An Ultraviolet Redshift Survey: A New Estimate of the Local Star Formation Rate

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Abstract. We present the first results of an ongoing spectroscopic survey of galaxies selected in the rest-frame ultraviolet. The source catalogue was constructed from a flux-limited sample of stars, galaxies and QSOs imaged at 2000 Å with the FOCA balloon-borne camera ([6]). The redshift distribution obtained for 45 galaxies spans $0 < z < 0.3$ and a high fraction of the spectra show intense nebular emission lines and ultraviolet-optical colors considerably bluer than can be accounted for via normal Hubble sequence galaxies. From the rest-frame ultraviolet galaxy luminosity function, and adopting a normal IMF, we use the integrated UV light to our survey limit to estimate the local volume averaged star formation rate. We find a value significantly larger than recent estimates and argue this must be a lower limit to the true value. Our results suggest the local abundance of star-forming galaxies has been underestimated in surveys based on optical data.

INTRODUCTION

Considerable progress has recently been made in delineating the star formation history of normal field galaxies (see [1] for a recent review). However, it remains unclear whether the various star formation rates (SFR) are being inferred consistently. Various diagnostics have been used including nebular emission lines ([2], [3]) and the far UV continuum flux ([4], [5]). In most cases, these estimates are based on only the bright portion of the luminosity function.

The existing and forthcoming data could be better interpreted if there was a greater overlap between the low and high redshift diagnostics. With this in mind, we are undertaking a deep UV-selected galaxy redshift survey based on FOCA balloon-borne images ([6]). Our survey is designed to span a moderate...
redshift range $0 < z < 0.3$ which aims to provide an independent measure of the declining SFR and a robust estimate of the present star formation density.

DATA

Our survey strategy can be summarized as follows:

• The most suitable field for study from Milliard et al’s series of 4 UV exposures is Selected Area 57 (SA57): it has been studied with both the FOCA 1000 and FOCA 1500 instruments, ensuring the deepest, most reliable wide-field ($2.3^\circ$) catalogue.

• The limiting magnitude for reliable photometry at 2000Å is $m_{UV}=18.5$ at which the surface density of galaxies is $\simeq 200$ deg$^{-2}$.

• The imaging resolution of FOCA data is 20 arcsec which provides a positional accuracy of $\simeq 4.5$ arcsec rms. Target astrometry suitable for multi-object spectroscopy has been obtained by matching the FOCA 1000 catalogue for SA57 with APM scans of the Palomar Sky Survey 103a-O and 103a-E plates.

• Optical spectroscopy has been conducted with the Hydra multi-fiber spectrograph on the 3.5m WYIN telescope within a $1^\circ$ field and work is continuing with the WYFFOS fiber spectrograph at the prime focus of the 4.2m WHT.

• Reliable spectra have so far been analysed for 45 sources to $m_{UV}=18.5$, of which 3 are QSOs and 2 are stars.

RESULTS

Figure 1 shows the redshift distribution obtained from our current sample. A high fraction of the spectra reveal strong [O II] emission lines. We have predicted UV-optical colors by folding model spectra from Poggianti (1997) [8] through the filter functions of both the UV ($\Delta \lambda=150$ Å) and photographic photometric systems. The UV-optical colors (Figure 2) are considerably bluer than can be accounted for via normal Hubble sequence galaxies ([7]) as would be expected if the bulk of the UV-selected sources are star-forming galaxies. The two starburst (SB) models in Figure 2 refer to models constructed assuming a $10^7$ year long burst of star-formation prior to the present time involving 30% and 80% of the galactic mass respectively. Extinction is not included in these models.

By assigning $k$-corrections on the basis of the color-redshift relation, we have also derived a UV luminosity function shown in Figure 3. Our best fit
FIGURE 1. Normalized redshift distribution for the WIYN results. The solid line is the predicted distribution assuming the King & Ellis (1985) type-dependent optical luminosity function and $k$-corrections derived from model spectra of Poggianti (1997).

FIGURE 2. Ultraviolet-B color versus redshift. Curves refer to the predicted color-redshift relation for the Poggianti (1997) model spectra and are used to assign $k$-corrections to each source. SB’s are two starburst models described in the text.

Schechter function has parameters indicated on the figure and has a surprisingly steep faint end slope. The luminosity density at 2000Å derived from the integrated emission of the observed galaxies, with absolute magnitudes $M_{UV} \lesssim -16$ and mean redshift $\bar{z} \sim 0.15$, is:

$$\rho_{2000} = (1.6 \pm 0.7) \times 10^{26} \ h \ ergs \ s^{-1} \ Hz^{-1} \ Mpc^{-3}. \hspace{1cm} (1)$$

The ultraviolet radiation flux can be used to indicate the instantaneous ejection rate of heavy element $\dot{\rho}_Z$ ([9]):

$$\frac{\rho_{2000}}{h \ ergs \ s^{-1} Hz^{-1} Mpc^{-3}} \approx 3.8 \times 10^{29} \ \frac{\dot{\rho}_Z}{h \ M_{\odot} yr^{-1} Mpc^{-3}} \hspace{1cm} (2)$$

The conversion efficiency is fairly insensitive to the assumed initial mass function (IMF), unlike that for the star-formation-rate $\dot{\rho}_*$. Assuming a Salpeter IMF:

$$\dot{\rho}_* = 42 \times \dot{\rho}_Z \approx (1.8 \pm 0.7) \times 10^{-2} h \ M_{\odot} yr^{-1} Mpc^{-3}. \hspace{1cm} (3)$$

This value is shown in Figure 4 together with other recently published estimates as a function of redshift ([9]). Our estimate appears to be twice as large.
FIGURE 3. The observed UV luminosity function \( (H_0=100 \text{ kms sec}^{-1} \text{ Mpc}^{-1}) \) and a Schechter function fit whose parameters are indicated.

FIGURE 4. The redshift dependence of the comoving volume-averaged star formation rate following Madau (1997) and assuming a Salpeter IMF. Our estimate is the diamond symbol placed at a mean redshift \( \bar{z} \sim 0.15 \). The \( H_\alpha \) data is from Gallego et al. (1995), the CFRS data from Lilly et al. (1996) and the HDF data from Madau (1997).

as that derived from \( H_\alpha \) surveys ([2]). As we have not taken dust extinction into account and our luminosity function is rising steeply at the faint end, the true integrated value could be even larger.

In summary, from various viewpoints, our data suggests that optical surveys of the local universe may have seriously underestimated the abundance of star-forming galaxies. If SA57 is a representative field, our result reduces quite significantly the claimed redshift evolution of the star-formation-rate inferred from the steep slope of the faint blue galaxy counts, a substantial fraction of which are being sampled at 2000 Å at modest redshift.

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