Star formation in M 33
Simon Verley
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Star formation
Motivations
The data
Radial study
Local study
Cluster birthline (E. Corbelli)

Study of star formation in the local spiral galaxy M 33

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The local late type spiral galaxy M 33

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M 33

- Blue low luminosity spiral galaxy ($D = 840$ kpc, $1'' = 4$ pc)
- Stellar mass: 6×10^9 $M_\odot$ (estimated from rotation curve)
- Atomic gas mass: $\sim 2 \times 10^9$ $M_\odot$ ($h_r = 16$ kpc)
- Molecular gas mass: $\sim 1.5 \times 10^8$ $M_\odot$ (CO $J = 1 - 0$, $h_r = 1.4 - 2.4$ kpc)

The Kennicutt-Schmidt law of star formation

Schmidt 1959, ApJ, 129, 243; Kennicutt 1998, ApJ, 498, 541

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$$\Sigma_{\mathrm{SFR}} \propto \Sigma_{\mathrm{gas}}^{N} ?$$

Questions:

- SFR: Hα, UV, bolometric, 24 μm?
- Gas: molecular (H_2), atomic (HI), total (H_2 + HI)?
- At which spatial resolution does it hold? Radially? Locally?
- Does the SFR correlates better with Σ_{gas} or ρ_{gas}?
- How important is the fitting method in determining N when dispersion is high?

Multiwavelength data

Gas:

- HI — Deul & van der Hulst 1987 Westerbork
- H_2 — Corbelli 2003; Heyer et al. 2004 FCRAO

SFR:

- Optical: Hα — Hoopes & Walterbos 2000 KPNO
- Ultraviolet: FUV — Gil de Paz et al. 2007 GALEX
- Infrared: IRAC+MIPS — Verley et al. 2007 *Spitzer*

Resolution 45″ given by the CO map.

Nature of the 24 μm sources

Verley et al. 2009, A&A, 493, 453; Corbelli et al. 2009 A&A, 495, 479

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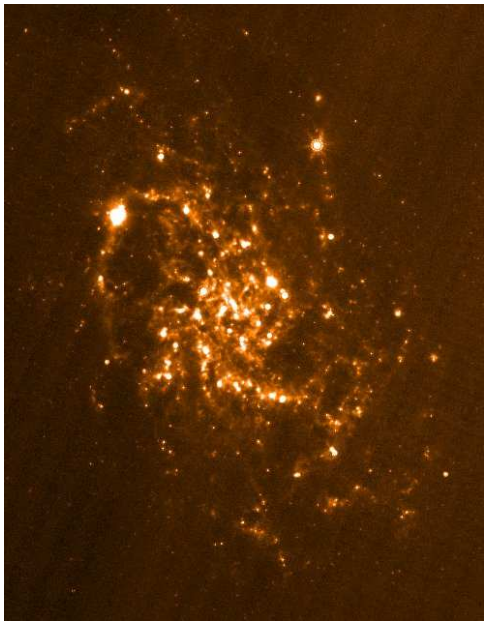
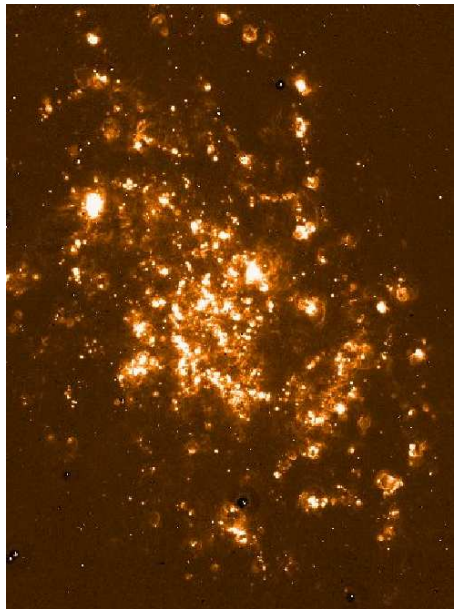
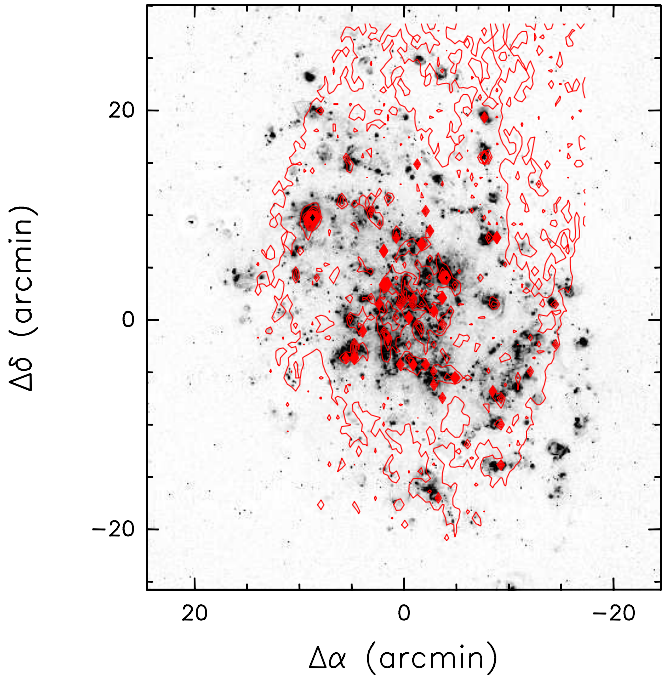


24 μm



Hα



24 μm contours on Hα image

- 24 μm: High diffuse fraction powered by evolved stars
- Hα: Incompleteness of IMF for low luminosity regions

Infrared, ultraviolet, and optical radial profiles

Verley et al. 2009, A&A, 493, 453

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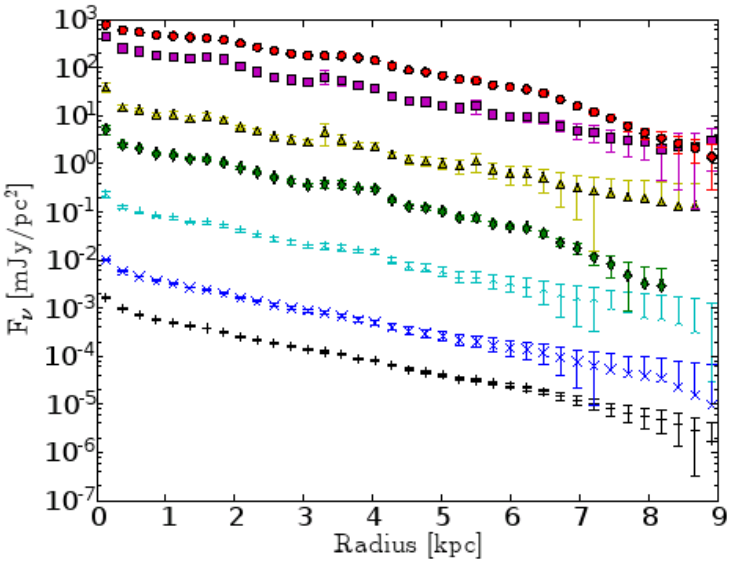

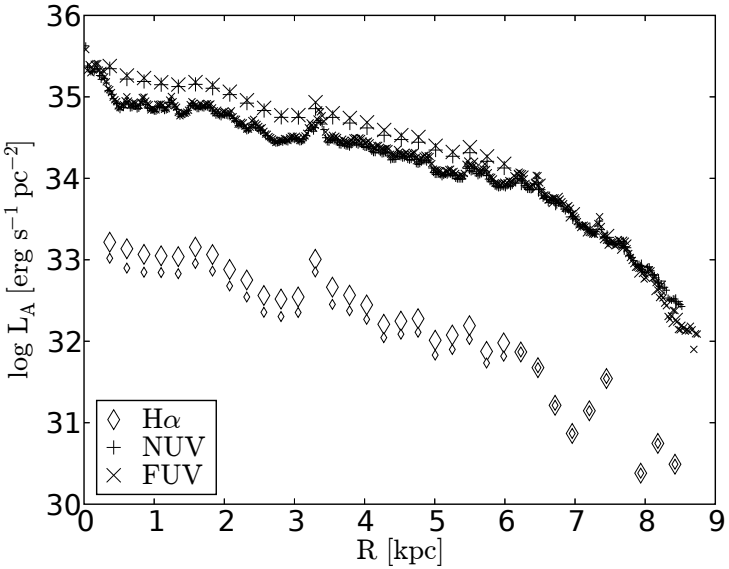

Multiwavelength SFR across the disk in M 33

Verley et al. 2009, A&A, 493, 453

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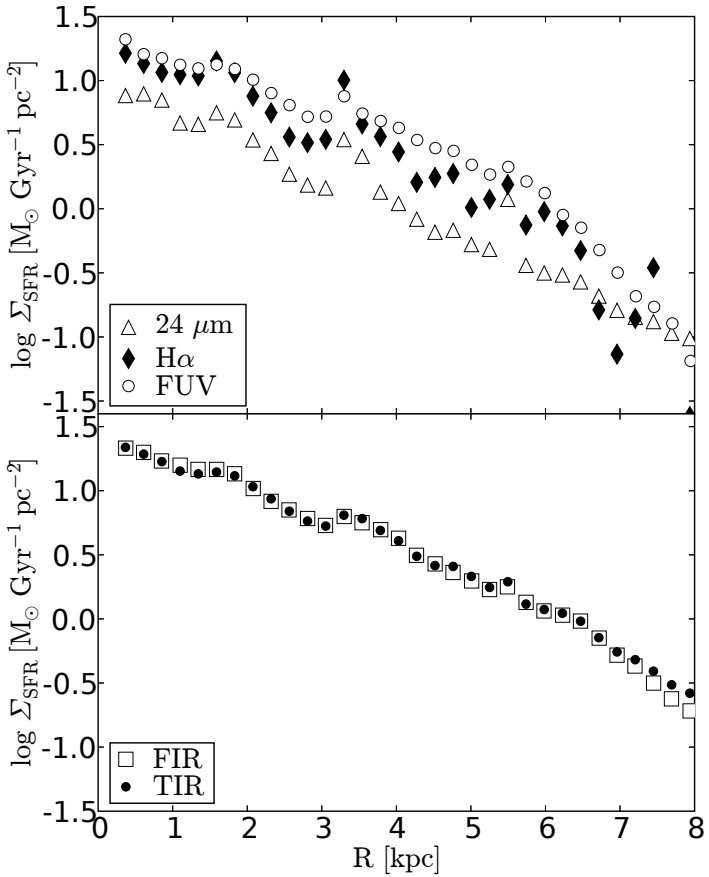

$$SFR = 0.45 \pm 0.10\ M_\odot\ yr^{-1}$$

The radial Kennicutt-Schmidt law in M 33

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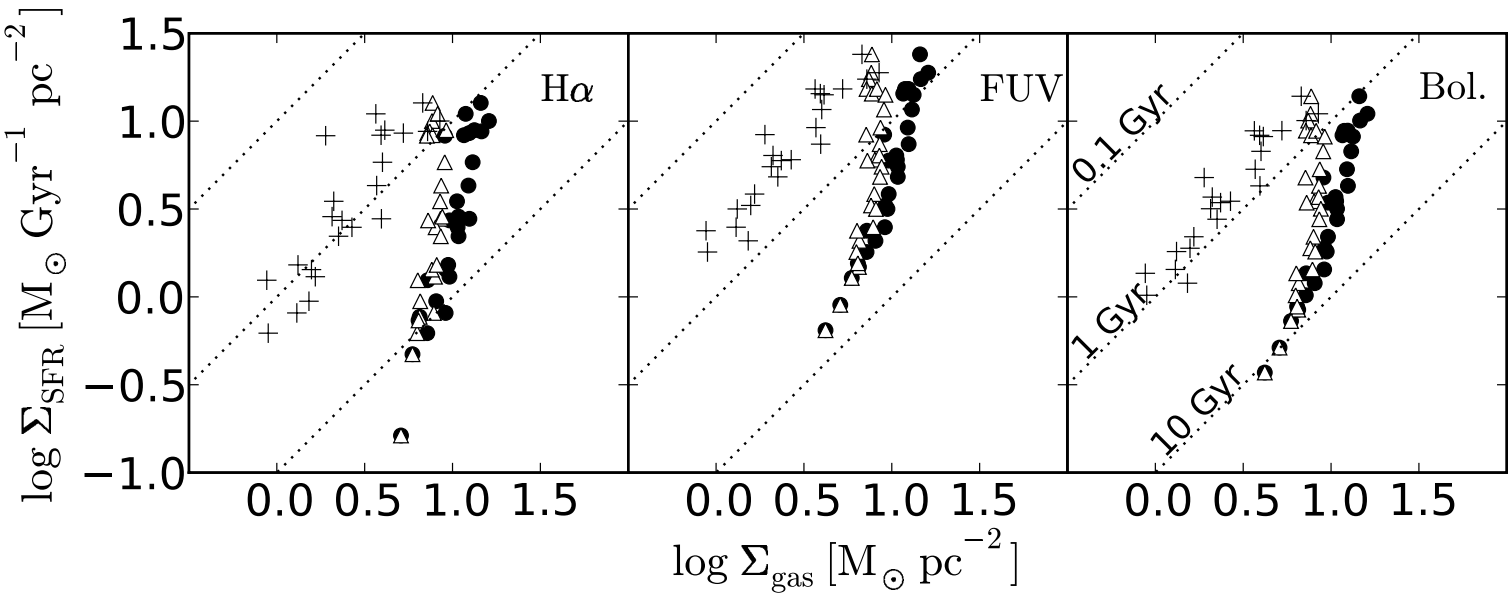

Kennicutt-Schmidt indexes:

Molecular gas	$N_{\mathrm{H}\alpha} = 1.3 \pm 0.2$	$N_{\mathrm{FUV}} = 1.1 \pm 0.1$
Total gas	$N_{\mathrm{H}\alpha} = 3.6 \pm 0.3$	$N_{\mathrm{FUV}} = 2.9 \pm 0.2$

The local Kennicutt-Schmidt law in M 33

Resolution: 180 pc

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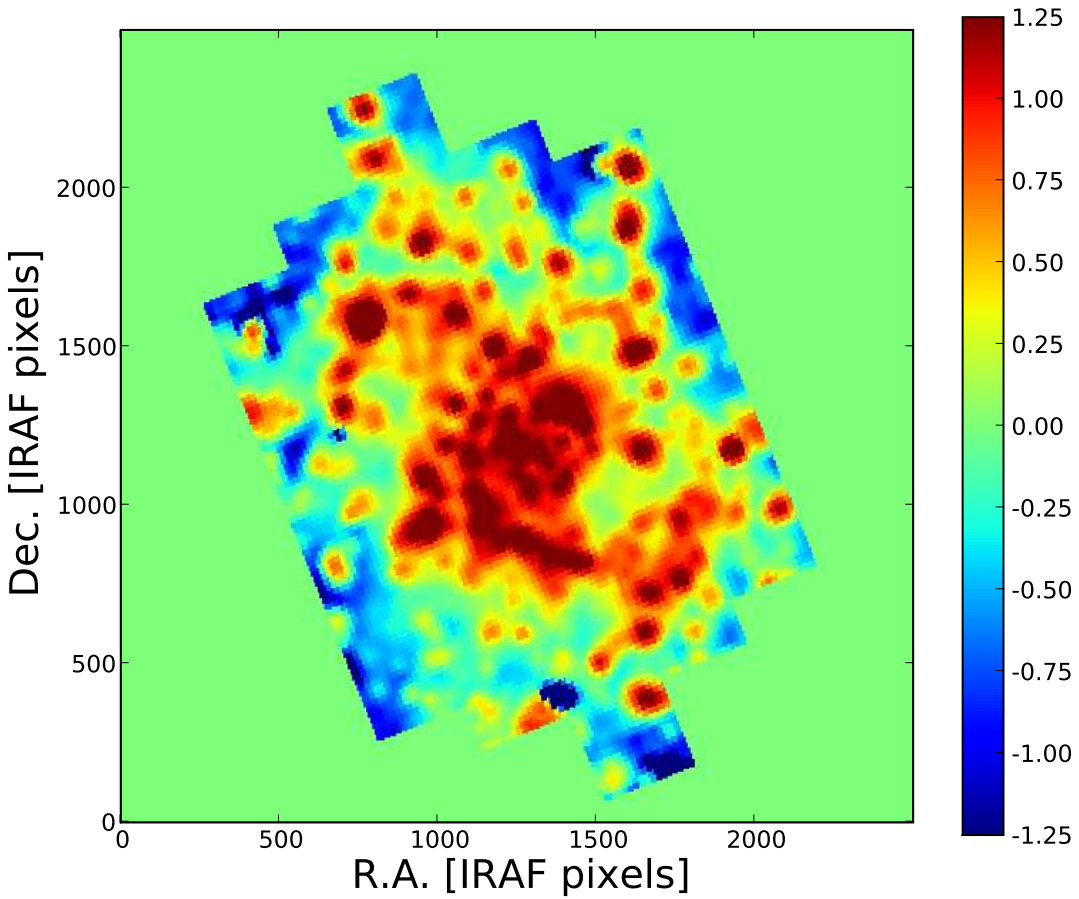

The local Kennicutt-Schmidt law in M 33

First fitting method

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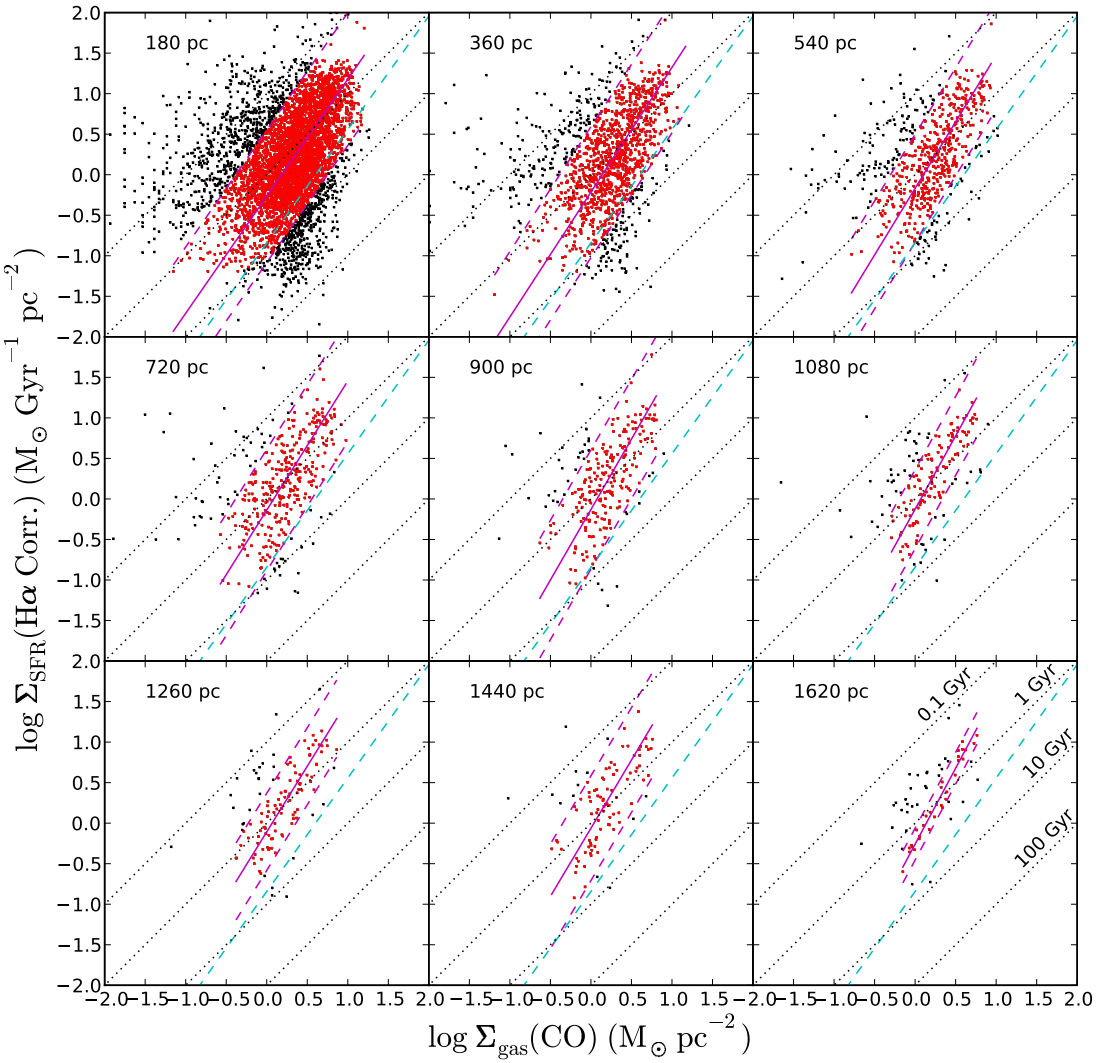


The local Kennicutt-Schmidt law in M 33

First fitting method

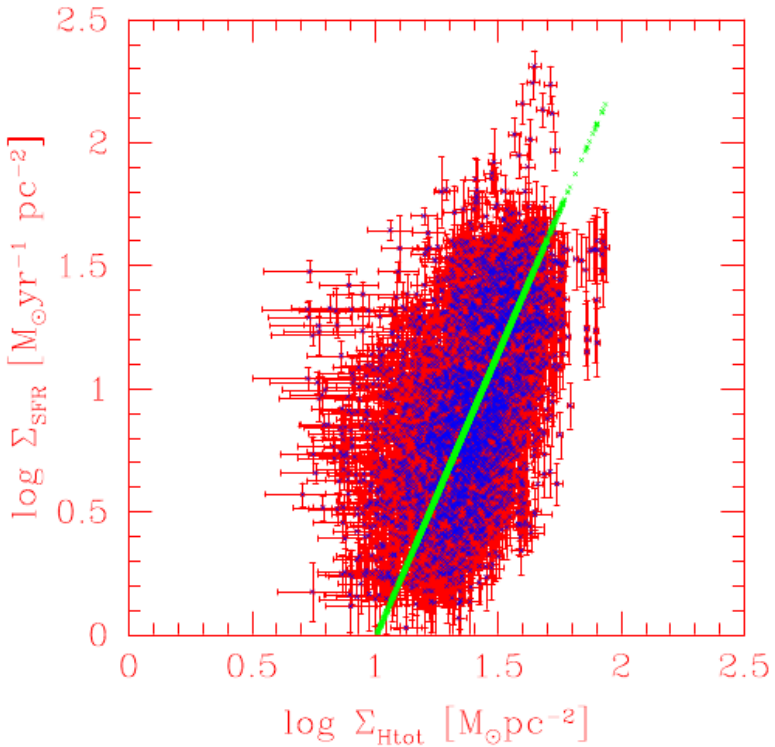
Res.	Molecular gas			Atomic gas			Total gas		
	Hα	FUV	Bol.	Hα	FUV	Bol.	Hα	FUV	Bol.
180 pc	1.44 (43)	1.12 (24)	1.12 (30)	2.53 (14)	1.96 (26)	1.96 (23)	2.59 (18)	1.91 (19)	1.90 (19)
360 pc	1.54 (16)	1.17 (25)	1.17 (28)	2.59 (12)	2.10 (14)	2.11 (15)	2.82 (8)	2.09 (17)	2.09 (18)
540 pc	1.64 (20)	1.17 (9)	1.17 (11)	2.88 (11)	2.18 (10)	2.24 (15)	3.39 (16)	2.40 (13)	2.41 (12)
720 pc	1.59 (7)	1.16 (11)	1.15 (9)	3.16 (11)	2.44 (10)	2.44 (13)	3.38 (10)	2.29 (9)	2.30 (12)
900 pc	1.74 (10)	1.28 (6)	1.28 (6)	3.29 (10)	2.09 (7)	2.10 (8)	3.49 (9)	2.22 (6)	2.24 (7)
1080 pc	1.81 (15)	1.27 (13)	1.22 (8)	3.62 (6)	2.80 (7)	2.85 (8)	3.98 (13)	2.27 (4)	2.28 (4)
1260 pc	1.62 (8)	1.18 (4)	1.17 (5)	2.77 (4)	2.82 (5)	2.83 (7)	4.08 (11)	3.05 (11)	2.88 (12)
1440 pc	1.68 (3)	1.38 (8)	1.39 (6)	2.79 (2)	2.73 (3)	2.74 (3)	3.18 (3)	2.60 (4)	2.61 (4)
1620 pc	1.87 (22)	1.16 (4)	1.16 (4)	3.76 (2)	3.18 (5)	3.19 (5)	3.42 (3)	2.66 (3)	2.68 (3)

Cons:

- CO below detection threshold included
- No correlation coefficient

The local Kennicutt-Schmidt law in M 33

Second fitting method



Second fitting method

- Best spatial resolution: 180 pc
- FCRAO CO flux above 2σ noise
- Errors in gas surface density, FUV SFR density as well as extinction corrections
- $N_{H_2} = 2.25 \pm 0.07$, Pearson correlation coefficient $= 0.45$
- $N_{Tot} = 2.64 \pm 0.07$, Pearson correlation coefficient $= 0.50$

Improving the correlation between gas and SFR

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- Toomre's Q and molecular gas fraction are regulated by hydrostatic pressure
- $\rho_{\rm gas} = \Sigma_{\rm gas}/h_v$, h_v from hydrostatic equation $(\sigma_\star, \sigma_{\rm gas}, \Sigma_\star, \Sigma_{\rm gas})$
- SF timescale $\propto (G\rho_{\rm gas})^{-0.5}$
- Linear relation: $\Sigma_{\rm SFR} \propto \Sigma_{\rm H_2}/\rho_{\rm gas}^{-0.5}$
- $N = 1.08 \pm 0.04$, Pearson coefficient $= 0.64$

- Linear relation: $\Sigma_{\rm SFR} \propto \rho_{\rm gas}^{N}$
- $N = 1.08 \pm 0.02$, Pearson coefficient $= 0.75$

Incompleteness of the IMF

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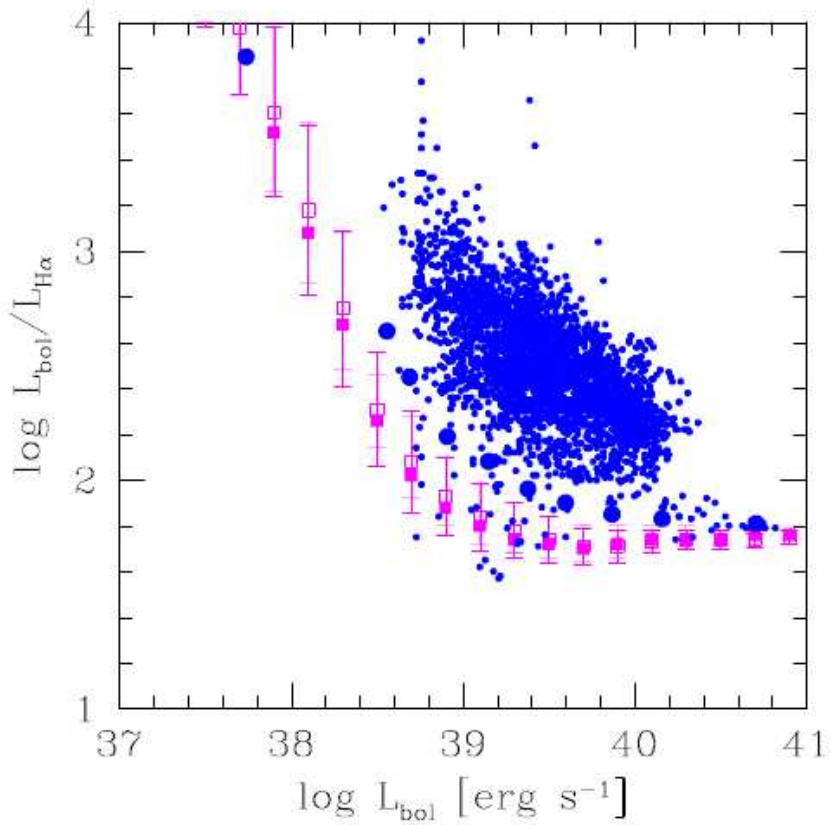
The steeper KS indexes obtained using the Hα as SFR tracer are due to the incompleteness of the IMF when the luminosity of the regions is $L_{\rm bol} < 10^{39}$ erg s^{-1}.



The modeled cluster birthline

Corbelli, Verley, Elmegreen, Giovanardi 2009, A&A, 495, 479

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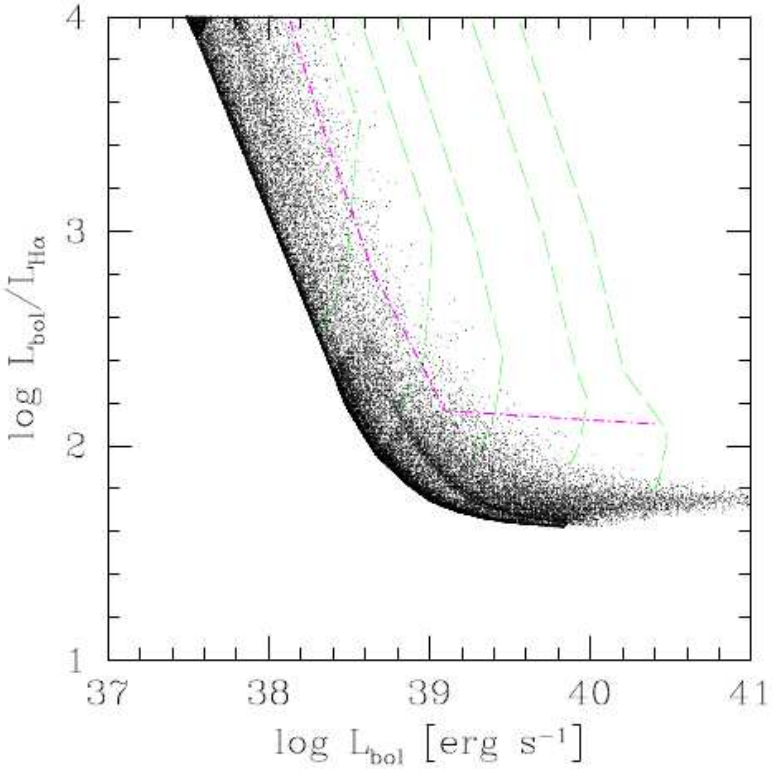

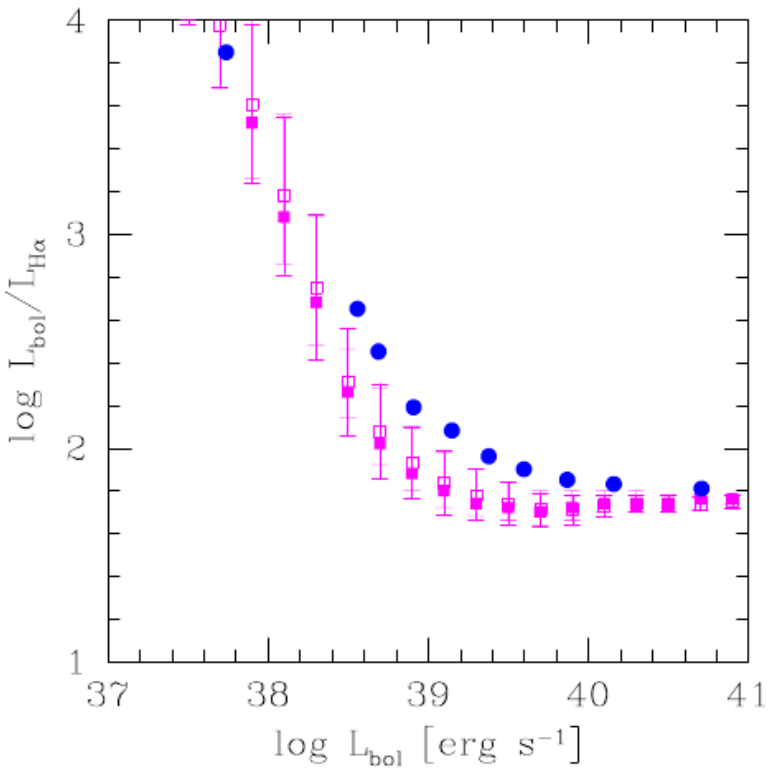

The cluster birthline in M 33

Corbelli, Verley, Elmegreen, Giovanardi 2009, A&A, 495, 479