The Phoenix Deep Survey: Evolution of Star Forming Galaxies

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Abstract. The Phoenix Deep Survey (PDS) is a multiwavelength survey based on deep 1.4 GHz radio observations used to identify a large sample of star forming galaxies to $z = 1$. Photometric redshifts are estimated for the optical counterparts to the radio-detected galaxies, and their uncertainties quantified by comparison with spectroscopic redshift measurements. The photometric redshift estimates and associated best-fitting spectral energy distributions are used in a stacking analysis exploring the mean radio properties of U-band selected galaxies. Average flux densities of a few µJy are measured.

1 Introduction

The study of galaxy evolution in recent years has included a strong focus on the star formation properties of galaxies. Many of these studies are based primarily on selection at ultraviolet (UV) and optical wavelengths, known to be strongly affected by obscuration due to dust. It has been shown that selection at these wavelengths results in samples of star forming systems that miss a significant fraction of heavily obscured galaxies [20]. There have moreover been suggestions that the most vigorous star forming (SF) systems suffer the most obscuration [2,17,6,22,16]. Radio selection provides an efficient tool to construct a SF galaxy sample free from dust induced biases, and the average obscuration in such samples indeed appears significantly higher than in optically selected samples [2,17].

Motivated to construct a homogeneously selected sample of SF galaxies, unbiased by the effects of obscuration due to dust, the Phoenix Deep Survey (PDS, see http://www.atnf.csiro.au/people/ahopkins/phoenix/) is based on a deep (60 µJy), wide-area (4.5 square degree) 1.4 GHz survey with the Australia Telescope Compact Array. This provides one of the largest existing deep 1.4 GHz source catalogues [14] containing a large fraction of SF galaxies spanning the broad redshift range $0 < z < 1$. The PDS has already been highly successful in providing a basis for several investigations of the nature of SF galaxies and their evolution ([12,2,14] and references therein). Throughout the present investigation we assume a ($\Omega_M = 0.3, \Omega_\Lambda = 0.7, H_0 = 70$) cosmology.

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2 Photometric Redshift Analysis

Deep *UBVRI* observations of about one square degree within the PDS have recently been analysed (these are described in detail in [21]). These data achieve a 5σ level of $R_{\rm AB} \approx 24.5$ and optical catalogues have been constructed and cross-correlated with the 1.4 GHz catalogues. This multicolour data has been used to estimate photometric redshifts for all ≈ 40000 galaxies detected in each of the 5 bands. This includes about 800 optical counterparts of the radio detected galaxies in this area.

For our analysis we use the photometric redshift code of Connolly et al. [10] (see also [7]). We use SED templates based on those of Coleman et al. [8] (hereafter CWW), providing four standard SEDs (E/S0, Sbc, Scd, Im), extended in the UV and IR wavelength regions using the GISSEL98 code [5]. Rather than using these four SEDs directly, we use the method of optimal subspace filtering [7] to provide a large number (61) of smoothly interpolated SEDs based on the reference CWW SEDs. This supports more realistic type estimates for most of the galaxies. We allow the possible photometric redshifts to range from 0.0 to 1.3 and also apply a prior constraining the absolute magnitudes of the galaxies to the broad range $-29 < M_B < -16$ (having the effect of removing photometric redshift fits with unphysically high or low redshifts).

Figure 1 compares the photometric redshift estimate with spectroscopic redshift for 116 radio sources with an optical counterpart having both *UBVRI* detections and spectroscopic data. The filled symbols (including points) indicate the spectroscopic classification, while the open symbols give an estimate of the best-fitting SED template type (after binning the 61 subspace filtered templates into four bins, based approximately on the closest CWW-type template). The reliability of the photometric redshifts can be characterised in several ways. The rms of $|\Delta z| = |z_{\rm photo} - z_{\rm spec}|$ is 0.1 for these 116 galaxies. The rms of $|\log[(1+z_{\rm photo})/(1+z_{\rm spec})]|$ is 0.028 (implying a typical uncertainty of 7% in $1+z_{\rm photo}$). The rms of $|\Delta z|/(1+z_{\rm spec})$ is 0.065. This level of reliability in the photometric redshifts compares favourably with that of other analyses [11,19]. As well as providing reasonable redshift estimates, the best-fitting SED is also a good indicator of the galaxy type, in the sense that spectroscopic absorption-line systems are mostly well-fit by early-type SEDs, while SF systems are mostly well-fit by late-type SEDs.

3 Stacking Analysis of *U*-Band Galaxies

The technique of stacking small subregions of an image at the locations of a known population of objects that are not otherwise detected, in order to extract a rough estimate of the mean emission properties of a population, has been used with some success at X-ray wavelengths [4,18]. This technique has been applied to XMM observations of the PDS [12] to explore the X-ray properties of radio-detected SF galaxies. Following this success we extended the method to radio wavelengths, performing a stacking analysis using the 1.4 GHz mosaic