THE NATURE OF THE FAINT SUB-MJY RADIO POPULATION

Nick Seymour$^1$, Ian M’Hardy$^2$, Katherine Gunn$^2$, and Derek Moss$^2$

$^1$Institut d’Astrophysique de Paris, 98bis boulevard Arago, 75014, Paris, France, Email: seymour@iap.fr
$^2$School of Physics & Astronomy, University of Southampton, Highfield, Southampton, SO17 1BJ, UK Emails: imh@astro.soton.ac.uk, kfg@astro.soton.ac.uk, dm@astro.soton.ac.uk

ABSTRACT

The up-turn in Euclidean normalised source counts below 1 mJy at 1.4 GHz is well established in many deep radio surveys. There are strong reasons, observationally and theoretically, to believe that this up-turn is due to strong evolution of the starforming population up to $z=2$. However this hypothesis needs further confirmation spectroscopically and the examples in the literature are sparse. Theoretically the up-turn is well modelled by the evolution of the local radio starforming population and is consistent with the up-turn seen in recent mid-infrared source counts at 15 $\mu$m (ISO) and 24 $\mu$m (Spitzer) and the tight correlation of the radio and MIR luminosities of starforming galaxies.

Key words: Radio Galaxies; Surveys.

1. INTRODUCTION

Early radio surveys were dominated by very distant, and hence very luminous, sources which could only be powered by very energetic processes. It is now accepted that this process is accretion of in-falling material onto a super-massive blackhole (and often accompanied by large-scale radio jets). As sensitivities improved many normal galaxies were detected in the radio. Here the radio emission is thought to be due from starformation (ie synchrotron radiation and HII regions) [Condon 1992].

2. 20CM FAINT SOURCE COUNTS

Euclidean normalised source counts (ie $S^{2.5}\times dN/dS$) have for a long time shown an up-turn below 1mJy [Windhorst et al. 1990]. This is now well characterised by many surveys (see Fig 1). Current models [King & Rowan-Robinson 2004, Seymour et al. 2004] explain this as the emergence of a rapidly involving starforming population. This idea is supported by the rapid rise in the starformation rate density (as derived from observations at many wavelengths, eg Hopkins 2004). Additionally, the similar rapid evolution of source counts in the MIR [Appleton et al. 2004, Pozzi et al. 2004] and the well-known correlation of the IR and radio luminosities of starforming galaxies suggests that starformation is the major radio emission process of the faintest radio sources. However the contribution of AGN in the radio below 1mJy is not well known as a) there are few direct observations of un-ambiguous AGN at faint flux densities and b) the reason why only 10% of AGN are strong radio emitters is not well understood (although there are now some more sophisticated models around, eg Jarvis & Rawlings 2004). The simple picture of two unrelated populations (AGNs and starforming galaxies) is most likely not true, especially if AGN activity is triggered by mergers which also induce starformation. The exact contribution to the source counts from AGN and starforming galaxies can only be determined from direct observations of the individual radio sources over the full SED range.
3. THE 13HR ROSAT/XMM SURVEY

Our survey [Seymour et al. 2004] is one of many (eg GOODS, COSMOS etc.) with deep radio observations complimented by deep observations at many other wavelengths. Crucially these all have deep X-ray, optical & IR data which is vital in determining the true nature of the radio emission. Very preliminary analysis of the 13hr ROSAT/XMM Survey indicates that the faint radio population may, indeed, be due to starformation. This hypothesis is suggested by the increase of radio-loudness ($S_{20cm}/S_R$) with increasing redshift and increasing luminosity for the non-AGN population. This result can be explained by the fact that more luminous starbursts, more common in the past, suffer from higher optical extinction due to more dust. AGN show a similar trend, but are clearly offset from the starformation population.

The identifications of starforming galaxies will be essential in determining the evolution of this population and their contribution to the evolution of the starformation density rate which is of particular importance as radio is an unbiased tracer of starformation (in the absence of an AGN contribution). Another possibility is that very distant, steep starformation (in the absence of an AGN contribution, McHardy, 2004). AGN show a similar trend, but are clearly offset from the starformation population.

4. EVOLUTION OF STARFORMING RADIO LUMINOSITY FUNCTION

As an example of what can begin to be done we present a sample of faint radio sources with optical spectra ($S_{20cm} > 30 \mu Jy$ & $R < 21.8$) where we have weeded out strong AGN (ie by using the optical spectra, X-ray luminosity/spectra or radio morphology). We can then use this sample to derive an evolving starforming radio luminosity function which we can compare to various models. We continue with the caveat that a few sources may be contaminated by weak AGN. A more robust separation of AGN activity and starformation will be aided when the Spitzer data is available and we have a full SED. Spitzer is sensitive enough that it is likely to detect all the radio sources, even those without optical counterparts.

The luminosity function is derived using the standard $1/V_{max}$ method where $V_{max}$ is the accessible volume determined by the two detection limits and is presented in Fig 2. The number of objects in each bin and their mean redshift are indicated for each point. The luminosity function at the redshifts indicated (dashed line) are plotted using the best fit evolution parameters.

5. DISCUSSION

The evolution of the luminosity function in Fig 2 is well fitted by the evolution presented (despite the clear incompleteness of the sample at high and low luminosities). However many different models and different combinations of density and luminosity evolution could fit the data presented here. Hence we are in the process of determining redshifts (spectroscopic and photometric) of optically fainter radio sources to create a larger sample. Using this sample we will be able to break the degeneracy of different models and the relative importance of luminosity and density evolution by accurate determination of the non-local luminosity function, the source counts and the starformation density rate.

REFERENCES

Appleton, P. N., Fadda, D. T., Marleau, F. R., et al. 2004, Astrophys. J., Suppl. Ser., 154, 147
Condon, J. J. 1992, ARAA., 30, 575
Hopkins, A. 2004, AJL., in press, astrophy/0407170
Jarvis, M. J. & Rawlings, S. 2004, in "Science with the Square Kilometer Array", eds. C. Carilli and S. Rawlings, New Astronomy Reviews (Elsevier: Amsterdam)
King, A. J. & Rowan-Robinson, M. 2004, MNRAS, 349, 1353
Pozzi, F., Gruppieni, C., Oliver, S., et al. 2004, AJ, 609, 122
Sadler, E. M., Jackson, C. A., Oliver, S., et al. 2004, AJ, 609, 122
Sadler, E. M., Jackson, C. A., Cannon, R. D., et al. 2002, MNRAS, 329, 227
Seymour, N., McHardy, I. M., & Gunn, K. F. 2004, MNRAS, 352, 131
Windhorst, R., Mathis, D., & Neuschaefer, L. 1990, in ASP Conf. Ser. 10: Evolution of the Universe of Galaxies, 389–403