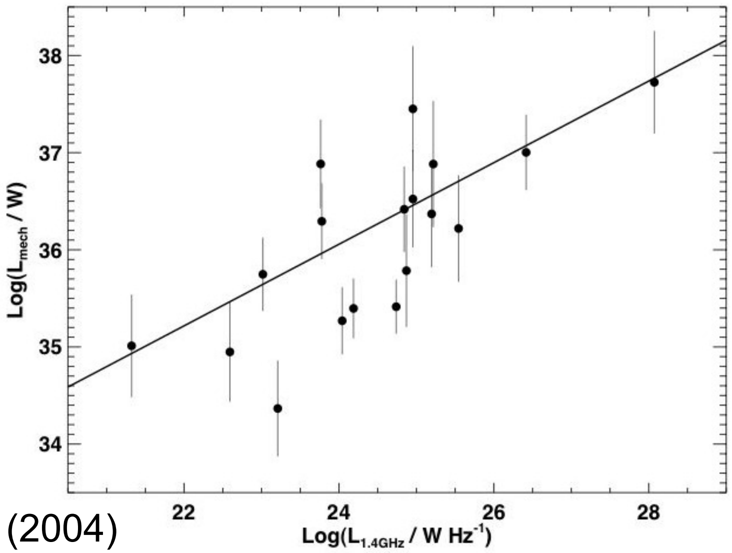
› Kinetic energy of a radio jet is typically **100-1000 times higher** than the observed total radio luminosity (e.g. Bicknell 95).

› Lobes expand and lift (buoyancy), transferring energy to the surrounding hot gas.

› X-ray cavities: mechanical energy up to 10^{45} erg/s.



MS3745.6+7421, McNamara et al. (2005)

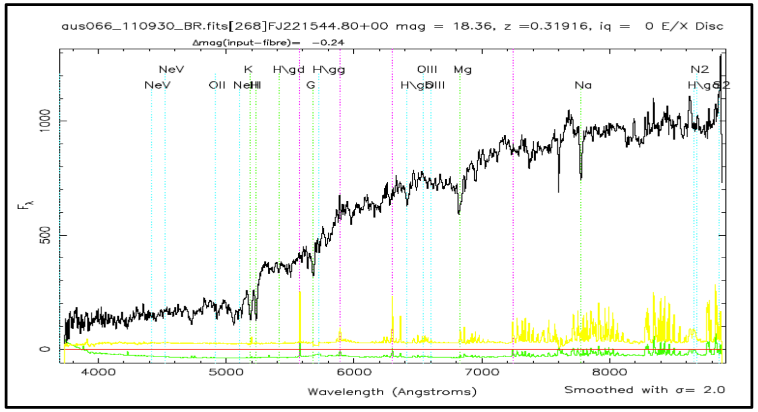


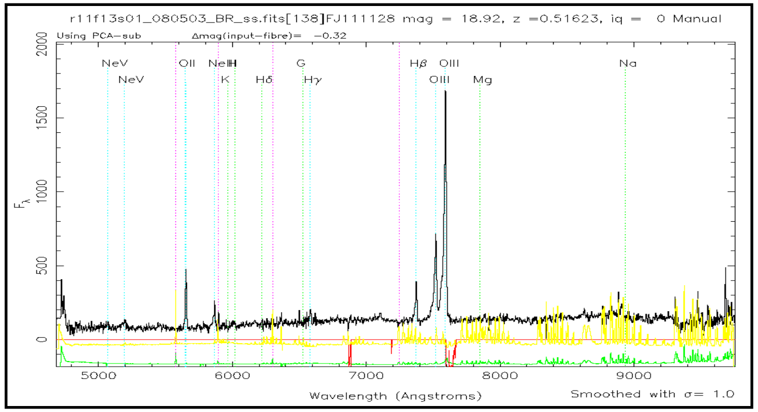
Best et al. (2006), Birzan et al. (2004)

1. Rationale: Hot and cold-mode

- ***Hot mode = radio mode = low ionization.***
- No UV/optical AGN signatures.
- Radiatively inefficient accretion, no thin disk.
- X-ray emission from jet (syncrotron?), hot halo?

- ***Cold mode = quasar mode = high ionization.***
- High-ionization emission lines.
- Strong continuum (if type 1).
- Radiatively efficient accretion disk.
- X-ray emission from inner disk and/ or corona.

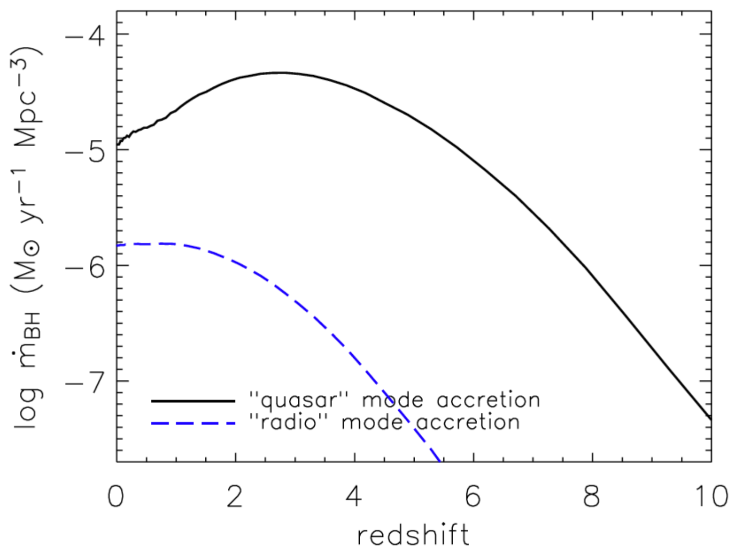




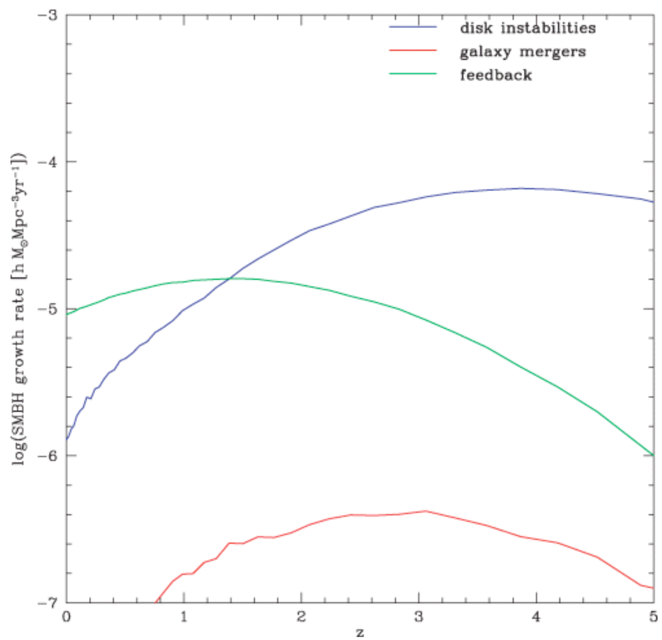
True dichotomy in radio galaxies: accretion mode? (e.g. Hardcastle et al 2007)

1. Rationale: Questions

- 1. Is this a true dichotomy?
- 2. At what stage in a galaxy's life do the different accretion modes occur?
- 3. We expect the two modes to evolve differently – do they?
- 4. Are our observations consistent with the current models that include radio-mode feedback?



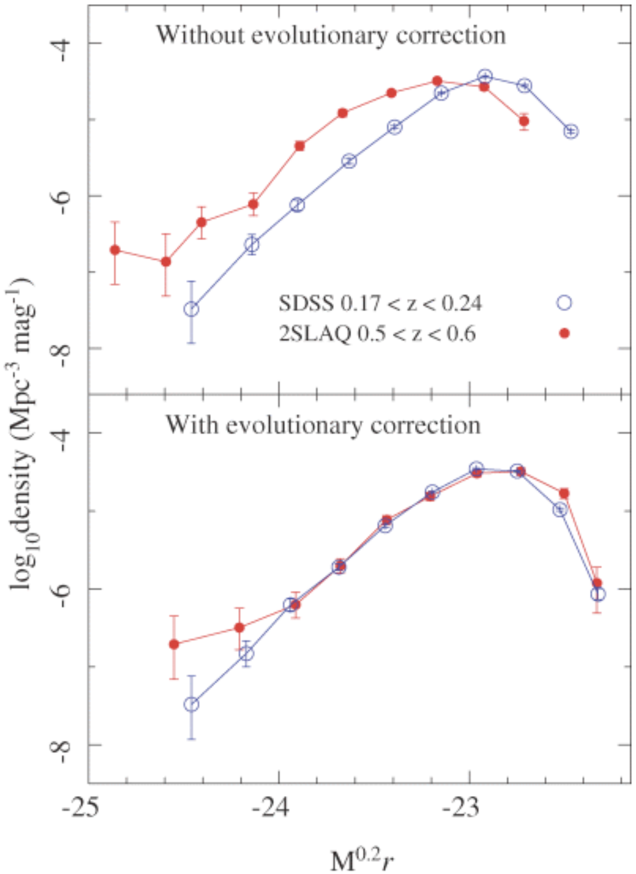
Croton et al. (2006)



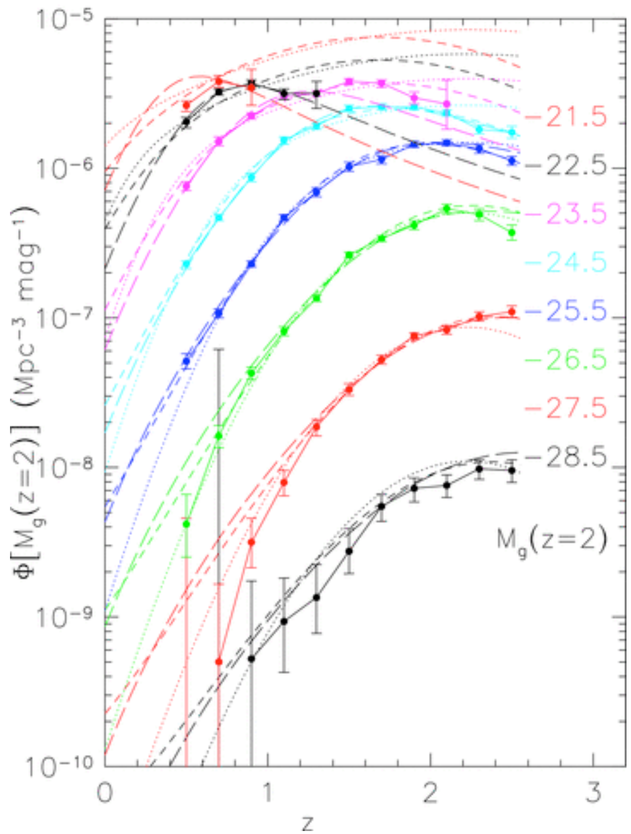
Bower et al. (2006)

1. Rationale: Evolution

2SLAQ LRGs: Wake et al. (2006)



2SLAQ QSOs: Croom et al. (2009)



The parent population of hot-mode radio galaxies evolves only weakly, while cold mode AGN evolve strongly.

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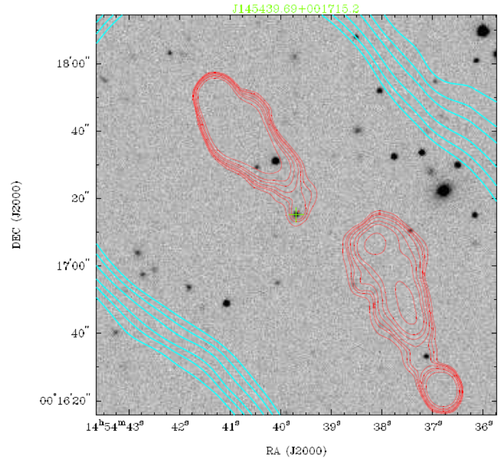
2. New spectroscopic surveys

- Cross-match FIRST ($S_{1.4GHz}$ > 1 mJy) components to SDSS (i_{mod} < 20.5)
  - Limited only by optical and radio flux (no colour selection).
  - Multi-stage matching process for complex morphologies.



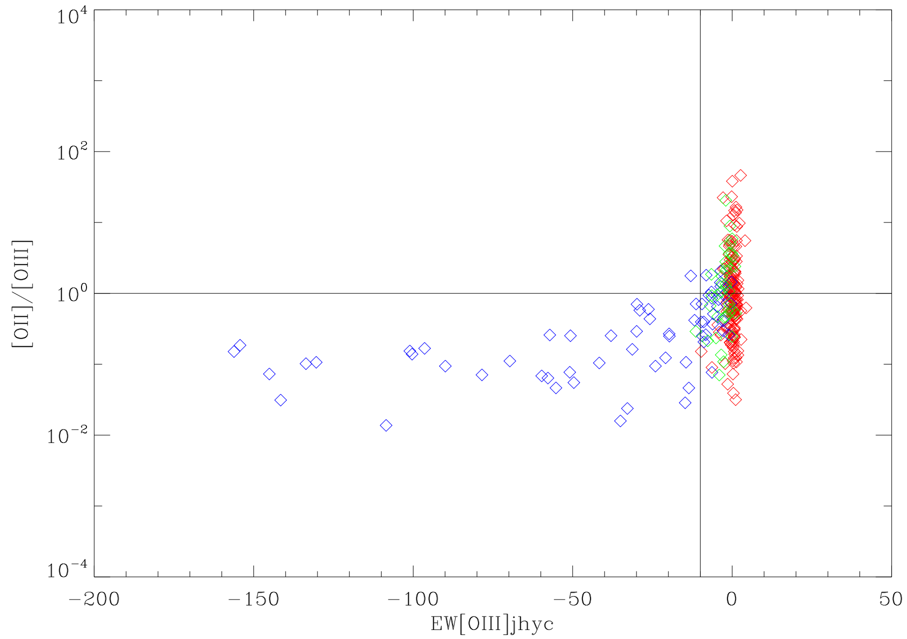
- Spectroscopic follow up including “spare-fibre” targets in various major surveys at the AAT:
  - WiggleZ dark energy survey.
  - Galaxy And Mass Assembly (GAMA).
  - AAOmega UKIDSS SDSS (AUS) Survey of Stripe-82.

- Spare-fibre targets in large spectroscopic surveys:
  - Radio galaxies are rare.
  - Parent sample for environmental measurements.
  - “Normal” galaxy sample to test biases.

2. New spectroscopic surveys

- Resulted in ~7000 spectra, of radio galaxies at $z<1$ and quasars to higher redshift.

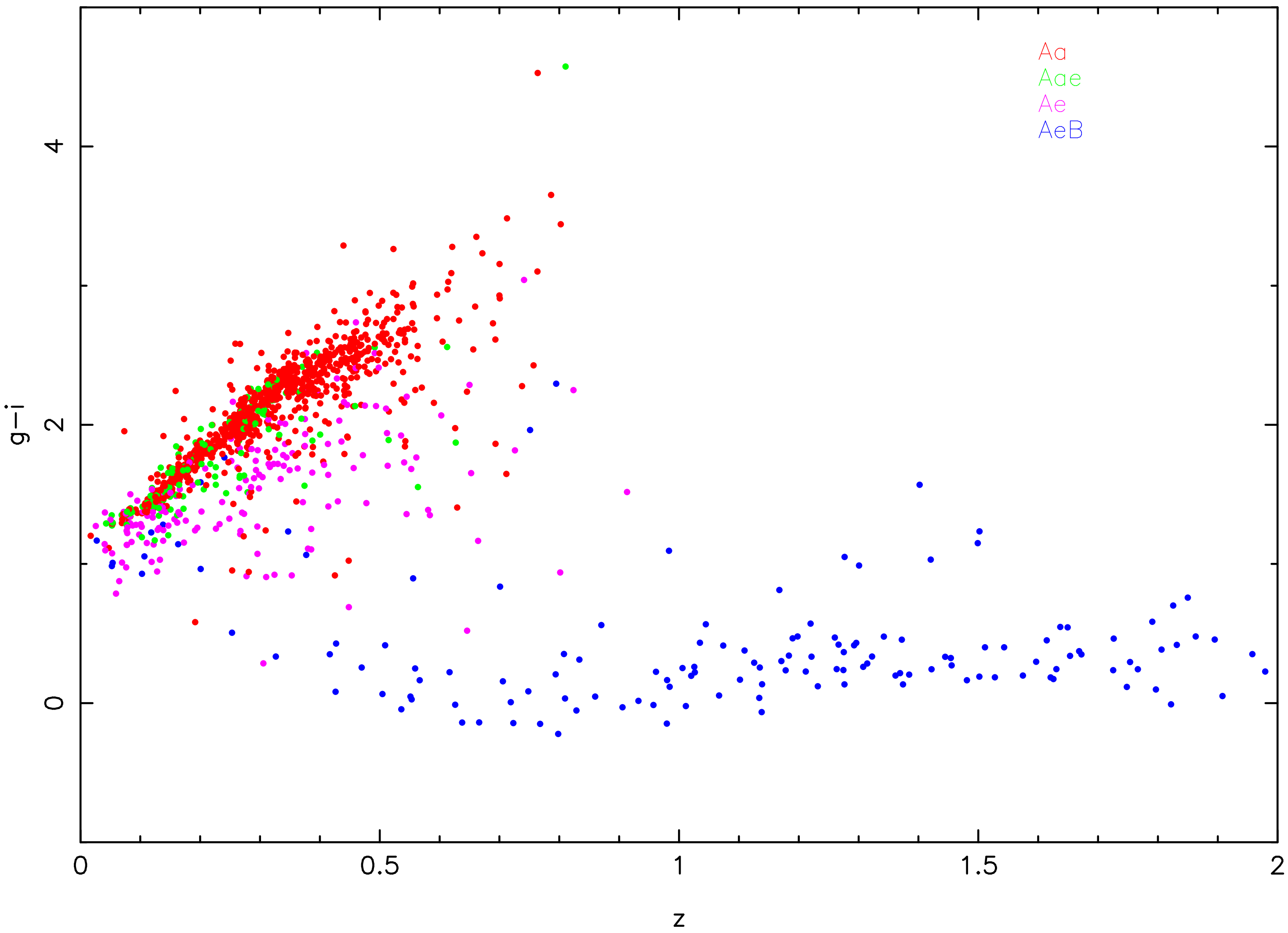
- Spectroscopic classification into hot and cold mode via emission line strength:
  - Equivalent width of [OIII] 5007.
  - Visual check of spectra.



- Classification scheme:
  - Aa – abs lines (hot mode)
  - Aae – abs+weak emission (???-mode)
  - Ae – strong narrow em lines (cold-mode)
  - AeB – broad emission lines (cold-mode)

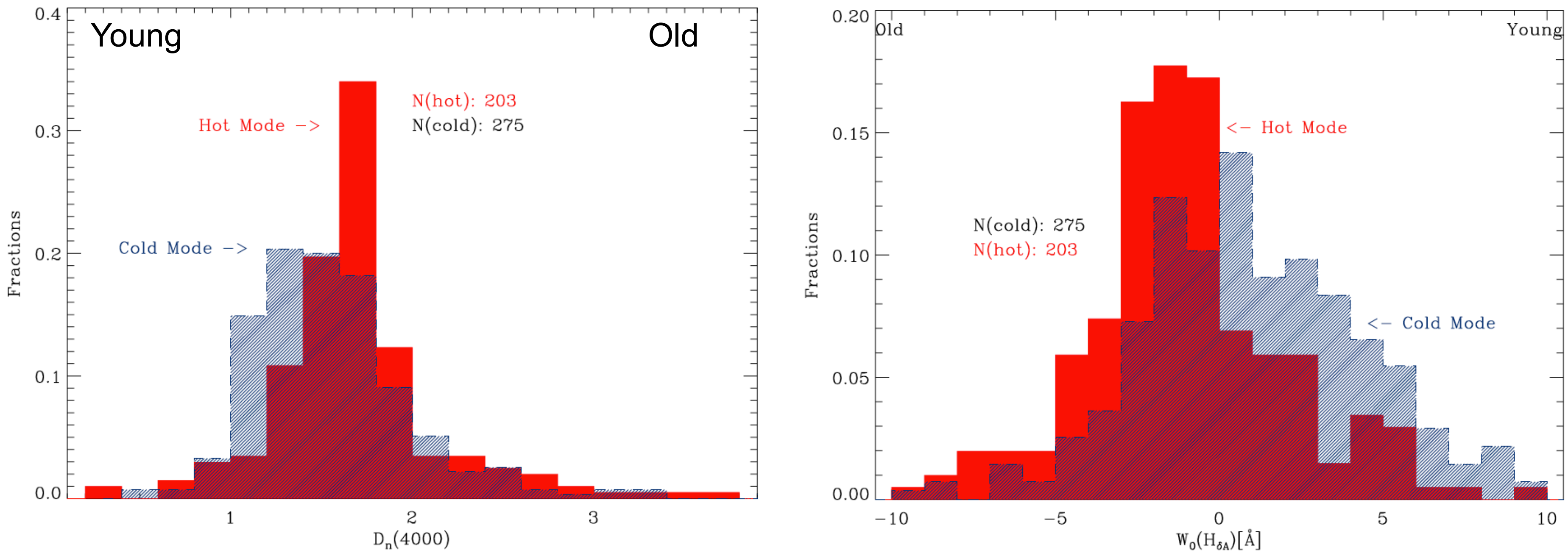
- Remove SF objects (via BPT diagrams).

3. First results: colour evolution



3. First results: stellar populations

- Measure age sensitive spectral indices: D4000 and Hδ.
- Multiple indices allow a range of ages to be explored.
- Also allow for consistency tests, and examining continuum contamination by AGN.
- **Cold-mode radio galaxies are clearly younger than hot-mode.**

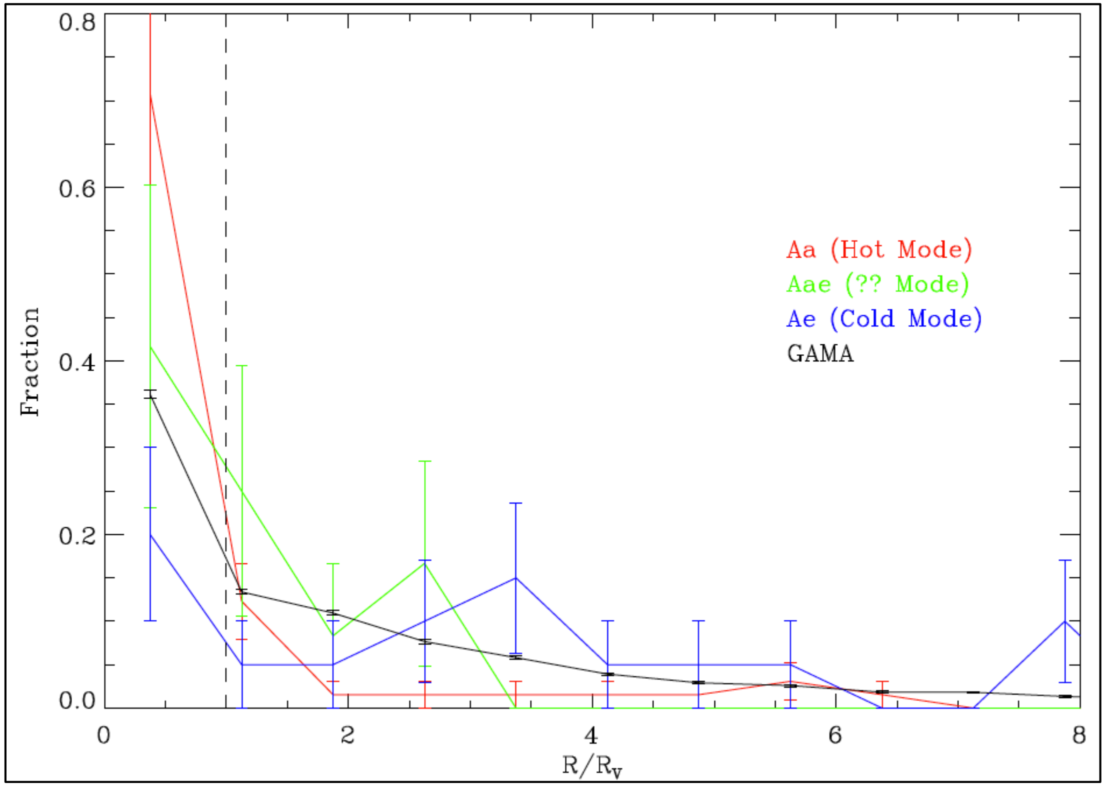


Ching et al. (in prep)

3. First results: environmental effects

› Location of radio galaxies wrt GAMA galaxy groups (Robotham et al. 2011).

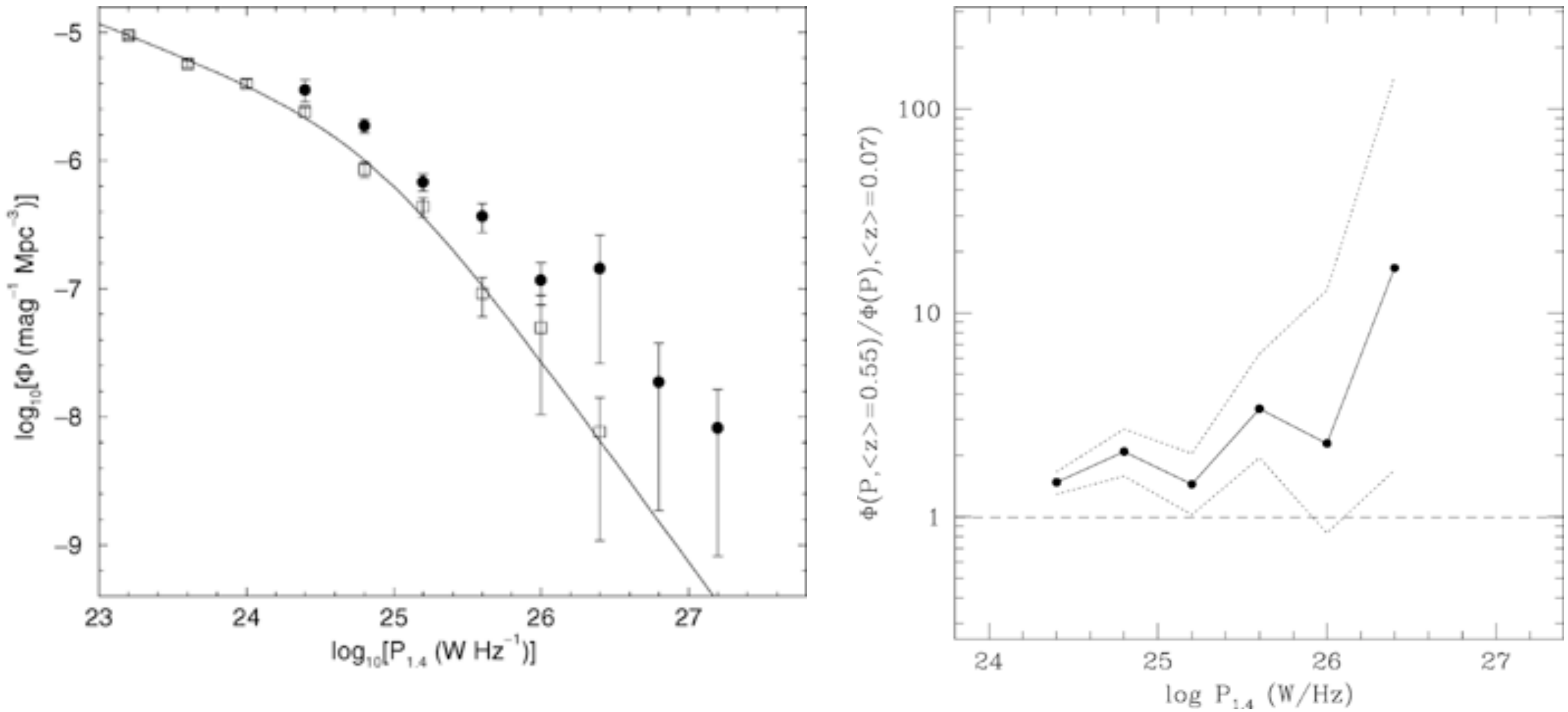
› **Much higher fraction of hot-mode RGs in centres of groups.**



Ching et al. (in prep)

3. First results: evolution (not yet!)

- Previous studies of LRGs from 2SLAQ (Sadler et al. 2007) show evolution in the LRG RG population using a sample of 391 RGs.
- **Factor of ~2 evolution in density from z=0.07 to z=0.55 for “low power” RGs, already a challenge for radio-mode feedback models.**



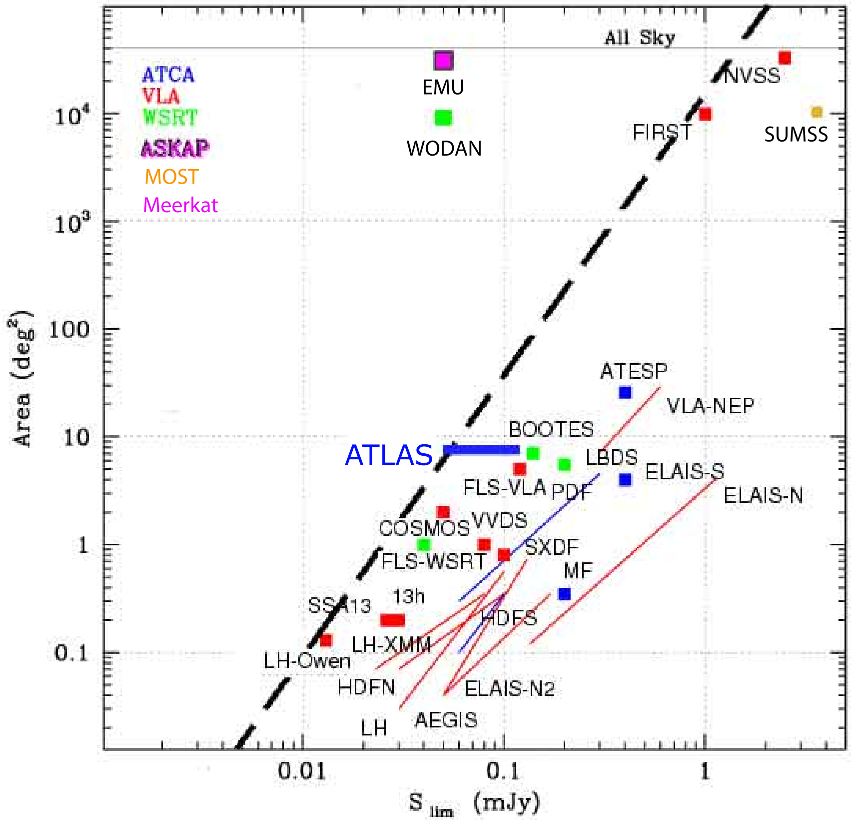
4. The future: ASKAP and EMU

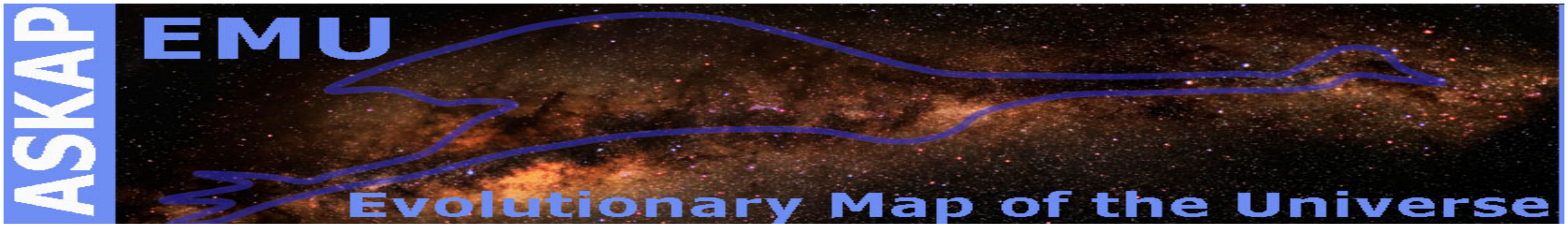
- ASKAP: Australian SKA Pathfinder
- 36x12m antennas each with 100 pixel phased array feeds (PAFs).
- 30 sq deg field of view.
- Six PAFs + digital systems Sept-Dec 2011
- 6 antenna BETA array testing early 2012
- Surveys starting ~end 2013.

- EMU: Evolutionary Map of the Universe
- 1.4GHz Continuum Survey of 75% of the Sky
- Project leader: ray Norris, Project Scientist: Andrew Hopkins
- Team: 150 scientists from 14 countries

4. The future: ASKAP and EMU

- EMU: Evolutionary Map of the Universe
- Deep radio image of 75% of the sky (to declination +30°)
- 40 x better sensitivity than NVSS (10 μJy rms across the sky)
- 5 x better resolution than NVSS (10 arcsec).
- Will detect and image ~70 million galaxies at 1.4GHz.
- Primary science goal: galaxy formation and evolution
- Images, catalogues, cross-IDs, to be placed in public domain.





4. The future: EMU and eROSITA for AGN

› LRGs at z~0.8 have typical radio fluxes of ~40uJy (based on stacking results), so a large fraction will be detected in EMU.

› eROSITA limit for AGN ~10^{-14} erg cm^{-2} s^{-1} at 0.5-2 keV.

› Likely to detect a large fraction of LRGs up to z~0.35 (based on known scaling relations: BH fundamental plane, e.g. Merloni et al. 2003).

› How well can point sources be deblended from clusters?

› The location of AGN within galaxy clusters. eROSITA should allow definitive tests. Is radio loudness just a function of galaxy mass? Does the larger-scale environment play a role?

› Need spectroscopic follow-up: phot-z not enough to determine accretion mode – Even bigger problem for EMU!

› Can we use radio + X-ray to better define emission mechanisms?
➔ LF, environments… as a function of physical processes.

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Summary

- Most natural divide for radio AGN is into accretion mode: hot & cold.
- New survey with ~7,000 radio galaxy spectra from WiggleZ, GAMA and AUS on the AAT.
- Early results:
  - Cold mode are younger, hot mode older.
  - Hot mode in denser environments.
  - Key aim is to measure the LF for the two accretion modes separately.
- ASKAP and EMU will revolutionize radio continuum observations:
  - 10uJy rms
  - 10 arcsec beam
  - 75% of the sky
- eROSITA connection:
  - Will be deep radio data available for ~all eROSITA AGN.
  - Connection between AGN and clusters will provide a rich area to aid our understanding of feedback.
  - Aim to disentangle different physical processes with multi-wavelength data.