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Measuring the cosmic star-formation rate density using deep radio surveys

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1. Introduction

There is now good agreement between the various methods of estimating the space density of the star-formation rate (SFRD) at low redshifts ($z < 1$), with uncertainties around 30–50%. However, the situation at higher redshifts remains much less clear, with uncertainties in the SFRD, due to e.g. poorly known dust absorption corrections, of as much as 300–500%. Radio emission from star-forming galaxies is unaffected by absorption and scales linearly with star-formation rate, thus the radio luminosity of star-forming galaxies provides an excellent independent, unbiased measure of their star-formation rate. The current deepest 'blank field' radio surveys (reaching <10 μJy rms at 1.4 GHz) are sensitive enough to detect starburst galaxies out to $z \sim 3$, and so potentially offer an excellent way to measure the SFRD. Indeed, modelling of the sub-mJy source counts requires an additional population of faint steep spectrum objects, that are very likely to be starburst galaxies.

2. Sorting the 'wheat from the chaff': discriminating between starbursts and AGN

A significant fraction of the sub-mJy radio population are accretion powered AGN, which must be filtered out to get a sample of purely starburst powered radio sources. We adopt a multi-pronged method for removing AGN powered sources from our deep 1.4 GHz selected radio sample in the 13^H field (Seymour *et al.* 2004). We utilise a wealth of multiwavelength data, including radio spectral and morphological information, optical-to-mid-IR SED modelling, as well as X-ray and optical spectroscopic classification, to select a clean star-formation powered sample.

Radio morphology and spectra. Starburst emission is typically extended on the scale of the optical galaxies, whereas most AGN are either compact or extended with obvious lobes. High resolution 1.4 GHz maps from MERLIN (reaching to ~18 μJy rms) reveal a clear increase in the fraction of resolved sources toward fainter fluxes (see also Muxlow *et al.* 2005). Starbursts have steep spectra with $-1 < \alpha < -0.5$ (where $S_\nu \propto \nu^\alpha$). AGN have a wider range of spectra, so flat or ultra-steep spetrum sources are very likely AGN. Our very sensitive 610 MHz GMRT observations provide spectra for most of the 1.4 GHz-selected radio sample.

Radio vs MIR ratio. The FIR and radio luminosities of starburst galaxies are tightly correlated (the relation spans many decades in luminosity, e.g. Yun *et al.* 2001). Thus we can confident that radio sources falling outside this relation must be AGN powered.

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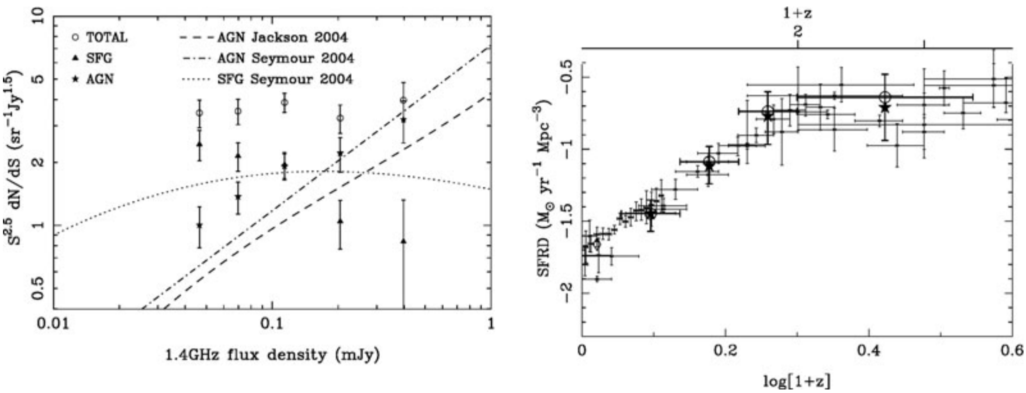

Figure 1. *Left:* Euclidean-normalised 1.4 GHz sub-mJy source counts by source type. *Right:* Star formation density from our radio sample as a function of redshift (coloured circles) compared to a compilation of other SFRD measures (black crosses) taken from Hopkins & Beacom (2006).

Other multiwavelength AGN indicators. *Spitzer* IRAC colour-colour plots can reveal buried AGN from their powerlaw continua which extend redward of the stellar bump (e.g. Lacy *et al.* 2004). Approximately 15% of the radio sources have X-ray counterparts in the deep *XMM-Newton/Chandra* imaging of the radio survey area. Any radio sources detected with $L_X > 10^{42}\,\mathrm{erg\,s^{-1}}$ almost cetainly harbour luminous AGN. Optical spectroscopy is available for nearly all our $R < 22$ radio sources. Broad emission lines cleary idicate the presence of an AGN. Narrow emission line ratio diagnostics are also available. We carry out SED modelling and calculate photometric redshifts using the 14 band near-UV/optical/mid-IR photometric coverage of our radio survey area.

3. Results

Using the AGN/Starburst discriminators listed above we identify signatures of AGN activity in ∼200 of an initial sample of ∼450 radio sources selected at 1.4 GHz. The remaining sources are most likely to be star-formation powered. In fig. 1 we present the sub-mJy 1.4 GHz source counts, with the AGN and star-formation powered populations shown separately. As predicted, the star-forming galaxies become the dominant population below ∼0.1 mJy. Note that the faint AGN counts are slightly higher than would be expected from simply extrapolating the AGN counts from brighter fluxes, possibly the 'tip' of the radio-quiet AGN population. We use the radio selected starburst sample to calculate an independent and unbiased measure of the evolving SFRD out to $z \sim 2$, also shown in fig. 1. The SFRD estimated from our radio sample is comparable with other measures from the literature (e.g. Hopkins & Beacom 2006), but is towards the higher end of the distribution. We are currently working to extend our work to a wider radio sample in order to mitigate the effects of cosmic variance, and to constrain better the SFRD at $z > 1$.

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