The Cosmological Evolution of Radio Sources with CENSORS

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Why study the radio source population evolution?

The number density of quasars drops at hi-z.
(Boyle et al 2000, Fan et al. 2001)

Comparing radio and optical AGN may lead to a better understanding of radio-loudness.

The black hole mass bulge relation implies a link between black hole and galaxy formation.
(Kormendy & Gebhardt 2001)

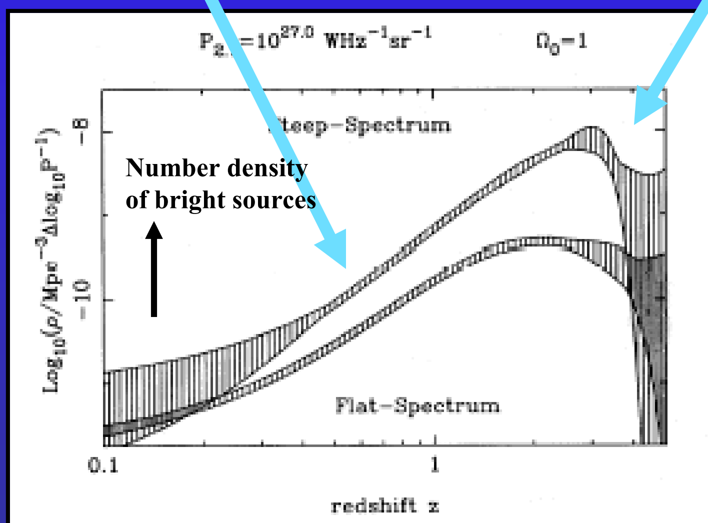
Probe the upper end of the black hole mass function evolution and may effect feedback in galaxy growth.

Radio loud AGN are associated with the most massive black holes
(Best et al. 1998)

What we do we already know about radio source evolution?

The comoving density increases from 0 to z ~ 2.5.
(Dunlop & Peacock 1990)

A decrease at higher z depends on photo-zs.



Jarvis & Rawlings 2000, Jarvis et al. 2001 and Waddington et al. 2001 suffer from a lack of depth or volume and fail to resolve the high-z behaviour.

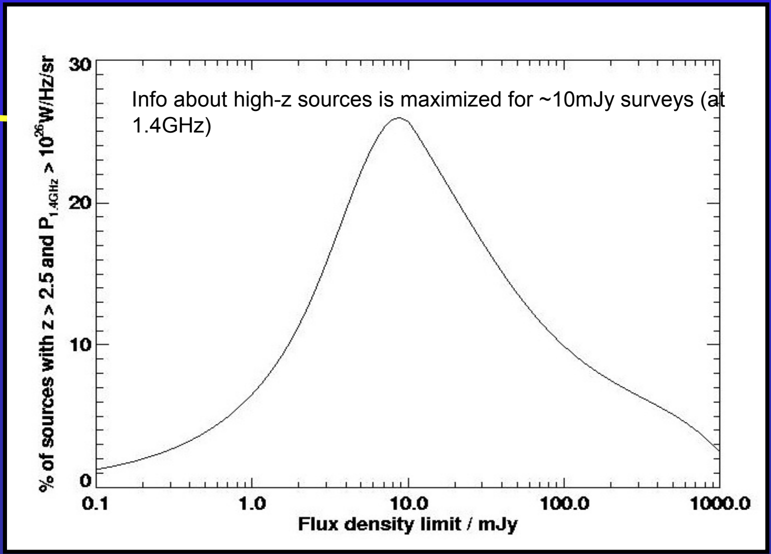
=> We need a survey which targets $z \geq 2.5$

The Combined EIS-NVSS Survey Of Radio Sources

ESO Imaging Survey (EIS):
Patch D; $2^{O}x3^{O}$; B, V, I Bands

NRAO Sky Survey (NVSS):
1.4 GHz

CENSORS: complete to 7.2mJy
150 sources

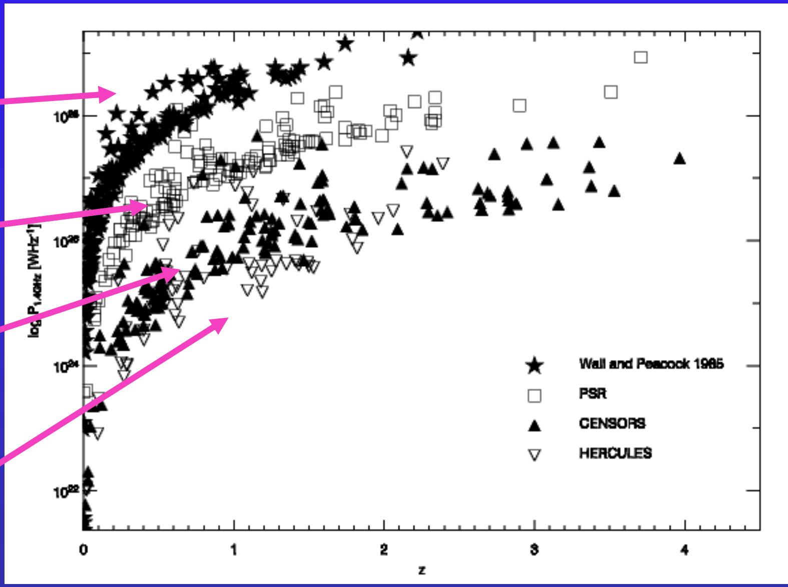


Follow-up:
- ✓Higher resolution 1.4GHz radio maps!
- ✓K band imaging of all but 1 source!
- ✓62% spectroscopically complete!
- ✓K-z relation estimates/photo-zs for all other sources

How do we constrain the radio luminosity function?

DATA: Several radio flux-density limited samples span the P-z plane, preventing luminosity-redshift degeneracy.

- Wall & Peacock
  - 2.7GHz, ≥ 2Jy, 9.81sr, Wall & Peacock 1985.
- Parkes Selected Regions
  - 2.7GHz, ≥ 0.1Jy, 0.075sr, Downes et al. 1986, Dunlop et al. 1989.
- CENSORS
  - 1.4GHz, ≥ 7.2mJy, 1.83×10^{-3}sr, Best et al. 2003.
- Hercules
  - 1.4GHz, ≥ 2mJy, 3.78×10^{-4}sr, Windhorst et al. 1984, Waddington et al. 2001.



We also fit to the integrated source counts and the local radio luminosity function.
Seymour et al. 2004, Windhorst et al. 1984, White et al. 1997, Kellerman & Wall 1987, Sadler et al. 2002, Best et al. 2005

How do we constrain the radio luminosity function?

MODELLING TECHNIQUE:

•The model parameters are the source densities in a grid spanning:

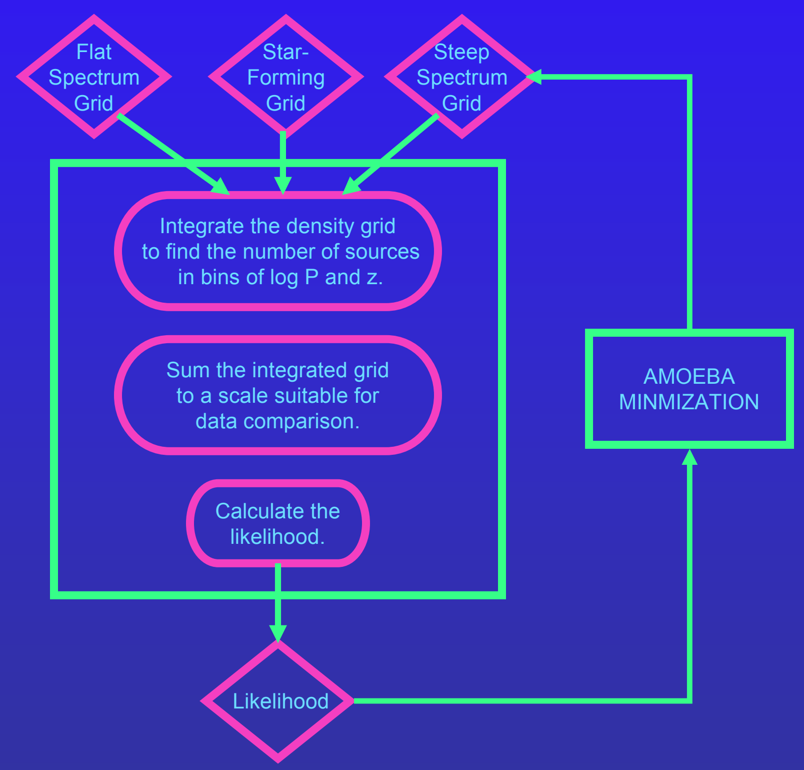
$$19.5 < \log P < 31$$

$$0 < z < 10$$

•Only the steep spectrum source population is modelled. Flat spectrum and star forming sources have fixed densities.

•The likelihood is based on comparison of sample redshift distributions, source counts and the local RLF and the model predictions of these quantities.

•The AMOEBA algorithm is used to minmize the likelihood by varying the densities in the steep spectrum source grid.



How accurate is the minimized density grid?

- Marginalized errors are calculated from a Hessian matrix.
- The Hessian matrix is produced by varying parameters individually, assessing the resulting change in the likelihood.
- It is assumed that the variations consider fall in a range such that ln (likelihood) varies as a Gaussian.

Error in parameter i

$$\sigma_i^{\,2} = [H_{i,i}]^{-1}$$

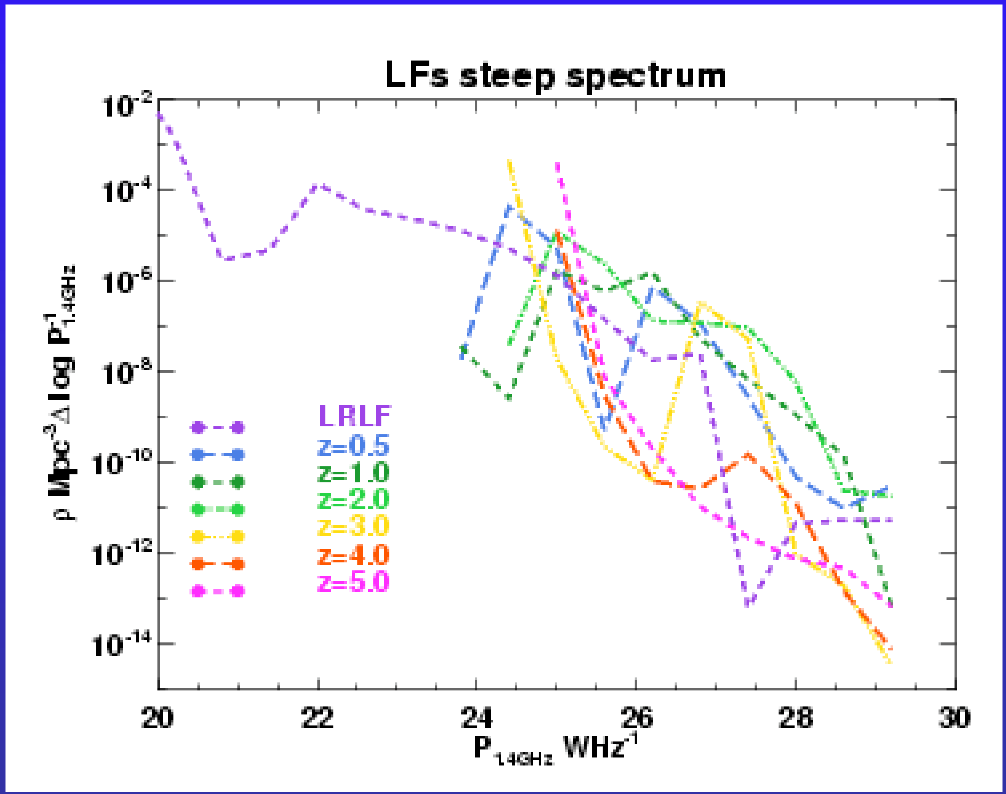
Hessian Matrix element

$$H_{i,j} = \frac{\partial^2 \ln L}{\partial p_i \partial p_j}$$

Likelihood

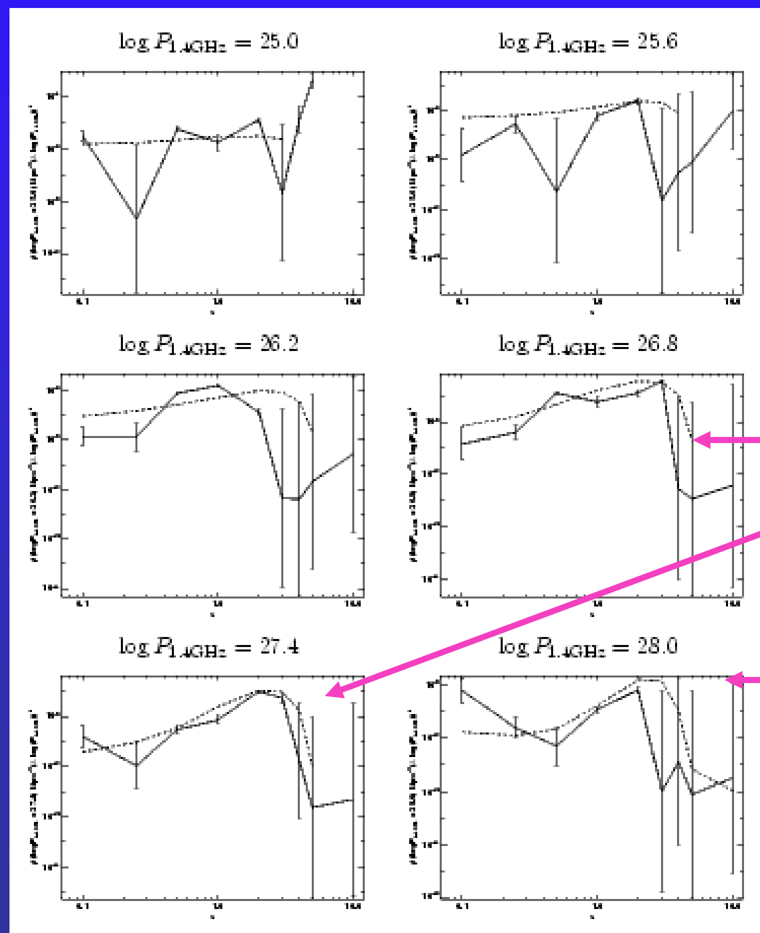
Parameters i and j
(density as a function
of grid position)

Results: Radio luminosity functions



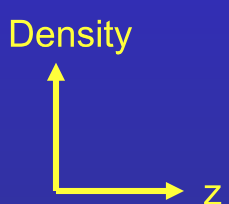
Results: Radio luminosity functions

- Points show the model predictions and errors.
- Dashed lines show the median Dunlop & Peacock result.



Suggestive of a decline in density

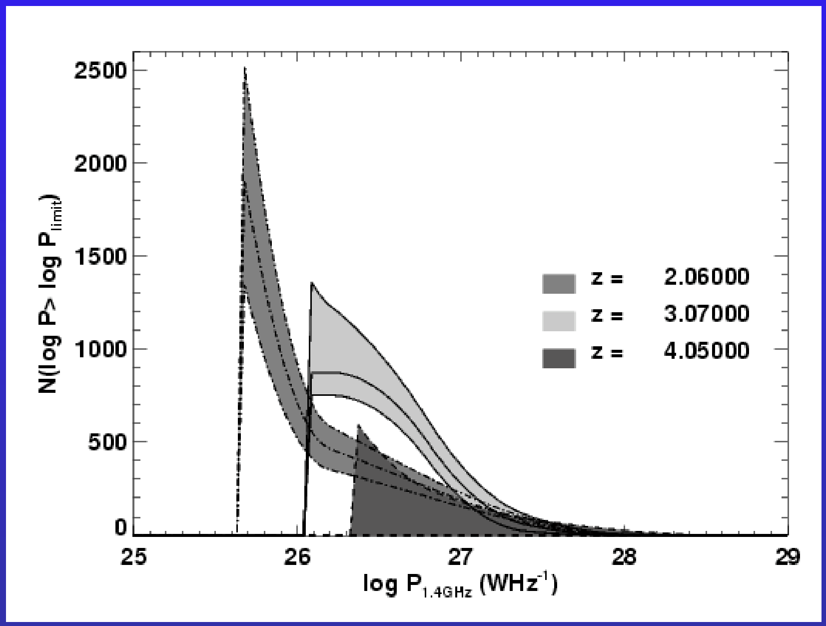
Errors show that we don't have the volume to investigate the most powerful sources



Results: Radio luminosity functions

- The cumulative distribution in log P is proportional to the densities at each redshift.
- This shows that, averaging over the brightest sources around log P ~ 26.5, there is evidence for a peak in the nuber density.

The number of sources of luminosity greater than log P for three redshifts.



The shaded region plots the extent of the marginalized errors

V/Vmax Testing provides an independent assessment of evolution

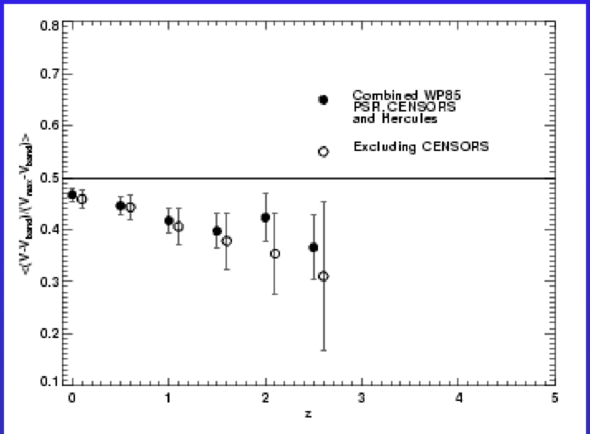
The V/V_{max} test compares the volume within which a source is contained to that within which it could have been detected.

$\langle V/V_{max} \rangle$ >0.5 indicates positive evolution

$\langle V/V_{max} \rangle$ <0.5 indicates negative evolution

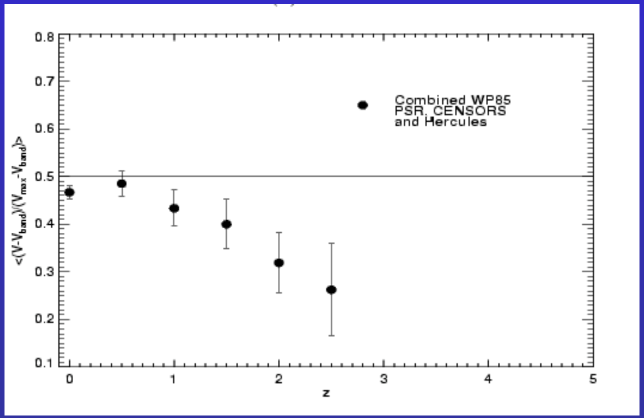
Plot 1

V/V_{max} for all sources above redshift z



There is mild evidence for a negative evolution for sources with z > 2.5

Plot 2



Similar to Plot 1, but only for sources with log P > 28.

Shows stronger evidence for a decline in number density.

Conclusions

- The CENSORS survey, selected from the NVSS, has been followed up using EIS, K-band imaging and spectroscopic observations to produce a radio sample capable of probing the source density in the regime: $z > 2.5$
- With a current spectroscopic completeness of 62%, CENSORS has been used in direct modeling of RLF evolution and in V/V_{max} tests.
- There is evidence for a shallow decline in number density of source in the luminosity range 10^{26} - 10^{27}WHz^{-1} at 1.4GHz.

For more information please see my poster at the conference.

You can contact me in person at the conference, or by email at:

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