Near-identical star formation rate densities from Hα and FUV at redshift zero

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Accepted xx. Received YYY; in original form ZZZ

ABSTRACT

For the first time both Hα and far-ultraviolet (FUV) observations from an Hi-selected sample are used to determine the dust-corrected star formation rate density (SFRD: \( \dot{\rho} \)) in the local Universe. Applying the two star formation rate indicators on 294 local galaxies we determine \( \log(\dot{\rho}_{\text{H} \alpha}) = -1.68^{+0.11}_{-0.08} \) \([M_\odot \text{ yr}^{-1} \text{ Mpc}^{-3}]\) and \( \log(\dot{\rho}_{\text{FUV}}) = -1.71^{+0.12}_{-0.13} \) \([M_\odot \text{ yr}^{-1} \text{ Mpc}^{-3}]\). These values are derived from scaling Hα and FUV observations to the Hi mass function. Galaxies were selected to uniformly sample the full Hi mass (\( M_{\text{Hi}} \)) range of the Hi Parkes All-Sky Survey (\( M_{\text{Hi}} \sim 10^7 \) to \( 10^{10.7} M_\odot \)). The approach leads to relatively larger sampling of dwarf galaxies compared to optically-selected surveys. The low Hi mass, low luminosity and low surface brightness galaxy populations have, on average, lower Hα/FUV flux ratios than the remaining galaxy populations, consistent with the earlier results of Meurer. The near-identical Hα- and FUV-derived SFRD values arise with the low Hα/FUV flux ratios of some galaxies being offset by enhanced Hα from the brightest and high mass galaxy populations. Our findings confirm the necessity to fully sample the Hi mass range for a complete census of local star formation to include lower stellar mass galaxies which dominate the local Universe.

Key words: galaxies: luminosity function – galaxies: star formation – surveys – ultraviolet: galaxies

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1 INTRODUCTION

The star formation rate density (SFRD: $\rho$) of the local Universe provides an important observational constraint on cosmological theories explaining the formation and evolution of galaxies and, therefore, on the build-up of stellar mass since the Big Bang. By combining ultraviolet (UV), optical, infrared and radio continuum survey results, Lilly et al. (1996) and Madau et al. (1999) showed how SFRD varies with redshift. In the subsequent two decades there has been considerable research quantifying the evolution of $\rho$ (for a summary see Madau & Dickinson 2014). There is a growing consensus that the SFRD of the Universe peaked at $z \sim 1.9$, $\sim 3.5$ Gyr after the Big Bang and then declined exponentially to the current epoch (e.g., see Gallego et al. 1995; Hopkins & Beacom 2006; Bauer et al. 2013; Madau & Dickinson 2014).

Different star formation tracers can be used to measure the local SFRD, and fluxes from the H$\alpha$ emission line and the far-ultraviolet (FUV) continuum are commonly used. Each tracer has its own strengths and biases (see the overview in Madau & Dickinson 2014). H$\alpha$ provides a direct estimate of the ionising output of a stellar population, and thus its content of ionising O-type stars. As such it provides a direct measure of recent massive star formation and does not require adjustment for factors such as chemical abundances, unlike other emission line tracers (e.g., Moustakas et al. 2006). Flux calibration, active galactic nuclei (AGN) contamination, stellar absorption, initial mass function (IMF) selection and dust extinction need to be considered, however, for H$\alpha$ surveys making SFRD measurements. Prominent and recent H$\alpha$ surveys include Gallego et al. (1995); Tresse & Maddox (1998); Sullivan et al. (2000); Brinchmann et al. (2004); Gunnawardhana et al. (2013); Van Sistine et al. (2016). See Gunnawardhana et al. (2013) for a useful compilation of SFRD measurements derived from narrowband surveys.

The ultraviolet continuum ($\lambda \sim 912 - 3000$ Å) is dominated by the emission of O- and B-type stars (Meurer et al. 2009) and thus is sensitive to the formation of somewhat lower mass stars than H$\alpha$ emission, and hence of longer main sequence lifetimes. With the advent of the GALEX satellite most of the sky has been imaged in the near and far ultraviolet (Martin et al. 2005). FUV-derived SFRD measurements require sizeable corrections for flux attenuation by dust (e.g., Driver et al. 2008; Robotham & Driver 2011), with considerable spread ($\sim$ 1 mag for $z \sim 0$) in the estimates made for this important correction (Madau & Dickinson 2014). Widely cited and recent UV-derived SFRD measurements include Schiminovich et al. (2005); Salim et al. (2007); Reddy & Steidel (2009); Bouwens et al. (2012); McLeod et al. (2015) and see the compilation in Madau & Dickinson (2014).

The selection of the sample used to estimate the SFRD of the local Universe is also important in making an accurate measurement (Meurer et al. 2006). Ideally all galaxies in a large volume of the local Universe should have their star formation rate (SFR) measured. Many surveys use optically-selected samples, although such surveys have well known biases against low luminosity and low surface brightness (LSB) galaxies (e.g., Kennicutt et al. 2008; Sweet et al. 2013). H$\alpha$ selection provides an alternative method for choosing the input sample for SFRD studies. It avoids the biases of optical selection and ensures the sample has an interstellar medium (ISM), a necessary condition for star formation (e.g., Leroy et al. 2008). While star formation occurs in a molecular medium (e.g., Shu et al. 1987; Wong & Blitz 2002; Bigiel et al. 2008), molecular ISM has proven difficult to detect in low luminosity and LSB galaxies, while H$\alpha$ is readily found (Mihos et al. 1999; Koribalski et al. 2004; Bigiel et al. 2008; Boselli et al. 2014; Van Sistine et al. 2016). An H$\alpha$-selected sample, therefore, helps to give a wide range of local gas-rich, star-forming galaxies but excludes gas-poor galaxies which typically have negligible star formation, such as early-types and dwarf spheroids (e.g., Meurer et al. 2006; Bigiel et al. 2008; Gavazzi et al. 2012). H$\alpha$-selection also tends to disfavour high density environments such as galaxy clusters (which also typically show little star formation), while favouring low density filaments and voids (Dènes et al. 2014; Moorman et al. 2014). Hanish et al. (2006) and Van Sistine et al. (2016) have previously calculated the local SFRD using H$\alpha$ observations on H$\alpha$-selected samples.

Until recent decades there have been very few galaxy surveys utilising two independent SFR tracers on a homogeneous sample (Meurer et al. 1999; Sullivan et al. 2000; Takeuchi et al. 2005; Boselli et al. 2009). Those with rigorously-selected samples provide an invaluable way to examine and directly calibrate the differences between the two SFR measurements, including at both extremes of the luminosity functions (e.g., Yan et al. 1999; Salim et al. 2007; Lee et al. 2009; Weisz et al. 2012).

For the first time we report on both H$\alpha$ and FUV observations of an H$\alpha$-selected sample of galaxies, thereby enabling a direct comparison of the SFRD ($z \sim 0$) values arising from these two commonly-used SFR indicators in the local Universe.

Targets for the Survey of Ionization in Neutral Gas Galaxies (SINGG; Meurer et al. 2006) and the Survey of Ultraviolet emission of Neutral Gas Galaxies (SUNG; Wong 2007) were chosen to thoroughly sample the H$\alpha$ properties of galaxies. The same number of targets in each decade of H$\alpha$ mass ($M_{H\alpha}$) were selected, to the extent allowed by the parent sample, with the nearest targets at each H$\alpha$ mass chosen for observation. The data typically contain just one H$\alpha$ source per set of multiwavelength images. This approach allows reasonable sampling of the full range of the H$\alpha$ mass function (HIMF) with limited telescope resources. It also allows us to derive volume densities by scaling to the HIMF, using the method employed by Hanish et al. (2006).

The paper is organised as follows: Section 2 outlines the two surveys, SFR calibrations, sample selection and the HIMF-based methodology we use to determine the SFRD for the local Universe. Section 3 presents the results of our calculations and details the systematic differences observed in H$\alpha$/FUV flux ratios. Section 4 shows how near-identical SFRD values arise despite the systematic differences between the two SFR indicators. We present our conclusions in Section 5.

The Salpeter (1955) single power-law IMF over a mass range of $0.1 - 100$ $M_\odot$, a Hubble constant of $H_0 = 70$ km s$^{-1}$ Mpc$^{-1}$ and cosmological parameters for a $\Lambda$CDM cosmology of $\Omega_0 = 0.3$ and $\Omega_\Lambda = 0.7$ have been used throughout this paper.
2 DATA AND METHODOLOGY

2.1 SINGG Survey

SINGG samples galaxies from the HI Parkes All-Sky Survey (HIPASS: Meyer et al. 2004; Zwaan et al. 2004; Koribalski et al. 2004). Hanish et al. (2006) sets out the approach taken here to calculate the SFRD in detail, and the Zwaan et al. (2005) HIMF parameters used are listed in Table 1. SINGG observations were made with both R-band and narrowband Hα filters to isolate Hα. Hα emission (at rest λ = 6562.82 Å) primarily arises as a result of the photoionisation of HI regions around high mass (M∗ ≥ 20 M☉), short-lived (t < 10 Myr) O-type stars.

The processing used on SINGG’s first data release (Meurer et al. 2006; Hanish et al. 2006) has been applied to the SINGG sample of 466 galaxies from 288 HIPASS objects (see Meurer 2018, in prep.). The distances and corrections for [NII] contamination, stellar absorption, and foreground and internal dust absorption are unchanged from Meurer et al. (2006). Optical observations are corrected for internal dust attenuation in accordance with the empirical relationship of Helmboldt et al. (2004), using uncorrected R-band absolute magnitudes and Balmer line ratios (see Meurer et al. 2006).

To ensure all star-forming areas were identified for each HIPASS target, an examination of the SINGG three-colour FITS images was undertaken (primarily by FAR and GM). Apertures were set in a consistent manner, ensuring all detectable Hα emission from the targets was included.

2.2 SUNGG Survey

SINGG’s sister survey, SUNGG, measured NUV (2273 Å) and FUV (1515 Å) fluxes. UV emission arises from both O- and B-type stars and consequently traces a wider range of initial masses (M∗ ≥ 3 M☉) and stellar ages than Hα emission. SUNGG observed 418 galaxies from 262 HIPASS objects at both FUV and NUV wavelengths (Wong 2007; Wong et al. 2016). We use FUV as our SFR tracer as it is not as contaminated by hot old stellar remnants (white dwarfs) as the NUV band is (e.g., Calzetti et al. 2000; Salim et al. 2007; Hao et al. 2011).

The SUNGG survey processing used in this work is largely unchanged from Meurer et al. (2009) and Wong (2007), and will be described in Wong 2018 (in prep.). SUNGG corrects for foreground galactic extinction using the reddening maps from Schlegel et al. (1998) and applying the Cardelli et al. (1989) extinction law. The FUV correction for internal dust attenuation is unchanged from Wong et al. (2016), and is based on the FUV-NUV colour and utilises the low redshift algorithm of Salim et al. (2007).

2.3 SFR calibrations

The Hα-derived SFR (SFRHα) for each SINGG galaxy is calculated assuming solar metallicity and continuous star formation, and applies a Salpeter (1955) single power-law IMF over the birth mass range of 0.1 to 100 M☉, which we adopt throughout. The Meurer et al. (2009) SFRHα calibration is applied and compared to the Kennicutt (1998) calibration (in parentheses):

\[ \text{SFR}_{H\alpha} \left[ M_\odot \, \text{yr}^{-1} \right] = \frac{L_{H\alpha} \left[ \text{ergs s}^{-1} \right]}{1.04 \times 10^{15} \text{H} \odot} \]  

(1)

The FUV-derived star formation rate (SFRFUV) is calculated using the Meurer et al. (2009) SFRFUV calibration, with the Kennicutt (1998) calibration in parentheses:

\[ \text{SFR}_{FUV} \left[ M_\odot \, \text{yr}^{-1} \right] = \frac{L_{\text{FUV}} \left[ \text{ergs s}^{-1} \text{Å}^{-1} \right] \times 9.12 \times 10^{18}}{9.09} \]  

(2)

Meurer et al. (2009) and Kennicutt (1998) star formation calibrations are derived with identical assumptions on the IMF slope and mass limits but the calibrations use different stellar populations models: Starburst99 (Leitherer et al. 1999) and Madau et al. (1998), respectively.
we sum the luminosities (Martins et al. 2010; LaMassa et al. 2013). are typically dwarfed by the emission at larger radii (e.g., formation activity lies within circumnuclear regions, which smaller than the flux of the most luminous galaxy in the Hi galaxies. For these targets, 160 are single galaxies and the remaining 50 analysed in this paper arise from 210 HIPASS targets. Of these targets, 160 are single galaxies and the remaining 50 lack the ability to distinguish individual galaxies within the 15’ survey, if it was incorporated into the sample. Appendix A discusses the galaxy and the disproportionate effects it would have on our survey, if it was incorporated into the sample. HIPASS provides the total Hi mass of the target, with no ability to distinguish individual galaxies within the 15’ beam of the Parkes 64-metre telescope. The 294 galaxies analysed in this paper arise from 210 HIPASS targets. Of these targets, 160 are single galaxies and the remaining 50 are systems with two or more galaxies, containing a total of 134 galaxies. For Hi sources comprised of multiple galaxies, we sum the luminosities (Hi, FUV and R-band) of the individual galaxies to get aggregate luminosities for the system. Eleven systems have one minor galaxy for which we have Hα data but not FUV data. The Hα flux of each of these minor system members is at least an order of magnitude smaller than the flux of the most luminous galaxy in the system. Despite the exclusion of the minor galaxy lacking FUV data, we assessed these systems as being materially complete and have, therefore, retained them in the sample. After having excluded J0242+00, we make no further allowance for AGN contamination in the sample, as AGN are not likely to make a major contribution to the total luminosity densities (e.g. Sullivan et al. 2000; Driver et al. 2018). Importantly, the impact of an AGN on the host’s star formation activity lies within circumnuclear regions, which are typically dwarfed by the emission at larger radii (e.g., Martins et al. 2010; LaMassa et al. 2013). The SFRD values derived in this paper are local, with the 294 galaxies spanning distances of 3 to 135 Mpc, at an average value of ~38 Mpc (median ~20 Mpc). This compares to the 110 galaxies in the first data release which, due to filter availability, were particularly local (median distance ~13 Mpc) and were predominantly standalone, rather than group members. The much larger sample used here spans over 3.5 orders of magnitude in Hi mass and ~4.5 dex in R-band luminosity (see Fig. 1).

### Table 1. Hi mass density (ρHi) and dust-corrected SFRD results using the listed HIMF models and SFR calibration Equations 1 (Hα) and 2 (FUV). Column descriptions [units]: Col. (1): Source reference. Col. (2): Schechter fit power-law slope. Col. (3): Schechter fit normalisation \[10^{-3} \text{Mpc}^{-3}\]. Col. (4): Schechter fit mass density \[10^{-3} \text{Mpc}^{-3}\]. Col. (5): Hi mass density \[10^{-3} \text{Mpc}^{-3}\]. Col. (6): SFRD derived from Hα observations, respectively, using the named HIMF and Equations 1 and 2, respectively. Cols. (6 – 7): Random and systematic errors have been added in quadrature, where applicable. See Section 4.3.1 for further discussion.

#### 2.4 The sample
The combined SINGG/SUNGG sample analysed here comprises the 294 galaxies that have flux measurements in four bands: R, Hα, NUV and FUV. Two galaxies (J0145-43 and J1206-22) meeting the above criteria are not included in the final sample, due to severe foreground star contamination.

One further galaxy, J0242+00 (NGC 1068), is shown in several figures but is excluded from the final SFRD calculations. It is remarkably luminous for its Hi mass and would increase \(\mu_{\text{H\alpha}}\) and \(\mu_{\text{FUV}}\) by 36 and 13 per cent, respectively, if it was included in the sample. Appendix A discusses the galaxy and the disproportionate effects it would have on our survey, if it was incorporated into the sample.

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60% complete Arecibo Ultra-Deep Survey (AUDS) (Hopmann et al. 2015), the 40% complete Arecibo Legacy Fast ALFA (ALFALFA) survey (Martin et al. 2010), the final ALFALFA catalog (Jones et al. 2018) and Hanish et al. (2006). Utilising a HIPASS-selected sample, Hanish et al. (2006) obtains distances from Karachentsev et al. (2004) and the Mould et al. (2000) model for deriving distances from radial velocities, allowing for infalling to nearby clusters and superclusters. In contrast, the Zwaan et al. (2005) HIMF applied in this paper uses pure Hubble flow distances for the HIPASS survey. See Sections 4.3.1 and 4.3.3 for further discussion.

3 RESULTS

3.1 Luminosity densities and the local SFRD

The R-band, Hα, FUV and NUV luminosity density values derived from the sample are listed in Table 2, with values given before and after correction for internal dust. Dust-corrected SFRD values $\rho_{\text{H} \alpha} = 0.0211$ and $\rho_{\text{FUV}} = 0.0197 \ [M_\odot \text{yr}^{-1}\text{Mpc}^{-3}]$ are generated from Equations 1 and 2, respectively. The quoted uncertainties correspond to an error of 11% – 35%. The choice of SFR calibrations is a possible source of systematic error. The Meurer et al. (2009) calibrations and the widely adopted Kennicutt (1998) SFR calibrations (Equations 1 and 2) were both applied, to aid comparisons with other studies. Using Kennicutt (1998) generates values of $\log(\rho_{\text{H} \alpha}) = -1.76$ and $\log(\rho_{\text{FUV}}) = -1.71 \ [M_\odot \text{yr}^{-1}\text{Mpc}^{-3}]$.

The relative importance of each mass bin to the total luminosity density is shown in Fig. 2. When comparing the contributions of different bins, note that the lowest mass bin is wider than the others, to ensure all bins contain a statistically significant number of galaxies. Figure 2 shows that the largest contribution to the total luminosity density is from the mass range $\log(M_{\text{HI}}/M_\odot) = 9.5 – 10.5$. This bin includes the grand-design spiral galaxy J1338-17 (NGC 5247; Khoperskov et al. (2012)), the target with the largest impact on the SINGG/SUNGG $l_{\text{H} \alpha}$ and $l_{\text{FUV}}$ values, comprising 4.6 and 3.9 per cent of the totals, respectively. See Table B1 for a list of galaxies with the highest impact on the total luminosity densities.

Individual galaxies within the two lowest H$_{\text{I}}$ mass bins
also make significant contributions. J1247-03 (NGC 4691), for example, with a low HI mass (log(M_{HI}/M_\odot) = 8.17), generates the second-highest I_{H\alpha} and I_{FUV} contributions (4.3 and 3.6 per cent, respectively). J1247-03 is a SBb peculiar galaxy with significant central star formation and supernovae activity (see Garcia-Barreto et al. (1995) for further discussion). The lowest mass bin contributes the same, or more, per dex to the total H\alpha and FUV luminosity densities and SFRDs than the highest HI mass bin (see columns (5) and (6) of Table 3a). Probing the low end of mass or luminosity functions is important. Gunawardhana et al. (2015), for example, increased their SFRD by \sim 0.07 dex to compensate for incompleteness arising from faint galaxies in their optically-selected sample (see also Gunawardhana et al. 2013).

### 3.1.1 Cumulative fractional contributions

It is instructive to dissect how galaxies contribute to the SFRD as a function of key parameters. We do this in Fig. 3, where we show the cumulative fractional contributions to H\alpha, FUV and R-band luminosity densities (I_{H\alpha}, I_{FUV}, I_{R}, respectively). The R-band flux from local galaxies originates primarily from established stellar populations and is, therefore, indicative of a galaxy’s total stellar content.

Figure 3a illustrates the cumulative fractional contributions to the total H\alpha, FUV and R-band luminosity densities as a function of HI mass. Generally, targets in low HI mass bins generate a higher fraction of the total SFRD compared to I_{H\alpha} and I_{R}. Conversely, targets in HI mass bins with log(M_{HI}/M_\odot) \geq 10.0 have higher I_{H\alpha} fractional contributions (see also Fig. 4a).

Figures 3b – 3f analyse the cumulative fractional luminosity densities for all 294 galaxies as a function of other key quantities. Galaxies with low R-band luminosity, low SFR_{HI\alpha} values and LSB galaxies (both in R-band and H\alpha) (Figs. 3b – 3e), make lower fractional contributions to I_{H\alpha} compared to I_{FUV} (see also Figs. 4b – c). Figures 3c – 3d show that, for both SFR_{HI\alpha} and R-band surface brightness (\mu_R), I_{H\alpha} follows I_{R}, indicative of the total stellar content.

Galaxies with little current star formation have low H\alpha equivalent width (EW) values (derived here from the SINGG R-band and H\alpha fluxes, consistent with Hanish et al. (2006)) and, as expected, make low H\alpha and FUV fractional contributions, compared to the more dominant R-band emission from their established stellar populations (Fig. 3f).

### 3.1.2 H\alpha/FUV ratios

The top panel of Table 3 quantifies the fractional contributions made by the HI mass binned data to the total luminosity density values, I_{H\alpha}, I_{FUV} and I_{R}. The table highlights how the I_{H\alpha}/I_{FUV} ratios vary significantly across the ranges of HI mass, R-band luminosity and R-band surface brightness. The 50 galaxies with the faintest R-band surface brightness (\mu_R) have a small I_{H\alpha}/I_{FUV} ratio of 0.46 and contribute only 2.2 and 4.8 per cent to the total H\alpha and FUV luminosity density values, respectively. In contrast, the 44 galaxies with the brightest \mu_R values contribute significantly to the H\alpha and FUV luminosity densities (35 and 30 per cent, respectively) at a much higher I_{H\alpha}/I_{FUV} ratio of 1.16. See Section 4.2 for further discussion.

The near-identical H\alpha and FUV SFRD values occur despite the differences noted above. In particular, low surface brightness, low luminosity and low HI mass galaxy populations make, on average, lower fractional contributions to I_{H\alpha} than I_{FUV}, compared to the overall sample.
Near-identical SFRD (Hα & FUV) at redshift zero

Figure 3. Cumulative fractional luminosity densities (l) analysed as a function of key quantities (a) H\textsubscript{i} mass, (b) R-band luminosity, (c) Hα star formation rate (see Eqn. 1), (d) R-band effective surface brightness, (e) Hα surface brightness, and (f) Hα equivalent width (EW) (approximated by the ratio of Hα flux density to R-band flux density, consistent with Hanish et al. (2006)). Cumulative fractional luminosity densities shown are: R-band (thick light grey line), Hα (thin red line), and FUV (thick dark blue line). Plot (a): H\textsubscript{i} mass: Note that the fluxes of the individual galaxies in multiple-galaxy targets have been totalled for this analysis of the 210 HIPASS targets (as described in Section 2.4). The low H\textsubscript{i} mass targets make larger FUV fractional contributions than Hα, while larger H\textsubscript{i} mass targets have higher Hα fractions.

3.2 Star formation efficiency

Star formation efficiency (SFE\textsubscript{H\textsubscript{i}} = SFR/M\textsubscript{H\textsubscript{i}}) measures the star formation rate relative to the neutral hydrogen component of the ISM. Although stars form from molecular gas, it is difficult to obtain molecular gas estimates, especially for low mass galaxies. Hence SFE\textsubscript{H\textsubscript{i}} remains a useful proxy measure of star formation potential. Figures 5a – 5c show how SFE\textsubscript{H\textsubscript{i}} varies as a function of key parameters for 129 of the single galaxies contained in the sample. While SINGG groups are not analysed in Fig. 5, Sweet et al. (2013) showed that the larger SINGG groups had SFE\textsubscript{H\textsubscript{i}} values consistent with the rest of the SINGG sample.

The important differences between Hα and FUV fluxes noted in Section 3.1, continue here, with low H\textsubscript{i} mass, low R-band luminosity and low surface brightness galaxies having systematically reduced SFE\textsubscript{H\textsubscript{i}}(Hα) compared to SFE\textsubscript{H\textsubscript{i}}(FUV) (see Figs. 5a – 5c). Log(SFE\textsubscript{H\textsubscript{i}}(FUV)) is little changed at ~9.8 yr\textsuperscript{-1} over three decades of H\textsubscript{i} mass (see Fig. 5a), consistent with Wong et al. (2016) (see also Table 4). SFE\textsubscript{H\textsubscript{i}}(Hα), however, increases by ~0.6 dex over the same range. The Hα best fit line has a slope of 0.21 ± 0.05 (see Table C1), representing a ~4σ detection.

Galaxies with low L\textsubscript{R} have systematically reduced SFE\textsubscript{H\textsubscript{i}} values (Fig. 5b), consistent with Lee et al. (2009). The trend is fractionally stronger in Hα, with a ~1.3 dex variation in SFE\textsubscript{H\textsubscript{i}}(Hα) across the range of L\textsubscript{R}. Increasing SFE\textsubscript{H\textsubscript{i}} with increasing R-band surface brightness (Fig. 5c) mirrors the results of Meurer et al. (2009), Kennicutt & Evans (2012) and Wong et al. (2016). SFE\textsubscript{H\textsubscript{i}}(FUV) values increase ~1.1 dex and SFE\textsubscript{H\textsubscript{i}}(Hα) by ~1.7 dex over ~6 orders of magnitude (both are >10σ detections: see Table C1).

The gas cycling time-scale (t\textsubscript{gas}) is an estimate of the time taken for a galaxy to process its existing neutral and molecular ISM. For consistency with Meurer et al. (2006) we use the typical ISM H2/H\textsubscript{i} ratio determined by Young et al. (1996), M\textsubscript{gas} = 2.3 M\textsubscript{H\textsubscript{i}}, which gives t\textsubscript{gas}(Hα) ≈ 2.3 (M\textsubscript{H\textsubscript{i}}/...
4 DISCUSSION

4.1 The local star formation rate density

The $H\alpha$ and FUV SFRD results are only marginally different (0.03 dex). The similarity of the results from two distinct tracers occurs despite the strong systematic trends in the $F_{H\alpha}/f_{\text{FUV}}$ ratios outlined in Section 3. The lowest HI mass bin has a low $H\alpha$/FUV fractional luminosity density ratio of 0.63 (see Table 3a), with more central bins having higher values, up to $l_{H\alpha}/l_{\text{FUV}}$ of 1.26. Scaling luminosities to the HIMF increases the $H\alpha$ contributions sufficiently overall to offset the impact of the low $H\alpha$ emission from low mass, low luminosity and LSB galaxies, and produces the near-identical $H\alpha$ and FUV SFRD values reported here.

Figure 6a shows that the SFRD results are towards the high end of the distribution of earlier $z \sim 0$ measurements, including those summarised in Hopkins (2004), Madau & Dickinson (2014) and Gunawardhana et al. (2013), and are consistent with the recent results of Gunawardhana et al. (2015). The SFRD values are also consistent, within errors, with another recent HI-selected survey, Van Sistine et al. (2016), as well as with the first data release of 110 SINGG galaxies (Hanish et al. 2006).

4.2 $F_{H\alpha}/f_{\text{FUV}}$ variations

$F_{H\alpha}/f_{\text{FUV}}$ varies systematically with several galaxy properties (see Figs. 5d – f), consistent with previous findings by Meurer et al. (2009) and others (e.g., Karachentsev & Kaisina 2013). Undetected or unmeasured $H\alpha$ emission would reduce the sample’s $F_{H\alpha}/f_{\text{FUV}}$ ratio and $l_{H\alpha}$ contributions. Detailed reviews of the observations ensured all discernible $H\alpha$ flux was measured (see Section 2.1). Lee et al. (2016) used deep $H\alpha$ observations in their work on dwarf galaxies, identifying previously undetected extended LSB $H\alpha$ emission and determined an extrapolated effect of ~5 per cent, insufficient to explain all of the low $F_{H\alpha}/f_{\text{FUV}}$ ratios in their research, or in our results.

Meurer et al. (2009) examined possible explanations for the $F_{H\alpha}/f_{\text{FUV}}$ variations. Dust corrections and metallicity considerations are largely discounted as possible causes, with escaping ionising flux unable to be ruled out, while both stochasticity and a non-universal IMF are seen as plausible explanations. Stochastic effects, due to the limited number of massive stars and short-lived intense star-forming periods, can account for some, if not all, of the observed IMF variations according to some recent research (e.g., Sullivan et al. 2000; Kroupa 2001; Gogarten et al. 2009; Fumagalli et al. 2011; Eldridge 2012; Koda et al. 2012; da Silva et al. 2014). Lower mass galaxies ($\sim 10^7 – 10^8 M_\odot$ particularly) may experience more intense episodes of star formation on shorter time-scales than other galaxies (e.g., Boselli et al. 2009; Weisz et al. 2012; Bauer et al. 2013), so stochastic effects may be important in explaining at least some of the observed $F_{H\alpha}/f_{\text{FUV}}$ variations.

Stochastic effects aside, there is some theoretical support for IMF variations (e.g., Elmegreen 2004; Bate & Bonnell 2005; van Dokkum 2008) and growing observational evidence since Meurer et al. (2009) that the IMF can vary with local conditions. Variations in the low-mass end of the IMF have been observed in old galaxies not currently forming stars (e.g., Martín-Navarro et al. 2015; La Barbera et al. 2016) and in ultra-faint dwarf galaxies (Geha et al. 2013), for example. The upper end of the IMF may be suppressed due to local conditions in disk galaxies, with reduced massive star formation theorised or observed in low mass and low luminosity stars.
Near-identical SFRD (Hα & FUV) at redshift zero

Figure 5. Analysis of the 129 single galaxies in the sample with a signal-to-noise ratio (S/N) of over 3 for both Hα and FUV fluxes. There are 160 single galaxies in the sample; the 31 single galaxies not meeting the S/N requirement are not included in the analysis above. All quantities have been corrected for Galactic and internal dust absorption. Panels (a) – (c) H2-based star formation efficiency (SFEH2) as a function of key galaxy parameters. SFEH2(Hα) (= SFRHα/MH2) and SFEH2(FUV) (= SFRFUV/MH2) values are represented by red open circles and blue filled triangles, respectively. Solid red lines and dashed blue lines show the ordinary least squares best fit lines (Y vs. X, with a 2.5σ iterative clipping) for Hα and FUV data, respectively. See Table C1 for further details. Dotted lines indicate ±2.5σ offsets to the fit, where σ is the dispersion in the residuals of SFEH2. The uncertainties for individual galaxy Hα and FUV SFE values are smaller than the symbols used and are not shown here. J0242+00 SFEH2(Hα) and SFEH2(FUV) values are overlaid with large filled orange symbols: circle and triangle, respectively. J0242+00 has not been included in the determination of the best fit lines, or in other calculations (see Appendix A for further discussion on this galaxy). Panels (d) – (f): Ratio of Hα line flux to FUV flux density as a function of H2 mass, R-band luminosity and R-band surface brightness; this ratio is equivalent to SFEH2(Hα)/SFEH2(FUV). Solid lines show the ordinary least squares best fit lines (Y vs. X, with 2.5σ iterative clipping); see also Table C1. The horizontal dashed lines (panels d – f) represent the expected FHα/FFUV value assuming a Salpeter (1955) IMF using Eqn. 3 from Meurer et al. (2009). The vertical dashed line in panel (d) shows the Schechter fit characteristic H2 mass (log(M∗/M⊙) = 9.86) of the Zwaan et al. (2005) HIMF.
luminosity galaxies (e.g., Hoversten & Glazebrook 2008), in
the less dense, outer regions of galaxies (Thilker et al. 2005;
Bruzze et al. 2015; Watts et al. 2018) and also in LSB
galaxies (e.g., Lee et al. 2004; Meurer et al. 2009). Top-
light IMFs have also recently been inferred in galaxies with
low star formation rates (e.g., Lee et al. 2009; Gunaward-
hana et al. 2011), in the centre of the Milky Way (Lu et al.
2013) and where gas surface densities lie below the Kenni-
cutt (1989) critical density (Thilker et al. 2005). Some recent
studies suggest that the observations of apparent IMF varia-
tions could be within the limits of statistical uncertainties,
or are due to the flaws in the approach followed (e.g., Bastian
et al. 2010; Krumholz 2014).

4.3 Systematic and random errors
Table D1 lists the quantified random and systematic uncer-
tainties in our luminosity density calculations. Errors are
generally calculated in accordance with the first data re-
lease (for details see Hanish et al. 2006) and are dominated
by corrections for internal dust attenuation, HIMF model
and sampling uncertainties.

### 4.3.1 HI mass function selection

A key source of systematic error in the results is the HIMF
used. Recent studies have found evidence that the density of
the environment affects the HIMF (e.g., Zwaan et al. 2005;
Schneider et al. 2008; Stierwalt et al. 2009; Jones et al. 2016),
so the HIMF selection requires careful consideration. High
density regions can exhibit a steeper HIMF slope at the low-
mass end (e.g., Zwaan et al. 2005; Moorman et al. 2014),
but few galaxies in clusters, consistent with findings that
selected galaxies are less clustered than optically-selected
samples with comparable luminosities (Doyle & Drinkwater
2006; Meyer et al. 2007; Passmoor et al. 2011).

To estimate the impact of the HIMF selection, five alter-
native published HIMF s were applied to the sample, keeping
all other variables unchanged. This approach also allows us
to estimate the uncertainties due to cosmic variance, as de-
scribed in Section 4.3.2. Table 1 sets out the HIMFs and
resultant SFRD and \( \rho_{HI} \) values. The HIMFs listed are de-

Table D1. Fractional luminosity density binned data for (a) the 210 targets analysed by H\( \alpha \) mass and the 294 galaxies analysed by (b) R-band luminosity and (c) R-band surface brightness. Notes: Col. (1) Bin limits for the listed parameters. Col. (2) Number of targets (a) or galaxies (b and c). Col. (3) Average bin values for (a) H\( \alpha \) mass [M\( HI \)/M\( \odot \)], (b) R-band luminosity and (c) R-band surface brightness. Cols. (4 – 6) Fractional contributions to the R-band, H\( \alpha \) and FUV luminosity density values (\( i_R \), \( i_{Halpha} \), \( i_{FUV} \)), respectively. Col. (7): Ratio of fractional contributions in H\( \alpha \)r and R-band, i.e., Cols. (5)/(4). Col. (8): Ratio of fractional contributions in H\( \alpha \r \)r and FUV, i.e., Cols. (5)/(6). Cols. (4 – 8) Quoted errors represent the standard deviation derived from 10,000 iterations of varying the underlying fluxes assuming normally-distributed errors.

| Parameter | Notes (1) | N (2) | Average \( i_R \) (3) | \( i_{Halpha} \) (4) | \( i_{FUV} \) (5) | \( i_{Halpha}/IR \) (6) | \( i_{Halpha}/IFUV \) (8) |
|-----------|-----------|------|---------------------|-----------------|-----------------|-------------------|---------------------|
| (a) log(M\( HI \)/M\( \odot \)) | 6.975 – 8.0 | 11 | 7.8 | 0.037 ± 0.012 | 0.042 ± 0.024 | 0.066 ± 0.020 | 1.12 ± 0.75 | 6.3 ± 0.42 |
| | 8.0 – 8.5 | 34 | 8.3 | 0.066 ± 0.034 | 0.103 ± 0.047 | 0.096 ± 0.037 | 1.57 ± 1.07 | 1.08 ± 0.64 |
| | 8.5 – 9.0 | 42 | 8.8 | 0.074 ± 0.028 | 0.056 ± 0.013 | 0.084 ± 0.014 | 0.77 ± 0.34 | 0.68 ± 0.19 |
| | 9.0 – 9.5 | 44 | 9.3 | 0.271 ± 0.072 | 0.220 ± 0.043 | 0.223 ± 0.032 | 0.81 ± 0.27 | 0.98 ± 0.24 |
| | 9.5 – 10.0 | 34 | 9.8 | 0.320 ± 0.046 | 0.349 ± 0.061 | 0.327 ± 0.051 | 1.09 ± 0.24 | 1.07 ± 0.25 |
| | 10.0 – 10.5 | 35 | 10.2 | 0.215 ± 0.042 | 0.216 ± 0.044 | 0.171 ± 0.031 | 1.01 ± 0.29 | 1.26 ± 0.35 |
| | 10.5 – 11.0 | 10 | 10.6 | 0.017 ± 0.004 | 0.014 ± 0.003 | 0.033 ± 0.016 | 0.83 ± 0.26 | 0.42 ± 0.22 |
| (b) log(F\( LR \) [L\( \odot \)]) | 6.5 – 8.1 | 50 | 7.8 | 0.023 ± 0.008 | 0.022 ± 0.011 | 0.054 ± 0.020 | 0.96 ± 0.58 | 0.41 ± 0.25 |
| | 8.1 – 8.7 | 50 | 8.5 | 0.041 ± 0.006 | 0.061 ± 0.029 | 0.089 ± 0.026 | 1.49 ± 0.92 | 0.69 ± 0.38 |
| | 8.7 – 9.4 | 50 | 9.1 | 0.061 ± 0.025 | 0.109 ± 0.030 | 0.101 ± 0.025 | 1.79 ± 0.88 | 1.08 ± 0.40 |
| | 9.4 – 10.0 | 50 | 9.8 | 0.186 ± 0.054 | 0.213 ± 0.052 | 0.230 ± 0.045 | 1.15 ± 0.43 | 0.93 ± 0.29 |
| | 10.0 – 10.6 | 50 | 10.4 | 0.309 ± 0.061 | 0.264 ± 0.053 | 0.283 ± 0.045 | 0.85 ± 0.24 | 0.93 ± 0.24 |
| | 10.6 – 11.4 | 44 | 11.0 | 0.380 ± 0.074 | 0.331 ± 0.060 | 0.243 ± 0.036 | 0.87 ± 0.23 | 1.36 ± 0.32 |
| (c) \( \mu R \) | \([\text{AB mag arcsec}^{-2}]\) | 25.2 – 23.4 | 50 | 24.0 | 0.022 ± 0.008 | 0.022 ± 0.008 | 0.048 ± 0.013 | 1.00 ± 0.51 | 0.46 ± 0.21 |
| | 23.4 – 22.4 | 50 | 22.8 | 0.049 ± 0.013 | 0.043 ± 0.013 | 0.069 ± 0.017 | 0.88 ± 0.32 | 0.62 ± 0.22 |
| | 22.4 – 21.7 | 50 | 22.0 | 0.080 ± 0.022 | 0.101 ± 0.026 | 0.121 ± 0.024 | 1.26 ± 0.48 | 0.84 ± 0.27 |
| | 21.7 – 21.0 | 50 | 21.4 | 0.161 ± 0.035 | 0.149 ± 0.029 | 0.183 ± 0.034 | 0.93 ± 0.27 | 0.81 ± 0.22 |
| | 21.0 – 20.0 | 50 | 20.5 | 0.318 ± 0.071 | 0.334 ± 0.077 | 0.276 ± 0.047 | 1.05 ± 0.34 | 1.21 ± 0.35 |
| | 20.0 – 17.5 | 44 | 19.5 | 0.370 ± 0.089 | 0.351 ± 0.084 | 0.303 ± 0.061 | 0.95 ± 0.32 | 1.16 ± 0.36 |
Near-identical SFRD (Hα & FUV) at redshift zero

Table 4. Contributions to SFE_{HI}, SFRD and luminosity densities analysed by HI mass bin. Column descriptions [units]: Col. (1): Log HI mass range. Col. (2): Number of HI targets within the HI mass range. Col. (3): SFE_{HI} value derived using HI observations [M_{⊙}yr^{-1}]. Col. (4): SFRD contribution per HI mass bin [M_{⊙}yr^{-1}Mpc^{-3}dex^{-1}]. Col. (5) R-band density contribution per decade of HI mass [ergs s^{-1}Å^{-1}Mpc^{-3} dex^{-1}]. Col. (6): SFE_{HI} value derived using FUV observations [M_{⊙}yr^{-1}]. Col. (7) SFRD contribution per HI mass bin [M_{⊙}yr^{-1}Mpc^{-3}dex^{-1}]. The 9.0 – 9.5 bin appears twice; the lower listing (in brackets) shows the impact of J0242+00 on this mass bin, if it was included in the final sample (see discussion in Appendix A). The remaining mass bins are not shown as the luminosity densities do not change if J0242+00 was included, although their uncertainties would change, reflecting increased uncertainty from sampling.
derived from a variety of recent large volume surveys in HI (Zwaan et al. 2005; Springob et al. 2005b; Martin et al. 2010; Hoppmann et al. 2015; Jones et al. 2018). The SFRD values derived vary by up to 0.10 dex compared to our adopted HIMF model, reflecting the small differences in the individual HIMF parameters for these wide-field surveys (see Table 1).

4.3.2 Cosmic variance

Due to the wide variety of galactic environments in the Universe, cosmic variance is a key source of uncertainty in all SFRD calculations (e.g., see Driver & Robotham 2010; Gunawardhana et al. 2015). By using HIPASS, a wide-field HI survey, and sampling the entire HI mass range, SINGG/SUNGG reduces the sampling biases that can become significant in surveys with smaller sampling volumes. The working assumption is that the mix of galaxy types depends only on HI mass and is well represented by our sample.

By design the SINGG and SUNGG surveys are not volume-complete. Galaxies were instead chosen to fully sample the HIMF and, within individual mass bins, the nearest galaxies were preferentially selected to optimise spatial resolution (see Meurer et al. 2006).

The impact of cosmic variance can then be assessed by comparing SFRD values derived from using HIMFs taken from different wide-field surveys (see Section 4.3.1) and, in particular, by using HIMFs from survey volumes with significantly different environmental characteristics. Applying the ALFALFA Survey’s (Jones et al. 2018) Spring HIMF (overdense and Virgo Cluster-dominated) and the Fall HIMF (underdense and void-dominated), for example, generates Hα SFRD values for our sample of 0.0248 and 0.0189 [M⊙ yr⁻¹ Mpc⁻³], respectively. The ~0.12 dex difference in the SFRD values is similar to the uncertainties arising from all other random and systematic sources, highlighting the importance of cosmic variance in the error analysis.

Using increasingly larger volume surveys for measuring the local SFRD can reduce cosmic variance uncertainties. Due to flux-detection limits, however, the accessible volume for low luminosity and LSB galaxies remains constrained by observational capabilities. With low mass (e.g., log(MHI/M⊙) < 9.0) and low luminosity galaxies contributing over 20 per cent of local Hα and FUV SFRD values (see Table 3), this is a significant constraint on the completeness of SFRD measurements.

4.3.3 Distance model

To gauge the systematic uncertainty arising from our choice of distance model, the SFRD was recalculated using the local-group distances of Zwaan et al. (2005). This increases ρHα and ρFUV by 0.022 dex and 0.011 dex, respectively. These values have been taken as the systematic error arising from the distance model selected (see Table D1).

4.3.4 [Nii] contamination and internal dust attenuation

The empirical relationship between [Nii] fluxes and uncorrected R-band magnitudes of Helmboldt et al. (2004), derived from The Nearby Field Galaxy Survey (Jansen et al. 2000), is used to adjust SINGG Hα fluxes for both internal dust attenuation and [Nii] contamination. Shioya et al. (2008) also uses this consistent approach, but most surveys have attenuation and [Nii] corrections derived from different galaxy populations. Commonly used alternatives for the [Nii] corrections apply the empirical relationships of Kennicutt et al. (2008); Kennicutt & Kent (1983); Kennicutt (1983) or simplistically reduce Hα fluxes by a fixed value, often based on one or more of these references. Jansen et al. (2000) showed, however, that the [Nii]/Hα flux ratio was more closely related to galaxy luminosity than morphology, and that earlier empirical relationships consistently over- or under-estimate the [Nii] contamination. Hα fluxes are adjusted by a factor of 0.05 (~0.12 AB mag) for [Nii] contamination and Hα and FUV fluxes are adjusted by factors of ~0.26 and ~0.38 (~0.66 and ~0.96 AB mag), respectively, for dust attenuation.

4.3.5 Stellar absorption and other errors

Brickeboom et al. (2004) determined Hα stellar absorption corrections ranging from 2 – 6 per cent were needed to the measured Hα fluxes and the mid-range of these values (4 per cent) is used to increase SINGG Hα and EW(Hα) measurements. Recent research shows average stellar absorption can vary systematically with galaxy luminosity (e.g., Hopkins et al. 2013) and galaxy mass (e.g., López-Sánchez & Esteban 2010), leading to an underestimation of the SFRD (see also Spector et al. 2012). Due to the relatively small contribution the stellar absorption correction makes to the total uncertainty (see Table D1) we do not apply a more elaborate correction.

5 CONCLUSIONS

We have presented the first parallel Hα and FUV-derived star formation rate density values obtained from an HI-selected sample of nearby galaxies. We find a consistent SFRD of ~0.020 [M⊙ yr⁻¹ Mpc⁻³] for the two measurements, with a difference between the two measurements which is within the 1-σ uncertainties of each (~0.13 dex). Figure 6 shows these measurements lie towards the top of the distribution of recent results, reflecting the more complete nature of our HI-selected sample, which is less biased against low luminosity and low surface brightness galaxies.

The HIMF-based methodology has been used by Hanish et al. (2006) and Van Sistine et al. (2016) and our results are consistent with theirs. This method facilitates the efficient derivation of SFRD and other volume densities, particularly when observing resources are limited. The thorough sampling along the HIMF, which forms the foundation for the sample selection, also leads to relatively better testing of the low HI-mass regime, compared to most optically-selected samples. The approach is supported by recent comparisons with the more commonly applied Vmax-based correction in volume-incomplete samples (see e.g., Gavazzi et al. 2013, 2015; Van Sistine et al. 2016), but is susceptible to extreme outliers, as experienced here with J0242+00.

The similarity of SFRD from the two SFR indicators occurs despite significant differences in the F(Hα)/F(UV) values in the sample. Galaxies with lower surface brightness,
luminosity or H\textsc{i} mass, tend to have lower $F_{\text{H}\alpha}/F_{\text{FUV}}$ values than those at the high end of those parameters. This ratio is equal to what is expected for a Salpeter IMF for galaxies near $M_{\text{H}\alpha}$; the fiducial H\textsc{i} mass in the Schechter mass function fit. The trends suggest IMF variations may be in effect at the extreme ends of this parameter space.

**ACKNOWLEDGEMENTS**

We thank the anonymous referee for constructive and detailed comments that have improved this paper. Partial funding for the SINGG and SUNGG surveys came from NASA grants NAG5-13083 (LTSA program), GALEX GI04-0105-0009 (NASA GALEX Guest Investigator grant) and NNX09AF85G (GALEX archival grant) to G.R. Meurer. FAR acknowledges partial funding from the Department of Physics, University of Western Australia. This research has made use of the NASA/IPAC Extragalactic Database (NED), which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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APPENDIX A: A REMARKABLE GALAXY

The nearby (D \sim 16.2 Mpc) galaxy HIPASS J0242+00, better known as NGC 1068, would contribute a phenomenal 27%, 12% and 14% of the total cosmic luminosity densities in H\alpha, FUV and R-band, respectively, derived using our methodology, if it was included in the sample (see Table B1). This reflects its remarkable luminosity, especially for its H\alpha mass (M_{H\alpha} \approx 10^{12} M_{\odot}) and is largely a by-product of our HIMF-based methodology. In a volume-complete sample J0242+00 probably would not have such an impact, however. Figure A1 shows this archetypal Type II Seyfert galaxy (Seyfert 1943) has extraordinarily intense emission, especially compared to galaxies having a similar H\alpha mass, but also compared to galaxies of similar luminosity for radii less than \sim 3 kpc. It is one of the most luminous objects known in the local Universe (e.g., see Blundell-Hawthorn et al. 1997) and only one of eight galaxies in our sample with M_{H\alpha} < \sim 23 AB mag.

The central region (r < 2.3′/180 pc) contributes 5 and 30 per cent of the galaxy’s total R-band and H\alpha fluxes respectively. Intense star formation is occurring within this small radius (Howell et al. 2007; Storchi-Bergmann et al. 2012) and, therefore, the AGN makes a minor direct contribution to the galaxy’s total R-band and H\alpha luminosities (6.64 \times 10^{40} ergs s^{-1} A^{-1} and 4.36 \times 10^{42} ergs s^{-1}, respectively). Similarly, Fanelli et al. (1997) found that most of the galaxy’s FUV flux does not originate from the AGN, but instead is predominately (\sim 81%) generated in the galaxy’s disk.

The unusually high surface brightness disk contains star forming knots of extraordinary mass and luminosity (see Neff et al. 1994; Blundell-Hawthorn et al. 1997; Romeo & Fathi 2016). These knots occur out to \sim 3 kpc from the central AGN region (Bruhweiler et al. 1991) and cause the rises in the radial profiles illustrated in Figure A1b and c (see also Neff et al. 1994; Raimann et al. 2003). This intense star formation, just outside the nucleus, is thought to arise from bar-driven gas flows, rather than being AGN-driven (see Telesco & Decher 1988; Schinnerer et al. 2000; Emsellem et al. 2006; Romeo & Fathi 2016).
Figure A1. The radial surface brightness profile of J0242+00 (shown with a thick orange line) dominates within the inner \(\sim 3\) kpc, in comparison to the other seven highest luminosity \(M_R < -23\) AB mag single galaxies in the sample (profiles shown in light grey) and the 40 other single galaxies in the same Hi mass bin (i.e., \(\log(M_{\text{Hi}}/M_\odot) = 9.0 - 9.5\), shown with thin blue lines). Data series with less than 5 points, or where \(S/N < 3.0\), are excluded. Panel (a) shows the \(R\)-band radial surface brightness profiles in AB mag arcsec\(^{-2}\) and panel (b) shows the log of the \(\text{H}\alpha\) surface brightness in units of erg cm\(^{-2}\) s\(^{-1}\) arcsec\(^{-2}\). The profiles are adjusted to face-on values (i.e., raw intensities multiplied by the minor to major axis ratio \(b/a\) of the elliptical apertures used to extract the profiles). Panel (c) shows the equivalent width \([\AA]\) derived from the ratio of \(\text{H}\alpha\) and \(R\)-band intensities.

The disproportionate impact of J0242+00, if it were included in the final sample, partly reflects the small size of the SINGG and SUNGG surveys. It has therefore been excluded from our analysis and results.
### Table B1

| Hi target | log \( \frac{M_{\text{HI}}}{M_\odot} \) | \( l_{\text{H}\alpha} \) fraction | \( l_{\text{FUV}} \) fraction | Notes |
|------------|-----------------|-----------------|-----------------|------|
| J1338-17  | 9.69            | 0.046           | 0.039           | NGC 5247: grand-design spiral (Khoperskov et al. 2012) |
| J1247-03  | 8.17            | 0.043           | 0.036           | NGC 4691: central starburst and outflows (Garcia-Barreto et al. 1995; Vila-Vilaro et al. 2003) |
| J0505-37  | 9.42            | 0.041           | 0.026           | NGC 1792: interacting with J0507-37 (below) |
| J1059-09  | 10.05           | 0.040           | 0.027           | Group: 10 galaxies with \( \text{H}\alpha \) observations, 9 FUV |
| J0342-13  | 9.86            | 0.028           | 0.017           | NGC 1421 Group: 2 galaxies with \( \text{H}\alpha \) observations, 1 FUV. |
| J0216-11c | 9.96            | 0.026           | 0.024           | NGC 873 |
| J0507-37  | 9.53            | 0.024           | 0.027           | NGC 1808: interacting with J0505-37 (above) |

Table B1. Col. (1) The HIPASS targets with the largest impact on \( \text{H}\alpha \) and FUV luminosity densities (\( l_{\text{H}\alpha} \) and \( l_{\text{FUV}} \), respectively). Cols. (2 – 3) The fraction of \( l_{\text{H}\alpha} \) and \( l_{\text{FUV}} \) arising from the listed targets. In comparison, if included, J0242+00 (\( \log(M_{\text{HI}}/M_\odot) = 9.17 \)) would make an extraordinary fractional contribution of 0.269 and 0.116 of increased \( l_{\text{H}\alpha} \) and \( l_{\text{FUV}} \) values, respectively.

### Table C1

Best fit line coefficients

| Figure description | Fig. ref. | Flux | A       | B       | \( \sigma_x \) | \( \sigma_y \) | N |
|--------------------|-----------|------|---------|---------|----------------|----------------|---|
| SFE v log(\( M_{\text{HI}}/M_\odot \)) | 5a | \( \text{H}\alpha \) | -11.62 ± 0.49 | 0.21 ± 0.05 | 2.13 | 0.44 | 127 |
| | | FUV | -10.09 ± 0.39 | 0.05 ± 0.04 | 7.28 | 0.34 | 127 |
| SFE v log(\( L_R \)) | 5b | \( \text{H}\alpha \) | -12.63 ± 0.27 | 0.32 ± 0.03 | 1.06 | 0.33 | 124 |
| | | FUV | -11.12 ± 0.26 | 0.16 ± 0.03 | 2.00 | 0.32 | 124 |
| SFE v log(\( \mu_R \)) | 5c | \( \text{H}\alpha \) | -3.64 ± 0.38 | -0.28 ± 0.02 | 0.96 | 0.27 | 124 |
| | | FUV | -5.75 ± 0.32 | -0.18 ± 0.01 | 1.35 | 0.24 | 124 |

| log(\( F_{\text{H}\alpha}/F_{\text{FUV}} \)) v log(\( M_{\text{HI}}/M_\odot \)) | 5d | | -0.48 ± 0.25 | 0.16 ± 0.03 | 1.23 | 0.20 | 119 |
| log(\( F_{\text{H}\alpha}/F_{\text{FUV}} \)) v log(\( L_R \)) | 5e | | -0.29 ± 0.16 | 0.14 ± 0.02 | 1.32 | 0.18 | 118 |
| log(\( F_{\text{H}\alpha}/F_{\text{FUV}} \)) v log(\( \mu_R \)) | 5f | | 3.02 ± 0.27 | -0.09 ± 0.01 | 1.93 | 0.18 | 115 |

Table C1. Coefficients and residuals of the best fit lines (ordinary least squares Y vs. X, using a 2.5\( \sigma \) cut) in Fig. 5. Column descriptions: Cols. (1,2) coefficients of the best fit line, where \( y = A + Bx \), together with their 1\( \sigma \) standard deviation values. Cols. (3,4) \( x \) and \( y \) residual dispersions, respectively. Col. (5) Number of galaxies used in the final fit, after iterative clipping (from a total population of 129 single galaxies meeting the S/N requirements described in Fig. 5).
Table D1. Analysis of luminosity density uncertainties (log values), for uncorrected and dust-corrected R, Hα and FUV fluxes. All errors, excluding (10), have been calculated in accordance with Hanish et al. (2006). Notes: (1) The sampling error is the standard deviation of the results from bootstrapping 10,000 samples of 294 randomly selected galaxies (duplication permitted). (2 & 3) Sky and continuum subtraction uncertainties are the standard deviations from 10,000 iterations where sky level and continuum levels were randomly altered for each galaxy within the error model. (4) The Hα flux calibration uncertainty is estimated at 0.04 mag for images using the 6568/28 narrowband filter and 0.02 mag for all others. FUV flux calibration uncertainties are in accordance with Morrissey et al. (2005, 2007). (5 & 6) The underlying $M_H'$ fits of Helmboldt et al. (2004, private communication) have a 0.23 dex dispersion arising from uncertainty in internal dust extinction and a 0.23 dex dispersion due to [Nii] correction. The quoted random errors are the standard deviations from two separate 10,000 realisations where each galaxy’s corrections were randomly altered with a 0.23 dex dispersion around the mean. (7 & 8) The zero-point error associated with the $M_H'$ fits random uncertainties (see Hanish et al. (2006)). (9) The quoted error is the difference in the SFRDs derived using our default Mould et al. (2000) model and the SFRD using the alternative local-group distances of Zwaan et al. (2005) (see Section 4.3.3). (10) The HIMF uncertainties are the differences in the derived SFRDs from using the default Zwaan et al. (2005) HIMF compared to the average of the five alternative wide-field survey HIMFs listed in Table 1 (see Section 4.3.1).