Measuring Star Formation at GMC Scales in NGC 300

Christopher M. Faesi[1], Charles J. Lada[1], Jan Forbrich[1,2], Karl Menten[3]

[1]Harvard-Smithsonian Center for Astrophysics, [2]University of Vienna, [3]Max-Planck-Institut für Radioastronomie

cfaesi@cfa.harvard.edu

Introduction

Galactic and extragalactic observations have demonstrated that star formation activity takes place within molecular clouds. Studies of local clouds suggest a linear correlation between the star formation rate (SFR) and molecular gas mass (M_{mol}), with significant scatter due to differing dense gas fractions characterizing the clouds. This linear scaling moreover appears to connect smoothly with global observations of galaxies. Here we report work in progress investigating star formation and molecular gas at 250 pc scales in a sample of H II regions in the nearby spiral galaxy NGC 300. We have developed a new method of estimating SFRs from multiwavelength data using population synthesis modeling. We compare our results to detailed studies of resolved star formation in the Milky Way as well as to existing extragalactic SFR prescriptions.

Observations and Data

We targeted 76 H II regions from the Deharveng et al. (1988) catalog with APEX and detected CO J=2-1 at 34 positions to a sensitivity of ~30 mK (3σ). We performed photometry on *Spitzer* 24µm and GALEX UV images using apertures matched to the APEX resolution.

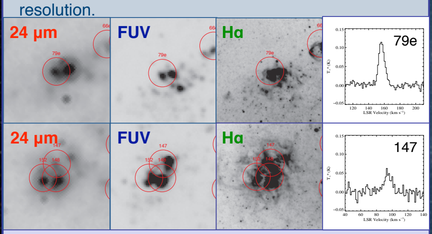


Figure 1 – *Spitzer* 24µm, GALEX UV, and ESO/WFI Hα zoomed-in images and APEX CO spectra of several CO-detected H II regions in our sample. The red circles (27" ~ 250 pc) each indicate an APEX pointing, and represent both the APEX FWHM and the aperture sizes used to perform photometric measurements. Source morphology is typically (but not universally) similar at all three wavelengths.

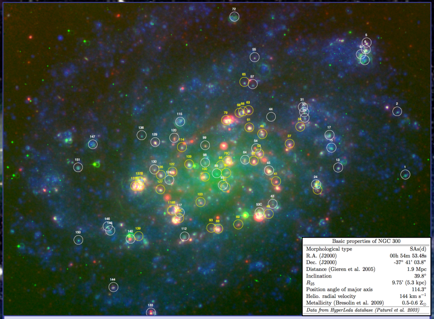
Tracing the molecular ISM: CO(2-1)

$$M_{mol} = \alpha_{CO} L_{CO} = 4.3\times10^{5}\left(\frac{0.7}{R_{21}}\right)\left(\frac{\alpha_{CO}^{1-0}}{4.35}\right)\left(\frac{I_{CO}}{\mathrm{K\,km\,s^{-1}}}\right) M_{\odot}$$

Solomon et al. (1997); Leroy et al. (2013)

Tracing SFR: Hα, FUV, and 24µm

- Hα traces ionizing photons from O stars
- FUV traces direct photospheric emission, primarily from young massive stars
- mid-IR probes dust, which is primarily heated by UV radiation from young stars in these HII regions; used to correct the other two tracers for extinction



Basic properties of NGC 300	
Morphological type	SAs(d)
R.A. (J2000)	00h 54m 53.48s
Dec. (J2000)	-37° 41' 03.8"
Distance (Gieren et al. 2005)	1.9 Mpc
Inclination	39.8°
R_{25}	9.75' (5.3 kpc)
Position angle of major axis	114.3°
Helio. radial velocity	144 km s^{-1}
Metallicity (Bresolin et al. 2009)	0.5-0.6 $Z_{\odot}$
Data from HyperLeda database (Paturel et al. 2003)	

Figure 2 – Three-color image of NGC 300: *Spitzer* 24µm (red), *GALEX* far-UV (blue), and ESO 2.2m WFI Hα (green). The H II regions with APEX CO J=2-1 detections are shown as yellow circles, and nondetections as white circles. The diameter of these circles is equal to the APEX FWHM (27"), corresponding to ~250 pc at the distance of NGC 300.

Determining Star Formation Rates

We present a new method of computing SFRs with Starburst 99, appropriate for single H II regions.

•FUV changes very little over Hα emission timescale
-> tracer of **population mass, M_{pop}**

•Hα decreases rapidly after ~2 Myr
-> tracer of **population age, τ**

•SFR ~ M_{pop} / τ

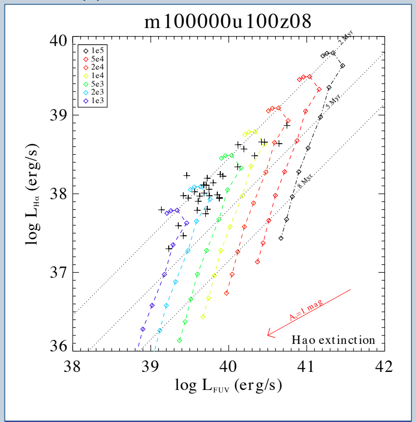


Figure 3 – Hα and FUV luminosities for grids of instantaneous burst, single population Starburst99 models of various masses. The dotted lines show the time evolution of individual populations. Our extinction-corrected (using Hao et al. 2011) data are shown as plus symbols. For each data point, interpolating the model grid leads to a direct estimate of the age and mass (and thus the SFR, with our assumptions). The reddening vector shows the effect of 1 A_V of extinction.

Modeling Details

Starburst99 parameters:

- Instantaneous burst
- Fixed mass population
- Kroupa IMF
- 100 $M_{\odot}$ IMF upper limit
- Z = 0.08 (40% solar)
- Geneva evolution models

SFR scaling law at 250 pc scales

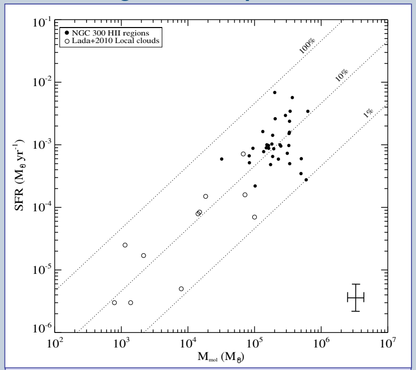


Figure 4 – SFR vs. molecular gas mass (as traced by CO) at 250 pc scales in CO-detected H II regions of NGC 300 (filled circles) compared with measurements of local clouds from Lada et al. (2010; open circles). Lines of constant dense gas fractions of 1%, 10%, and 100% are overplotted as dotted lines. The NGC 300 data by themselves show no clear evidence of a significant scaling relation between SFR and cloud mass, although the large scatter over a limited dynamic range of our data could easily mask a linear scaling similar to that observed for local clouds. Some of this scatter is intrinsic and likely reflects the dense gas fraction or evolutionary state of these star-forming regions.

Complications

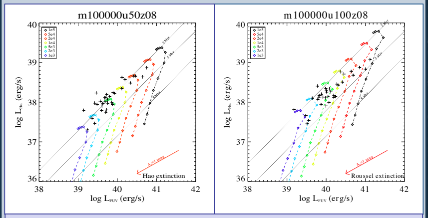


Figure 5 – Adjusting the upper mass limit of the IMF down to 50 $M_{\odot}$ (left) results in lower Hα emission (and lower FUV, to a lesser extent) for a given population mass. Even if there is no physical cutoff to the IMF, low mass populations may nonetheless exhibit a dearth of higher mass stars, and so adjusting this parameter may be necessary for the low mass H II regions. The results of this modeling are also very sensitive to extinction; the right plot shows the effects of using a single extinction value (from Roussel et al. 2005) for our H II regions.

H II Region Characteristics

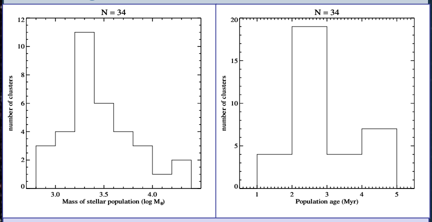


Figure 6 – Cluster mass function (left) and distribution of ages (right) derived by treating our H II regions as single stellar populations. Our Hα-based selection criterion biases us toward young clusters; the majority are less than 3 Myr old, and all are under 5 Myr. The mass function above ~1500 $M_{\odot}$ has a best-fit power law slope of -0.9, although this is highly uncertain due to limited sample size and uncertain completeness.

Comparison to other methods

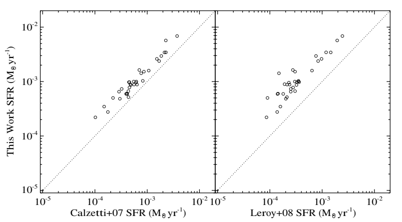


Figure 7 – SFRs for our sample compared with two literature prescriptions applied to our data: the hybrid Hα+24µm method of Calzetti et al. (2007; left), and the FUV+24µm method of Leroy et al. (2008; right). There are significant correlations between the three methods, but our new prescription derives higher star formation rates by an average of a factor of 1.8 and 3.4 as compared to the Calzetti and Leroy methods, respectively.

Conclusions

•We have sampled the star formation activity and molecular gas in H II regions in NGC 300 at 250 pc scales. Cloud masses suggest Galactic-like GMCs.

•We have developed a new method for estimating SFRs for single stellar populations using Starburst99 modelling. Results are sensitive to extinction and to the IMF upper mass limit chosen for the models.

•The SFR-M_{mol} relation in our sample is consistent with the extrapolation of the relation in local clouds. The large scatter may reflect differing dense gas fractions or evolutionary states and explain our inability to detect a correlation between SFR and gas mass over the restricted dynamic range of our data.

•Derived SFRs for our sample are higher than those computed using standard extragalactic prescriptions.

REFERENCES: Deharveng et al. 1988 • Solomon et al. 1997 • Leitherer et al. 1999 • Roussel et al. 2005 • Calzetti et al. 2007 • Leroy et al. 2008 • Lada et al. 2010 • Hao et al. 2011 • Lada et al. 2012 • Leroy et al. 2013

CMF is supported by an NSF Graduate Research Fellowship.