# The Star Formation Density of the Local Universe from SINGG

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## Abstract

We have used H$\alpha$ data from SINGG (the Survey for Ionization in Neutral Gas Galaxies, see poster 179.18) to measure the star formation rate density of the local universe to be $\log(\dot{\rho}_{\rm SFR}(0)\ [\mathcal{M}_\odot\ {\rm yr}^{-1}\ {\rm Mpc}^{-3}]) = -1.80\ ^{+0.13}_{-0.07}(random)\ \pm 0.03(systematic) + \log(h_{70})$. The volume-averaged H$\alpha$ equivalent width of our sample is found to be $EW({\rm H}\alpha) = 28.8\ ^{+7.2}_{-4.7}$ Å, indicating that star formation in the SINGG galaxies is occurring at about one-fourth of its past average rate. This confirms that star formation has decreased drastically in gas-rich galaxies since $z \sim 1.5$.

We break down the H$\alpha$ and $R$ band luminosity densities in terms of the properties of the sample galaxies, including HI mass, stellar luminosity, dynamical mass, and surface brightness. A comparison of the dynamical masses of our galaxies with their stellar and HI masses shows significant evidence of downsizing: the most massive galaxies have a larger fraction of their mass locked up into stars than HI, while the opposite is true for less massive galaxies.

## Introduction

- The star formation density of the universe has changed considerably since $z \sim 2$, decreasing by approximately an order of magnitude.
- Redshift-dependent luminosity densities remain some of the best constraints on models of galaxy evolution.
- Estimates of $\dot{\rho}_{\rm SFR}(0)$ from previous studies span a factor of two or more, and do not always agree within their stated uncertainties.
- IR and UV surveys are biased towards galaxies with little or high dust content, while objective-prism surveys bias towards galaxies with high surface brightness, high equivalent width emission lines.
- To avoid these biases, SINGG selects targets solely by HI mass and distance.
- We have observed 93 HI targets (111 H$\alpha$ sources), using H$\alpha$ flux to measure star formation.
- Since the SINGG sample is not volume complete, we tie our results to the HIPASS HI Mass Function of Zwaan *et al.* (2005).

**References:**

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## Methodology

We measure the H$\alpha$ and $R$ band luminosity of each SINGG galaxy. Each is then weighted by our HI Mass Function to derive a luminosity density:

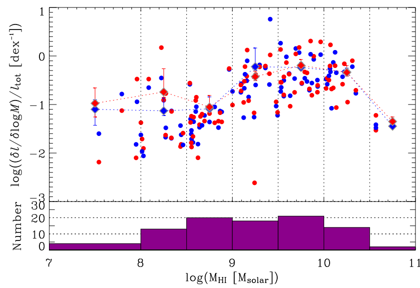


Figure 1. Fraction of the local luminosity density per HI mass decade. Red symbols represent H$\alpha$ luminosities, while blue symbols denote $R$ band luminosities. Circles represent the value for the individual SINGG galaxies. Diamonds and error bars are the average values and standard deviations of mean for each mass bin. All values are corrected for internal extinction.

- The majority of the SINGG H$\alpha$ and $R$ band luminosity densities are found in galaxies with HI masses of $10^9$ to $10^{10}\ \mathcal{M}_\odot$.

We also derive a dynamical mass, $\mathcal{M}_{\rm dyn}$, by assuming that the broadening in the HI velocity distribution is equivalent to the rotational velocity of the galaxy at a radius containing 90% of the $R$ band luminosity. Relating this mass to other quantities:

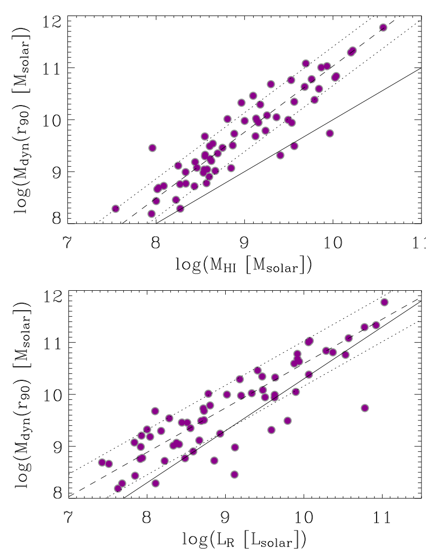


Figure 2. Dynamical mass, $\mathcal{M}_{\rm dyn}$, as a function of (a) HI mass and (b) $R$ band luminosity. Solid lines denote (a) $\mathcal{M}_{\rm dyn} = \mathcal{M}_{\rm HI}$ and (b) $\mathcal{M}_{\rm dyn} = 2\ L_R$ in solar units. Dashed lines denote the best linear fit, with dotted lines denoting the standard deviation of the fit.

- $\mathcal{M}_{\rm dyn} \sim \mathcal{M}_{\rm HI}{}^{1.27}$ and $\mathcal{M}_{\rm dyn} \sim L_R^{0.85}$, so as mass increases, the fraction of the dynamical mass consisting of HI decreases, while the fraction consisting of visible stars increases.

## Results

We present our estimates of the luminosity densities of the local universe. Without correction for internal extinction, we find:

- $l'_R(0) = (4.4 \pm 0.7) \times 10^{37}\ h_{70}$ erg s$^{-1}$ Å$^{-1}$ Mpc$^{-3}$, approximately 70% of the SDSS-derived value
- $l_{\rm H\alpha}{}'(0) = (9.4 \pm 1.8) \times 10^{38}\ h_{70}$ erg s$^{-1}$ Mpc$^{-3}$
- $\log(\dot{\rho}'_{\rm SFR}(0)\ [\mathcal{M}_\odot\ {\rm yr}^{-1}\ {\rm Mpc}^{-3}]) = -2.13\ ^{+0.08}_{-0.09}(ran.)\ \pm 0.03(sys.) + \log(h_{70})$

To correct for internal dust extinction, we use the relationship between $A({\rm H}\alpha)_{\rm int}$ and $M'_R$ given by Helmboldt *et al.* (2004); averaged over our sample, this correction is 0.82 magnitudes for $l_{\rm H\alpha}(0)$. This gives:

- $l_R(0) = (7.0\ ^{+1.5}_{-0.3}) \times 10^{37}\ h_{70}$ erg s$^{-1}$ Å$^{-1}$ Mpc$^{-3}$
- $l_{\rm H\alpha}(0) = (2.0\ ^{+0.6}_{-0.4}) \times 10^{39}\ h_{70}$ erg s$^{-1}$ Mpc$^{-3}$
- $\log(\dot{\rho}_{\rm SFR}(0)\ [\mathcal{M}_\odot\ {\rm yr}^{-1}\ {\rm Mpc}^{-3}]) = -1.80\ ^{+0.13}_{-0.07}(ran.)\ \pm 0.03(sys.) + \log(h_{70})$

When the SINGG local star formation rate density is compared to the values derived from other low-redshift surveys, we find:

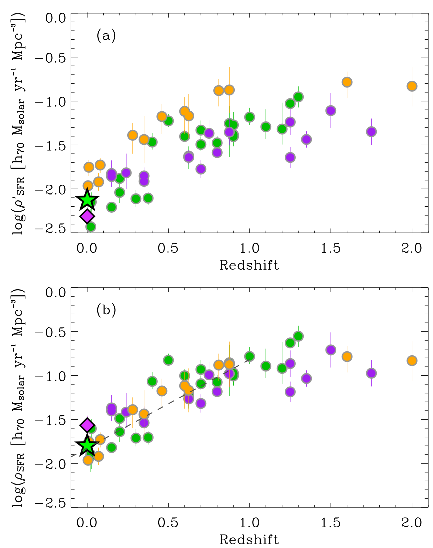


Figure 3. Star formation density, (a) without and (b) with corrections made for internal dust extinction. Green symbols are optical emission-line surveys (usually H$\alpha$). Purple symbols are UV surveys. Orange symbols are IR/sub-mm surveys. The star at $z \approx 0$ is the SINGG H$\alpha$-derived value, while the diamond is the UV-derived result from our sister survey, SUNGG (poster 179.17). Other values are drawn from Hopkins (2004). The dashed line in (b) corresponds to the best fit from $0 < z < 1$.

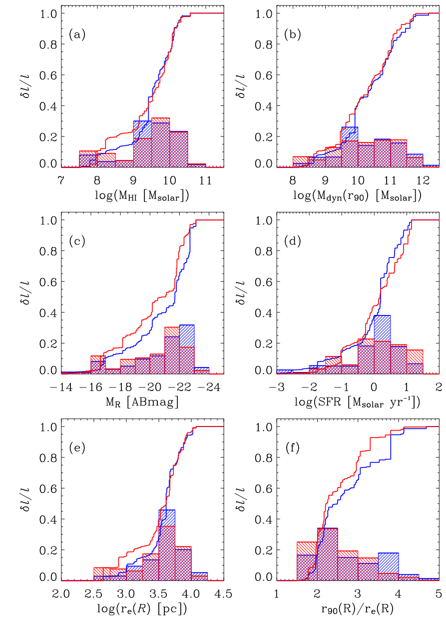


Figure 4. Fraction of the total luminosity density, $l$, as a function of various quantities. Red lines correspond to H$\alpha$ luminosity, while blue lines correspond to $R$ band luminosity.

By comparing each galaxy's contributions to the total luminosity densities, we find several trends:

- Galaxies with HI masses below the "knee" of our HI mass Schechter function contribute more than 70% to each of the luminosity densities.
- Integrating the H$\alpha$ luminosity functions of other surveys imply that more than 20% of the H$\alpha$ luminosity density should be found in galaxies with star formation rates higher than 10 $\mathcal{M}_\odot$ yr$^{-1}$, but less than 10% of our value is above this threshold.
- Galaxies with $R$ band effective radii of less than 4 kpc contribute half of each luminosity density.
- Disk-dominated "late-type" galaxies ($r_{90}/r_e \leq 3.0$) are responsible for the majority of our luminosity densities (71% $R$, 82% H$\alpha$).
- In general, the smaller, less massive galaxies contribute substantially more to the SINGG H$\alpha$ luminosity density (and therefore $\dot{\rho}_{\rm SFR}(0)$) than they do to the $R$ band density. This supports the "downsizing" model of galaxy evolution, where star formation activity shifts to smaller galaxies over time.

## Conclusions

Our value for the star formation rate density of the local universe is similar to those of most previous $z \sim 0$ studies. When compared to the results of other surveys, this agrees with the consensus that the star formation density has decreased by an order of magnitude from a redshift of $z \sim 1$ to the present.

Our results suggest a shift from the faster "burst" star formation process to the slower "quiescent" process, and that the decrease is largely driven by the secular decay in SFR after earlier accretion events.