The evolving role of radio-AGN in suppressing star-formation in massive galaxies

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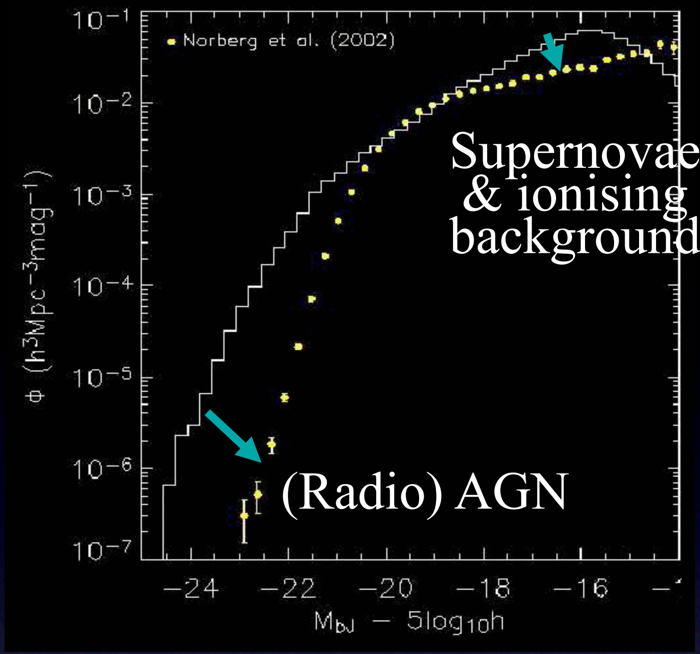
Motivation



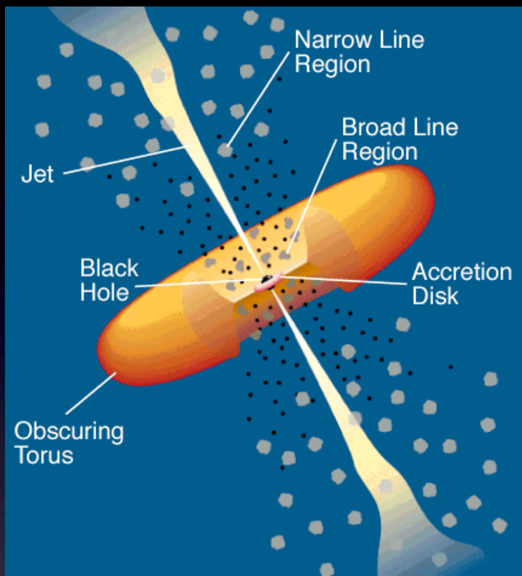
"AGN feedback" is currently postulated to explain many issues in galaxy evolution

- Black-hole - bulge mass relation
- Avoidance of over-production of massive galaxies
- "Old, red and dead" appearance of massive ellipticals

In particular, recurrent radio-loud AGN activity is thought to be responsible for the latter two, and hence a strong driver of the declining SF history of massive galaxies. But

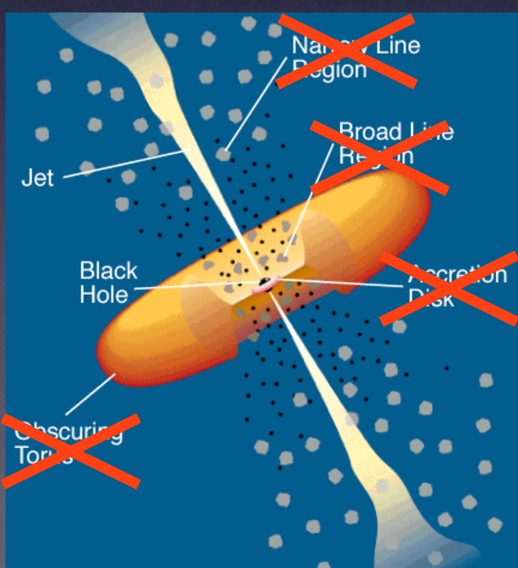
- what type of radio-AGN activity?
- how and when is the radio-AGN activity triggered?
- how does this radio-AGN activity evolve over cosmic time?

Two types of AGN



"Standard" / 'Quasar-mode' AGN have:

- Luminous accretion disk (+ X-ray corona)
- Bright line emission (ionised by disk)
- Dusty obscuring torus (emits IR/sub-mm)
- Orientation-dependent properties
- Sometimes, extended radio jets



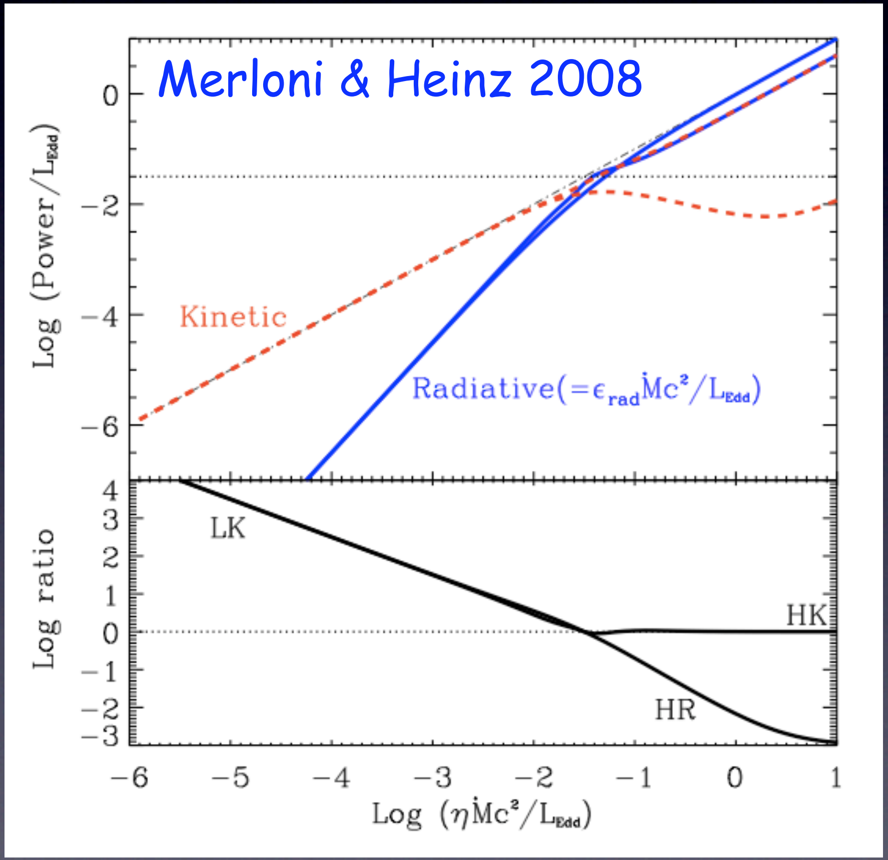
Low excitation / 'radio-mode' AGN have:

- No strong emission lines / X-ray emission
- Radiatively inefficient; no accretion disk
- No IR evidence for torus
- Only evidence of AGN activity is the jet

Why different AGN?

Accretion models predict a change in the nature of accretion flows at low fractions of Eddington:

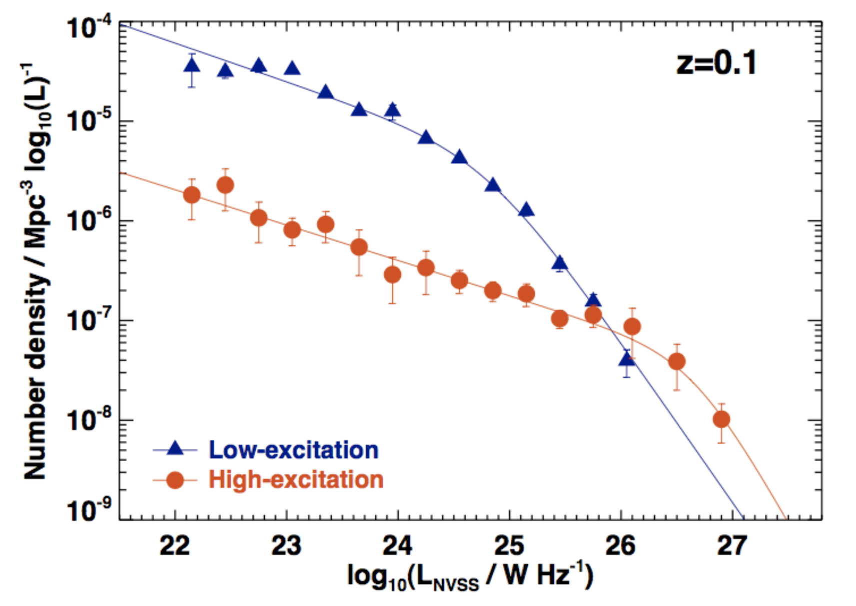
- high accretion - optically thick, geometrically thin disk; strong radiative emission, sometimes also with jets
- low accretion - advection dominated accretion flow; most energy comes out as jets in "kinetic" mode.
- cf. microquasar modes



Local radio AGN populations

Best & Heckman 2012, MNRAS, 421, 1569

- Cross-matched SDSS DR7 with radio catalogues
  - sample of >18,000 radio sources
- Classify all radio galaxies as high- or low excitation
  - use SDSS emission line ratios (where possible)
  - use [OIII] 5007 line equivalent width
- Both classes are found over most of the range of luminosities, but LERGs dominate at low powers.

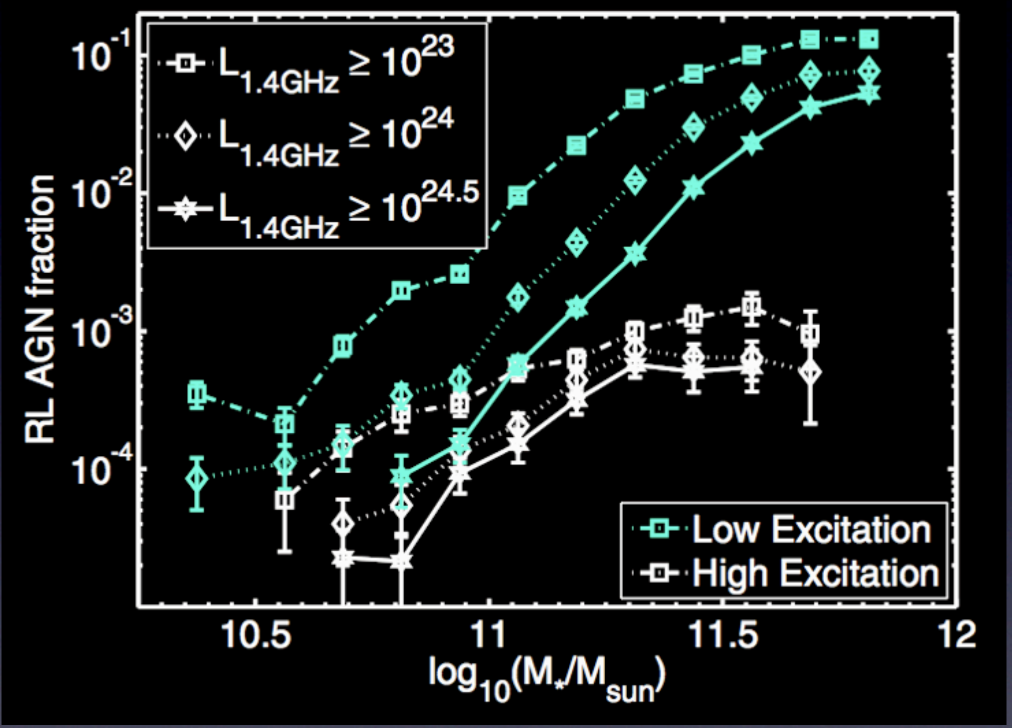


Mass dependence of radio-AGN classes

Janssen et al 2013

The fraction of galaxies that host low-excitation radio sources is a very strong function of galaxy mass.

The fraction of galaxies that host high excitation sources varies only weakly with mass, and less on radio power; these are similar to optical AGN



It is the radiatively inefficient LERGs that have the strong mass-dependence (and also other properties, e.g. red colours) indicative of “maintenance mode” feedback

Testing accretion mode picture

Best & Heckman 2012, MNRAS, 421, 1569

Estimate the Eddington-scaled accretion luminosities of all of the classified radio-AGN as

$$f_{Edd} = L / L_{Edd} = (L_{rad} + L_{mech}) / L_{Edd}$$

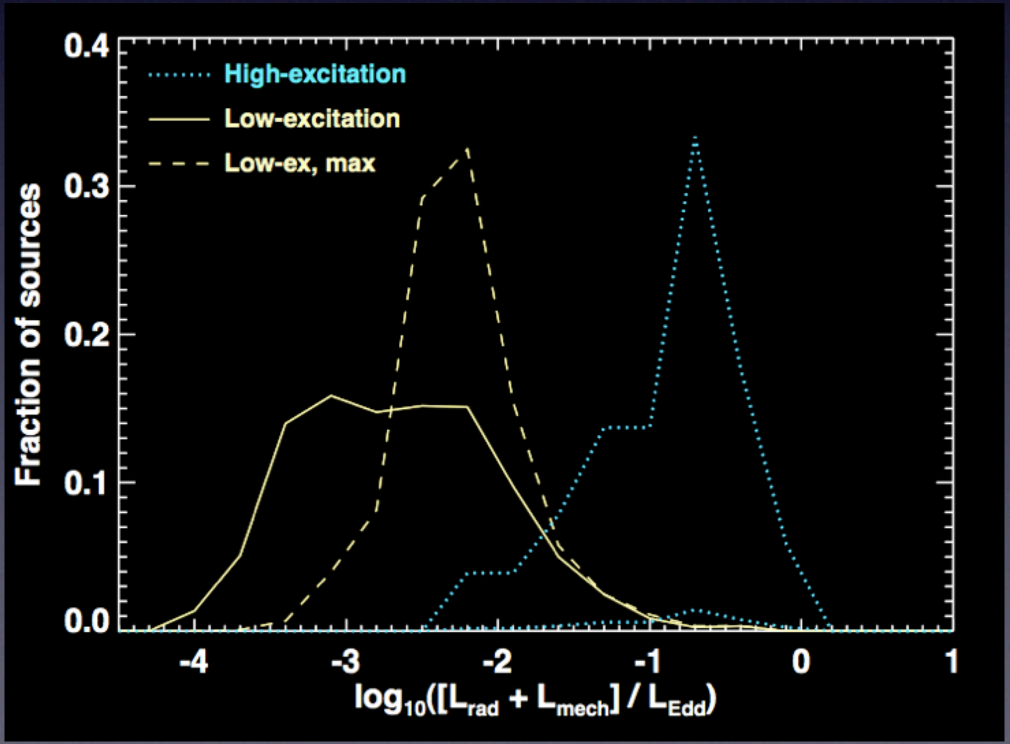
- Estimate black hole masses from velocity dispersions
- Calculate radiative luminosity, scaling from [OIII] 5007
  - corrected for reddening using Hα/Hβ line ratio
  - calibrated using quasars (cf. Heckman et al 2004)
- Estimate mechanical (jet) luminosity from radio luminosity
  - estimates from "X-ray cavities" and from minimum energy synchrotron broadly agree, for best-guess assumptions

Accretion modes of low-z RGs

Best & Heckman 2012, MNRAS, 421, 1569

Putting together radiative and mechanical luminosities and black hole mass estimates for the SDSS radio sample, we determine Eddington-scaled accretion luminosities (± 0.8 dex / source)

- Clear dichotomy between two source classes.
- Good match to the theoretical expectations of advection dominated accretion flows setting in below few % Eddington



Origin of different classes?

'Standard' AGN ('quasar-mode' or 'radiative' or 'cold-mode' or HERG....) fuelled through 'standard' accretion disks

- need a plentiful supply of cold gas
- perhaps brought in through mergers/interactions?

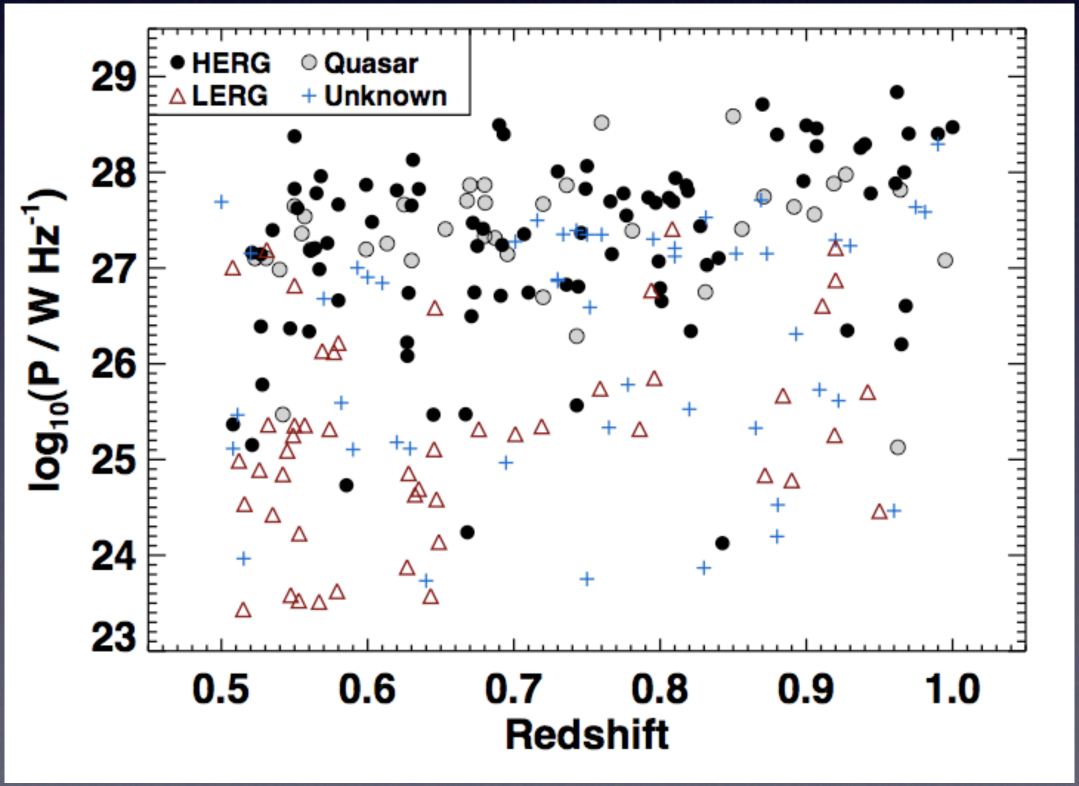
'Other' radio sources (LERG, or 'radio-mode', or 'hot-mode' or 'radiatively inefficient'....) fuelled at low rate via ADAF

- low rate can be supplied by cooling hot gas in galaxy/cluster halo
- in local Universe, the time-averaged radio-AGN energetic output is sufficient to balance radiative cooling from halo
- possibility of radio-AGN feedback cycle

To determine the evolving importance of radio-AGN feedback we need to measure cosmic evolution of the LERG population

Cosmic evolution of radio-AGN

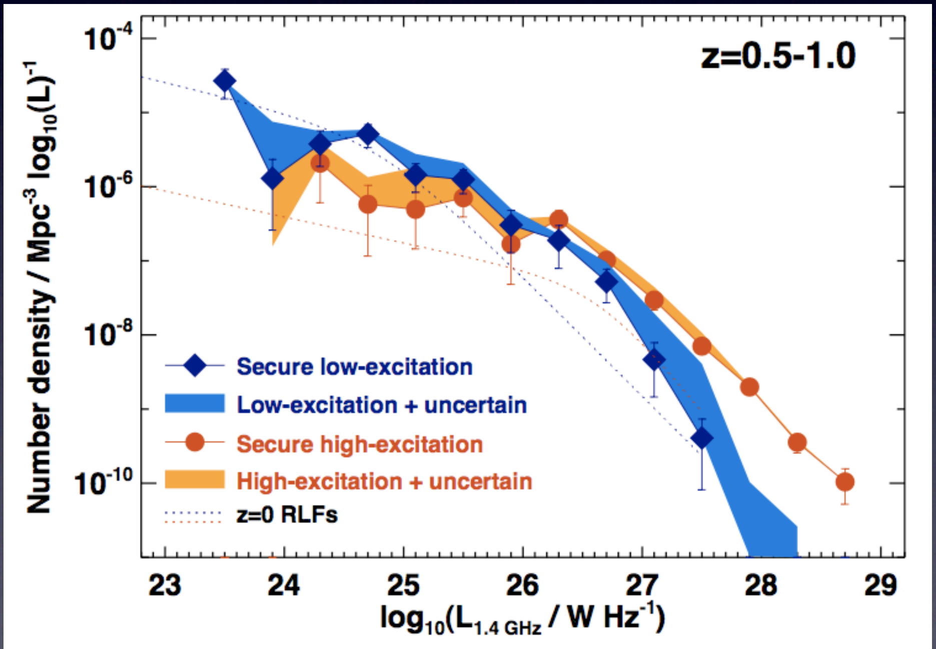
We have combined 8 radio source samples at 0.5<z<1.0, to get good coverage of the P-z plane, and used spectroscopy to determine radiatively efficient/inefficient classifications (Ker, PhD)

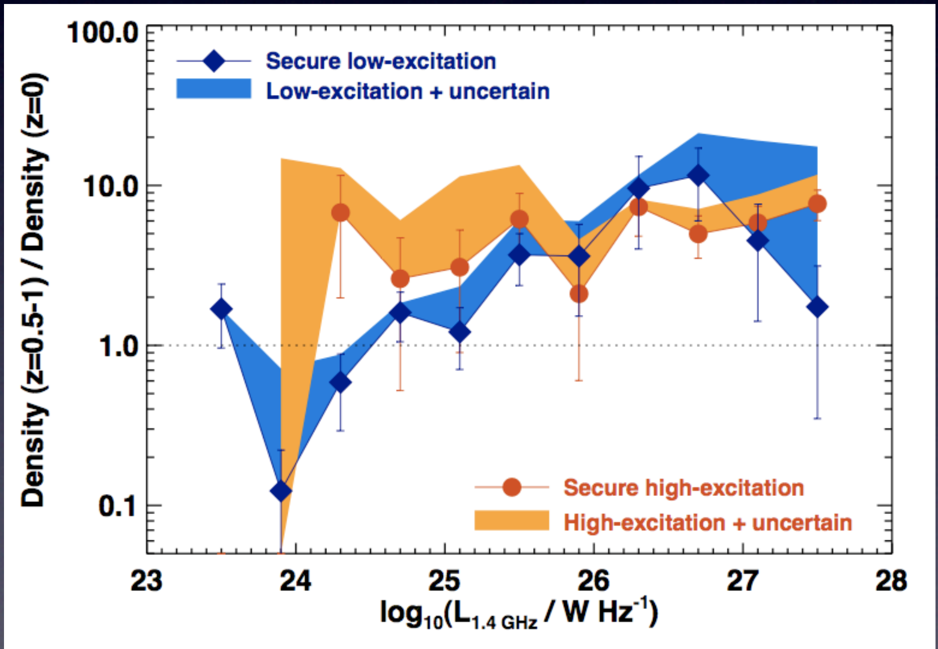


Cosmic evolution of radio-AGN

Best et al 2013, in prep

This has allowed us to derive the luminosity functions of the two separate populations, to compare with the local RLFs





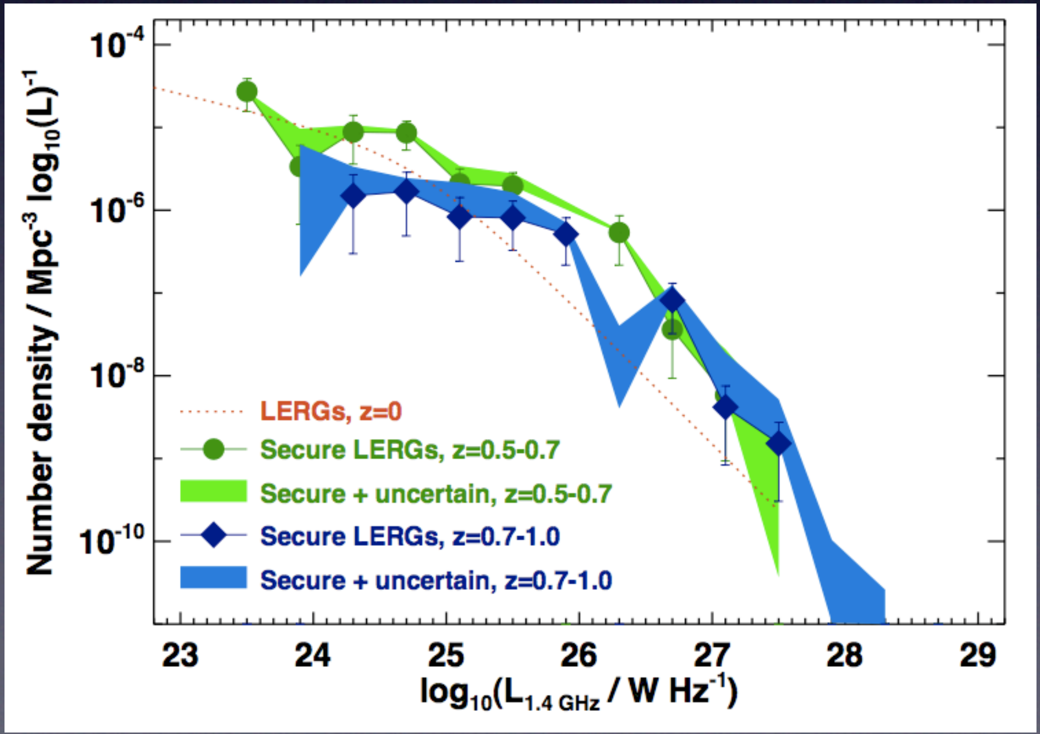
High-excitation (efficient) AGN evolve by factor ~7 at all powers

LERGs show no evolution at low power, but like HERGs at high-P

Cosmic evolution of radio-AGN

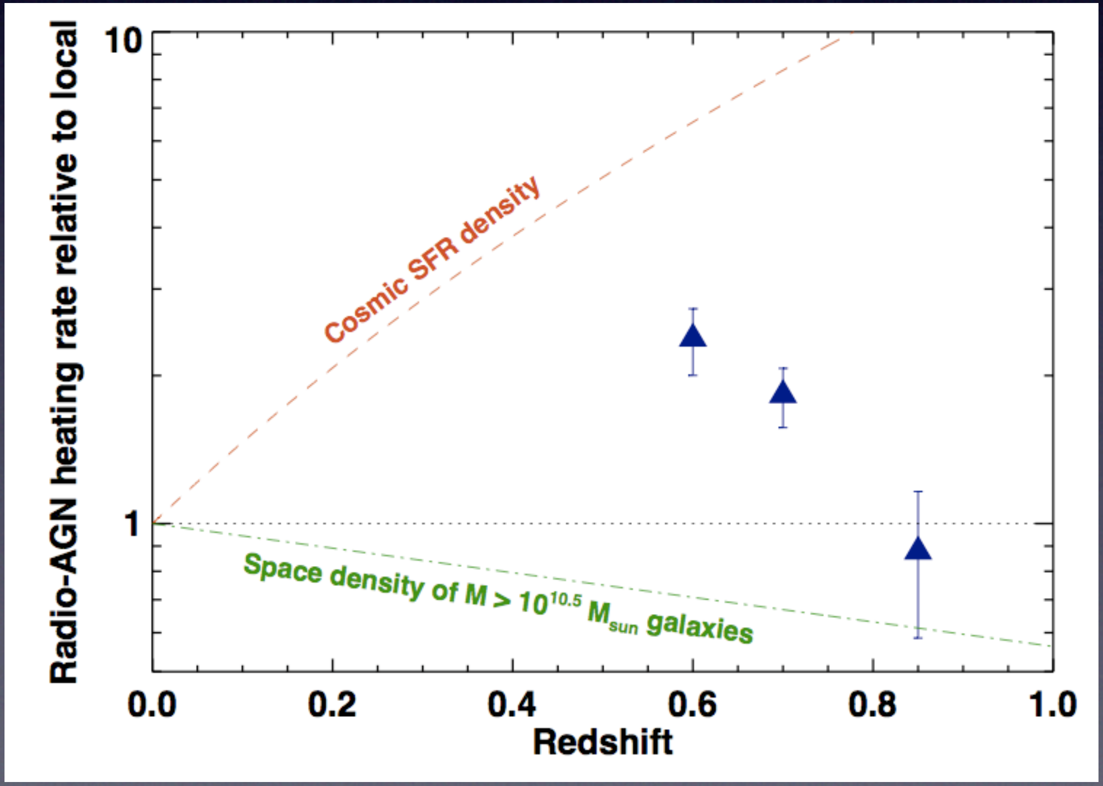
Best et al 2013, in prep

Samples large enough to separate the radiatively inefficient AGN (LERGs) into two sub-slices in redshift. LERG space densities decline at z > 0.7.



Evolving radio-AGN heating rate

Converting radio luminosity functions into heating rates, assuming the local relation, the "feedback" energetic output of radio-AGN peak at z~0.5 and then declines.



Summary

- Not all AGN follow the "standard" accretion disk picture.
- A population of low accretion rate, radiatively inefficient, radio sources, dominates the low-luminosity end of RLF
- These sources are in massive galaxies, and are probably fuelled directly or indirectly from the hot gas halo.
- Low luminosity radio source activity is highly-recurrent with a fast duty cycle, especially in the most massive gals
- In the local Universe the energetic output (over-?) balances cooling rates, leading to feedback cycle.
- The cosmic radio-AGN heating rate increases out to z~0.5, but then peaks and declines to higher redshift.