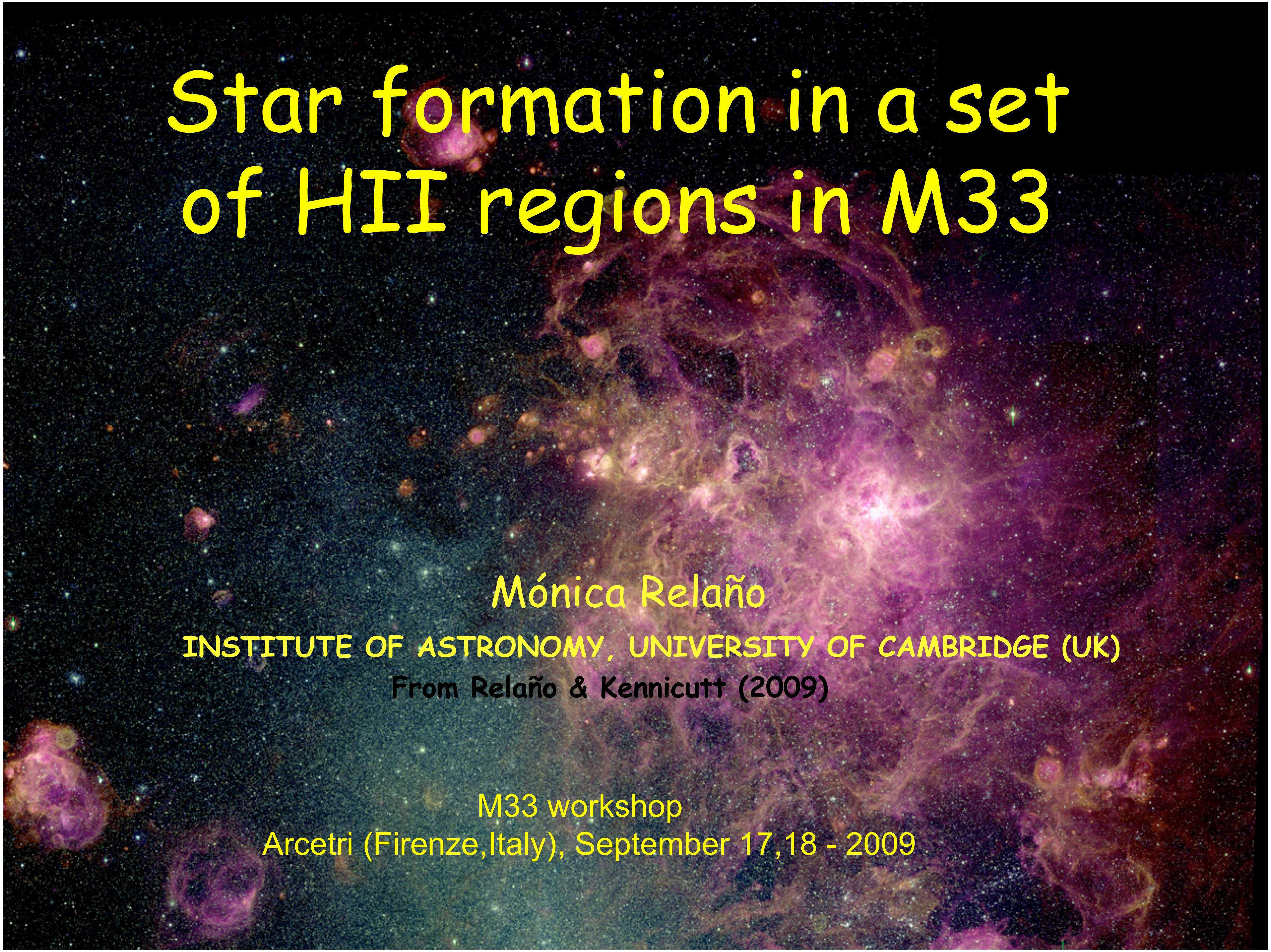

Star formation in a set of HII regions in M33

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From Relaño & Kennicutt (2009)

M33 workshop
Arcetri (Firenze,Italy), September 17,18 - 2009

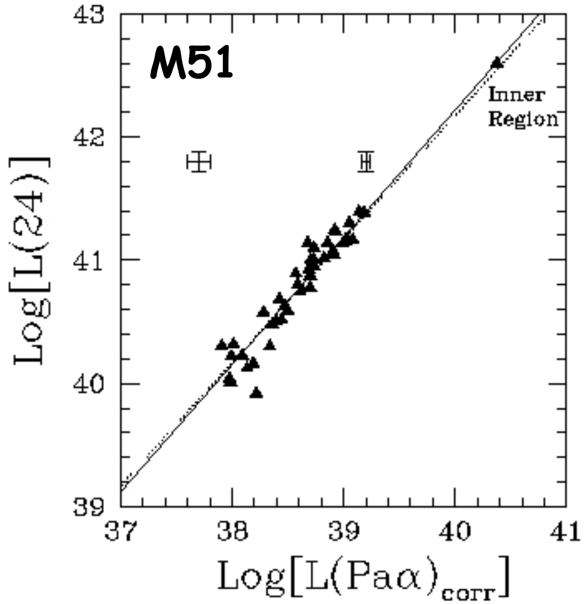
Overview

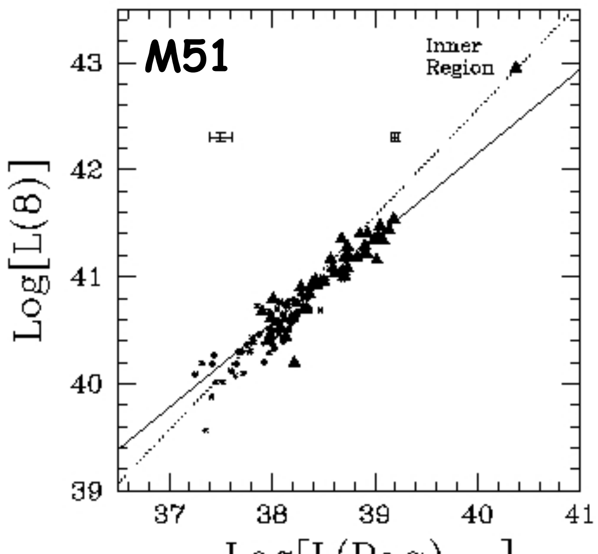
• New SFR calibrators based on IR emission from SPITZER telescope:

•24μm and 8μm luminosities are related to the extinction-corrected Hα luminosity

• HII knots in M51 (Calzetti et al 2005) and M81 (Pérez-González et al. 2006).

• Also confirmed in more complete studies involving larger samples of galaxies (e.g. Wu et al. 2005; Calzetti et al. 2007; Relaño et al. 2007) and Alonso-Herrero et al. (2006) for LIRGs, ULIRGs.





24μm and 8μm luminosity as a function of the extinction-corrected Paα luminosity for 42 HII knots in the inner region of M51 (from Calzetti et al. 2005)

Overview

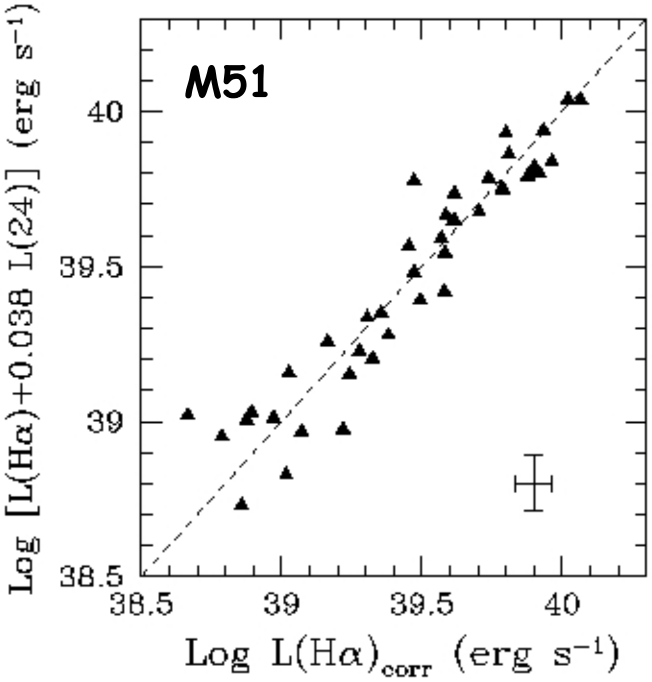
- Kennicutt et al. (2007) suggest that the amount of extincted Hα radiation should scale with the luminosity re-radiated in the infrared:

$$L(H_\alpha)_{corr} = L(H_\alpha)_{obs} + a \times L(24\mu m)$$

where a is obtained from the scaling relation that is empirically fitted.

- This linear combination correlates better than other SFR tracers with the extinction-corrected Hα luminosity.

- Also confirmed in HII regions of a more complete galaxy sample (Calzetti et al. 2007) and for entire galaxies (Zhu et al. 2008, Kennicutt et al. 2009)



24μm and observed Hα luminosity combination as a function of the extinction-corrected Hα luminosity for the same 42 HII knots in the inner region of M51 (from Kennicutt et al. 2007).
The best fitted is found for the linear combination with a=0.038. The scatter reflects a combination of errors in the measured luminosities and the effects of cluster age and dust geometry in the linear combination assumption

Overview

… And within the HII Regions?

• Little has been done to corroborate the spatial correlations of the emission proposed as tracers of the star formation and the geometries of the gas and dust relative to the position where the stars actually form. (See Churchwell et al. 2006 and Watson et al. 2008 for Galactic HII regions and Verley et al. (2007;2009) for an study of dust emission across M33 disk)

• Using spatially resolved observations we are able to test the assumptions upon which the statistical studies rest.

Dust emission distribution in HII regions of M33

M33 (840 kpc) is an ideal object to study the dust emission distribution within the star forming regions.

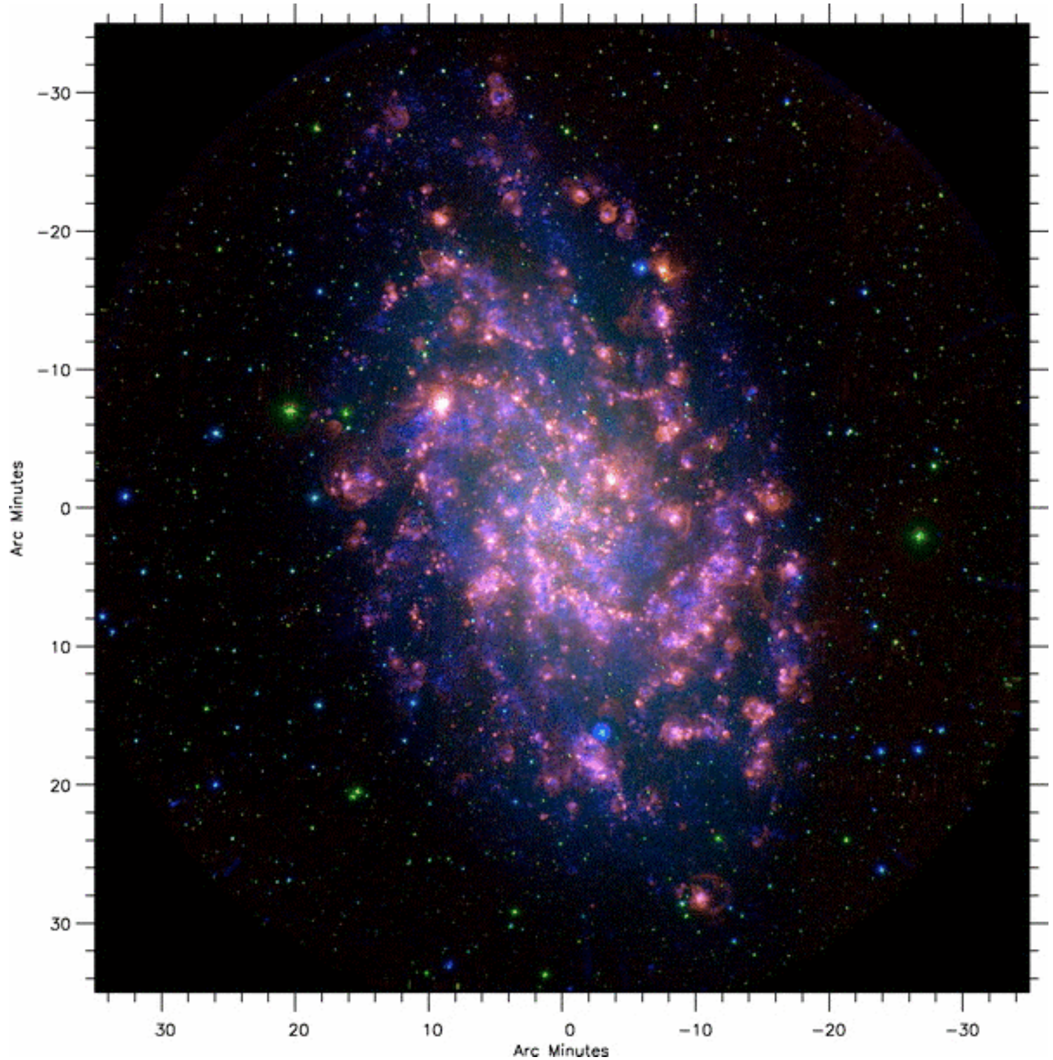
Selection of high luminous HII regions: NGC 595, NGC 604, NGC 588, NGC592 and IC131.

<u>- Infrared Data from SPITZER:</u>
IRAC (8.0μm) and MIPS (24μm) with spat. resolutions: 1.2¨~ 5 pc, IRAC and 5¨~ 20 pc, MIPS-24μm

- F<u>UV Data:</u> GALEX Mission (res ~5¨)

- <u>Optical Data:</u> Hα and Hβ

- <u>For some HII regions</u>: CO molecular data from Wilson & Scoville (1992) res ~ 8¨



Multiwavelength view of M33 (Thilker et al. 2005): Color channels Hα + continuum (*red*), continuum (*green*) and *GALEX* NUV (*blue*).

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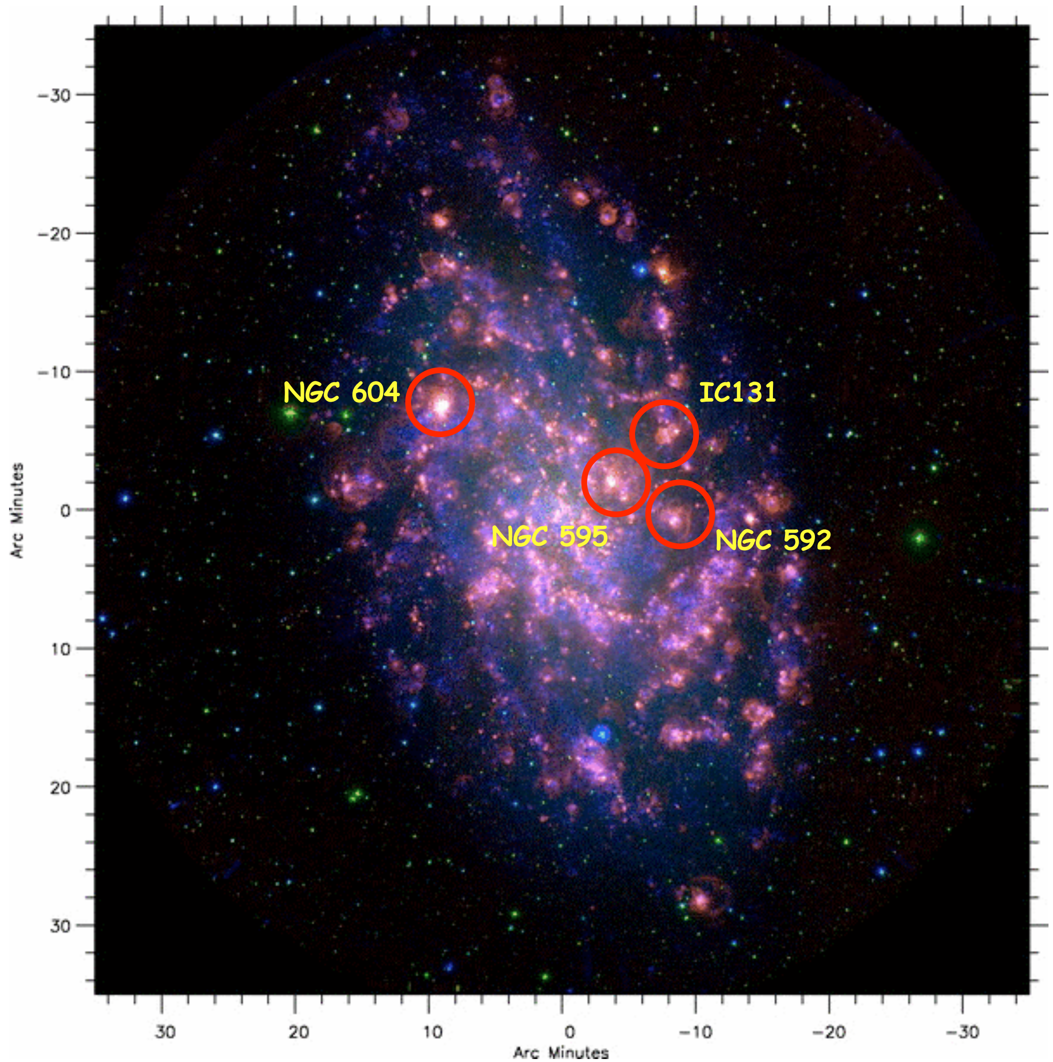


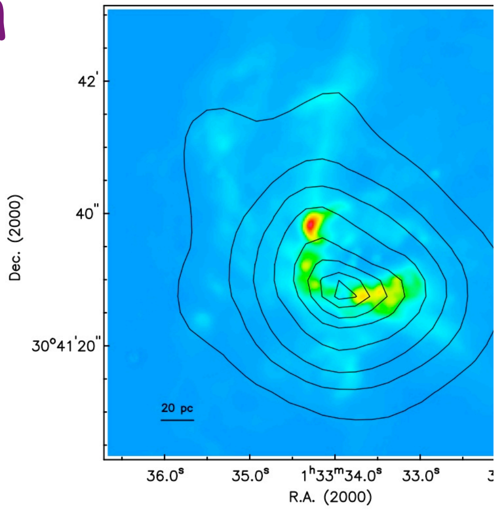
Multiwavelength view of M33 (Thilker et al. 2005): Color channels Hα + continuum (*red*), continuum (*green*) and *GALEX* NUV (*blue*).

Hα and 24μm emission

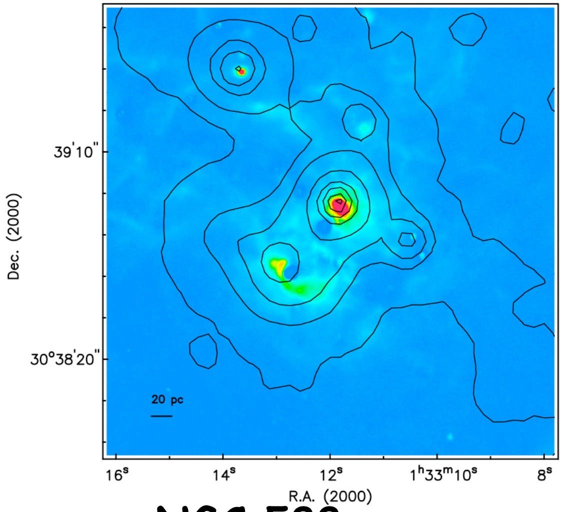
- Good spatial correlation between 24μm and Hα emission: the 24μm emission is a well ***local*** star formation tracer of the current star formation (e.g. Calzetti et al. 2007, Kennicutt et al. 2007)

- Dust emitting at 24μm would be heated by emission coming from OB stars within the HII region.

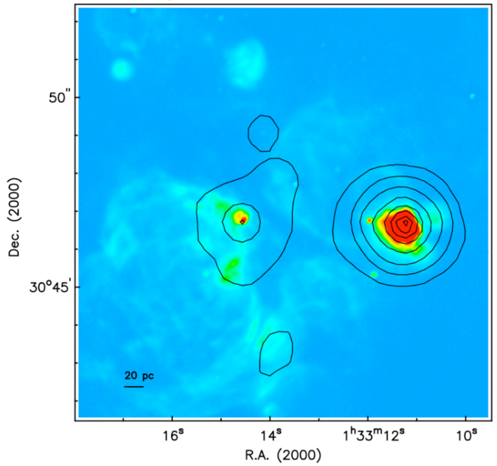
NGC 595



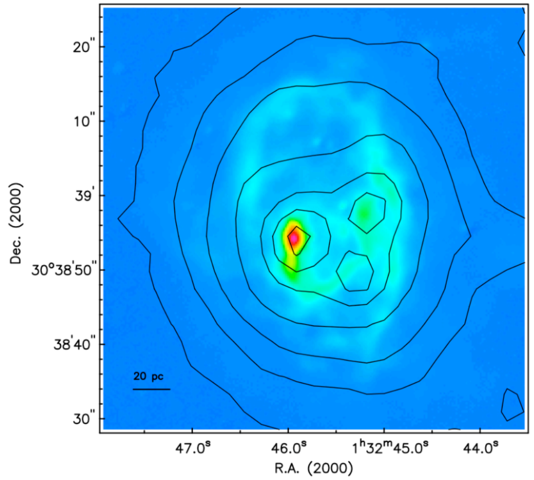
NGC 592



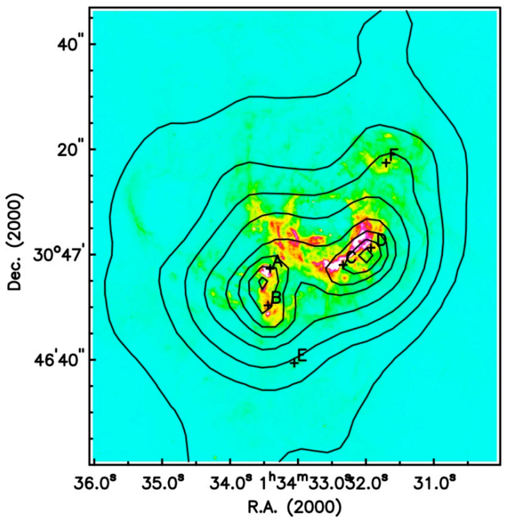
IC 131



NGC 588



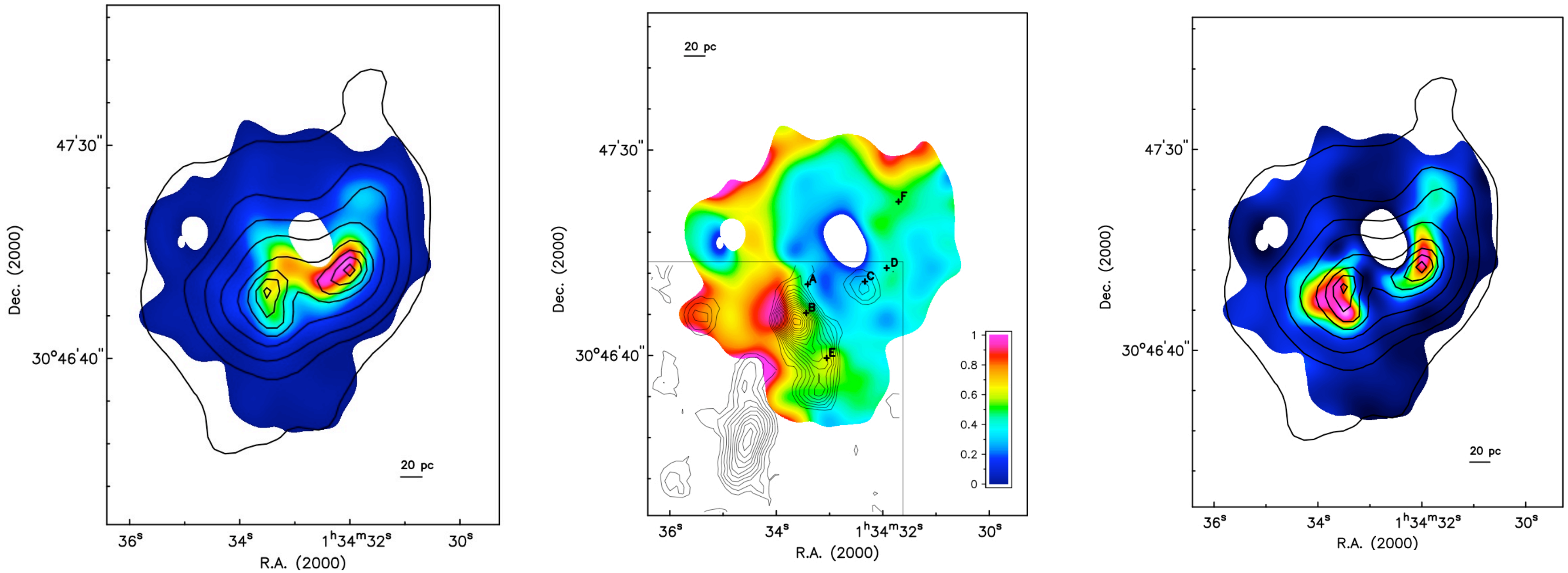
Hα (color) plus 24μm emission contours at (2, 5, 10, 20, 40, 60, 80, 95)% of the maximum 24μm intensity (2%=10σ)



NGC 604

L(Hα)$_{observed}$, L(Hα)$_{absorbed}$ and L(24μm)

L(Ha)$_{observed}$ | **Balmer Extinction map** | **L(Ha)$_{absorbed}$**



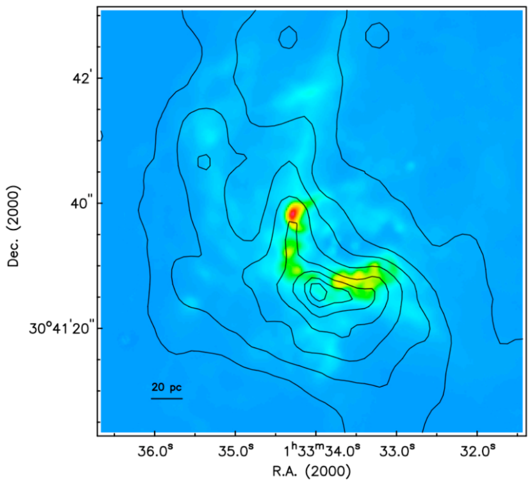
- L(Hα) map at 6¨ resolution with 24μm overlaid.
- Balmer extinction map at 6¨ resolution (from HST Hα and Hβ images)
- Absorbed Hα luminosity map as a difference of the total extinction corrected Hα luminosity and the Hα luminosity corrected for the foreground Galactic extinction.

In spite of the relatively low extinction in NGC 604, the absorbed Hα luminosity correlates better with the 24μm than the observed Hα luminosity. This results qualitatively confirms that the 24μm emission is directly linked to the extincted star formation.

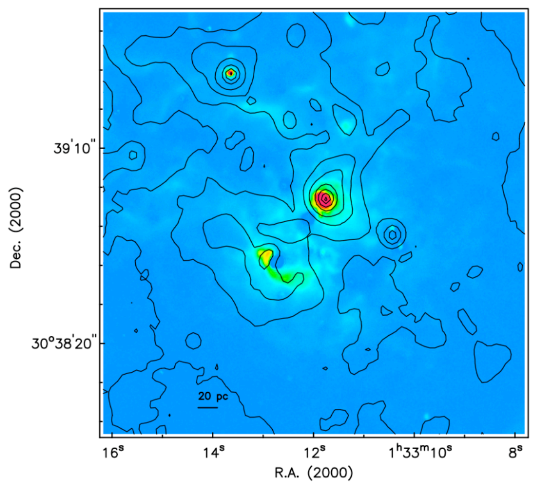
Hα and 8μm emission

- The 8μm emission traces the filamentary structure delineating the Hα filaments and shells. In the central part, the 8μm maxima is displaced from the Hα maxima (also seen in Helou et al. 2004, Watson et al. 2008)
- Agreement with previous studies that fail to find a correlation between the Hα and 8μm luminosities (e.g. Calzetti et al. 2007)

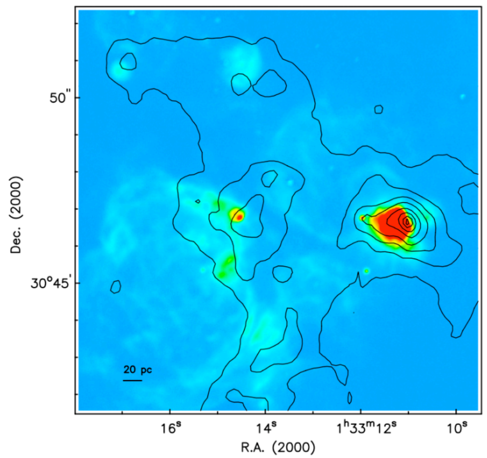
NGC 595



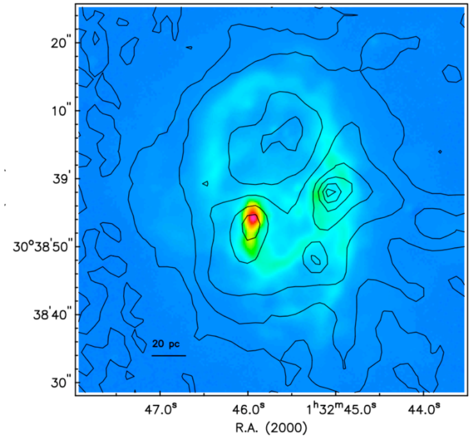
NGC 592



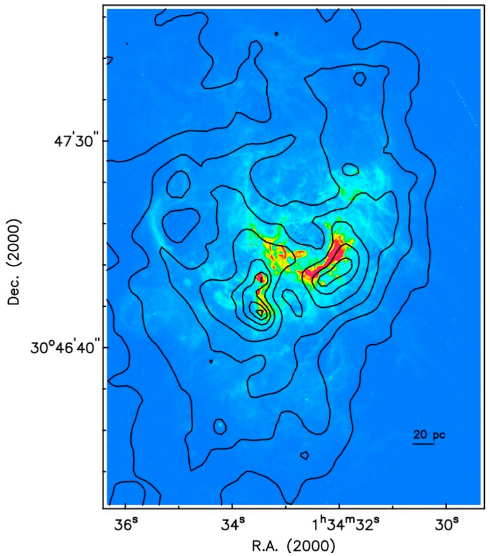
IC 131



NGC 588



Hα (color) plus 8μm emission contours at (2, 5, 10, 20, 40, 60, 80, 95)% of the maximum 8μm intensity (2%=2-6σ)



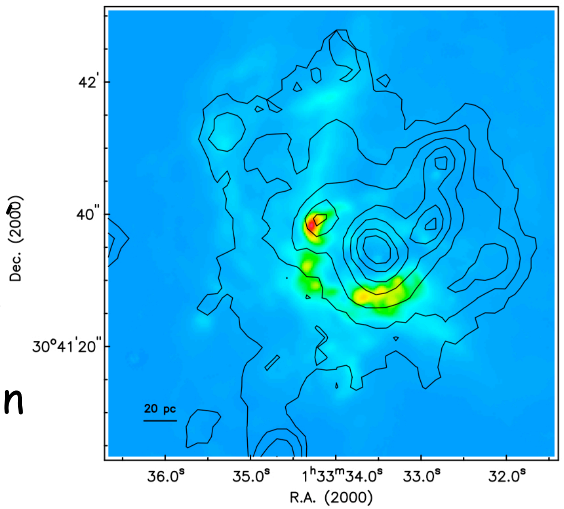
NGC 604

- The morphology suggests that the 8μm emission is more related to the PDR than to the location where the ionizing stars are.

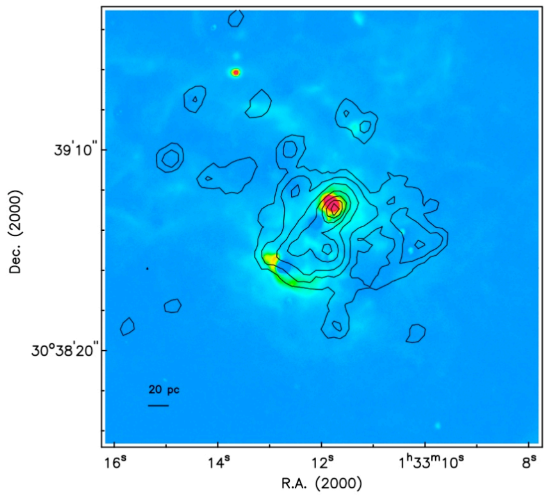
Hα and UV emission

- The UV stellar emission follows different distribution from the dust emission at 24μm and 8μm and the ionized gas.
-Since it is absorbed by the dust we would not expect to observed UV and dust emission at the same location within the HII regions.
-Hα emission surrounds the FUV in all HII regions of our sample, except IC131-West.
-This trend alson seen in M51 (Calzetti et al. 2005) and in M33 in general (Thilker et al. 2005)

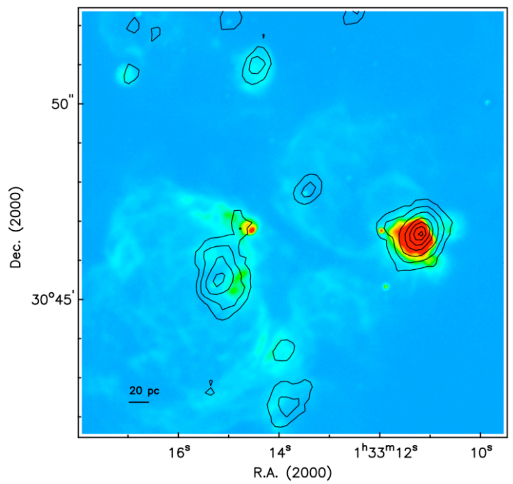
NGC 595



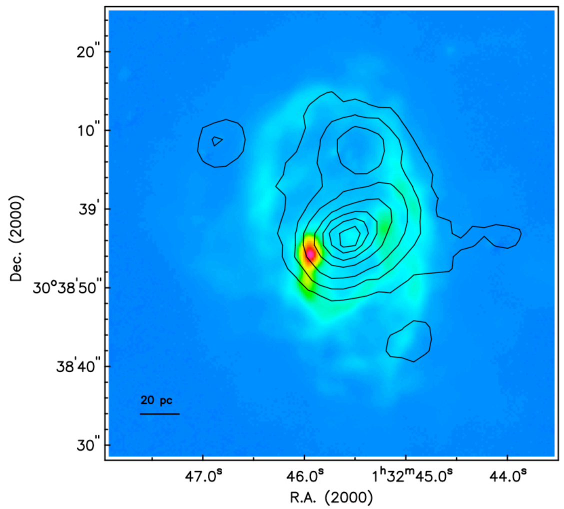
NGC 592

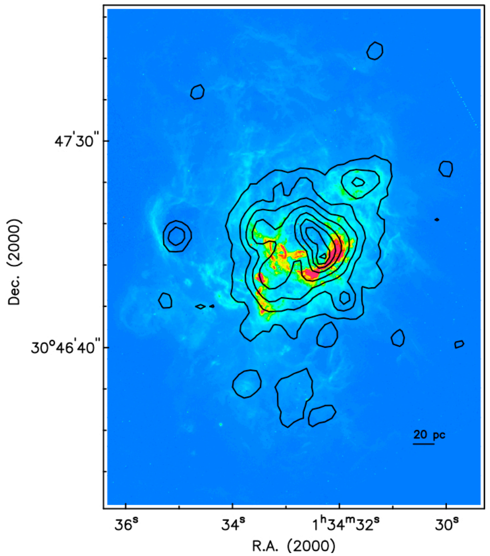


IC 131



NGC 588

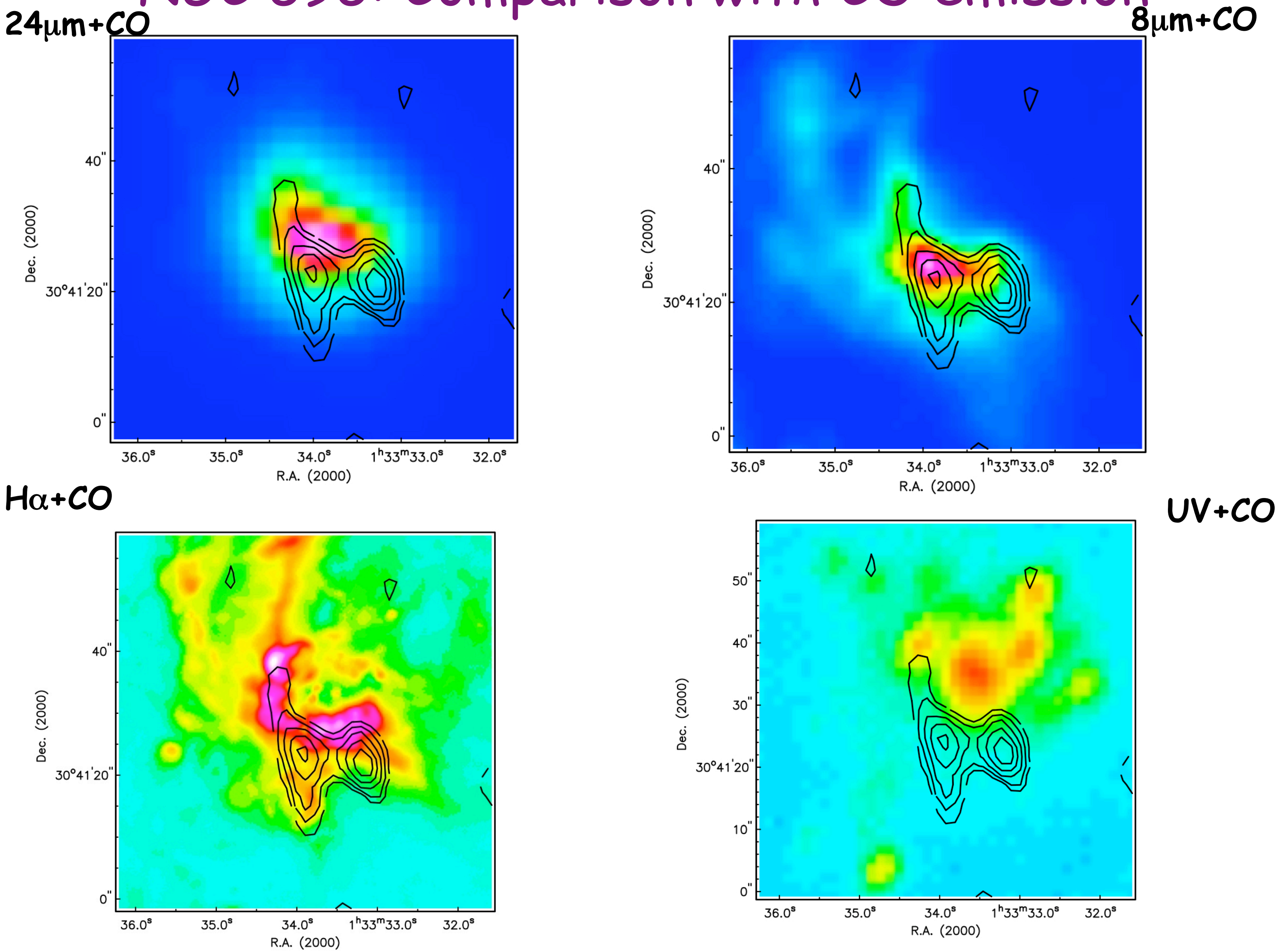




NGC 604

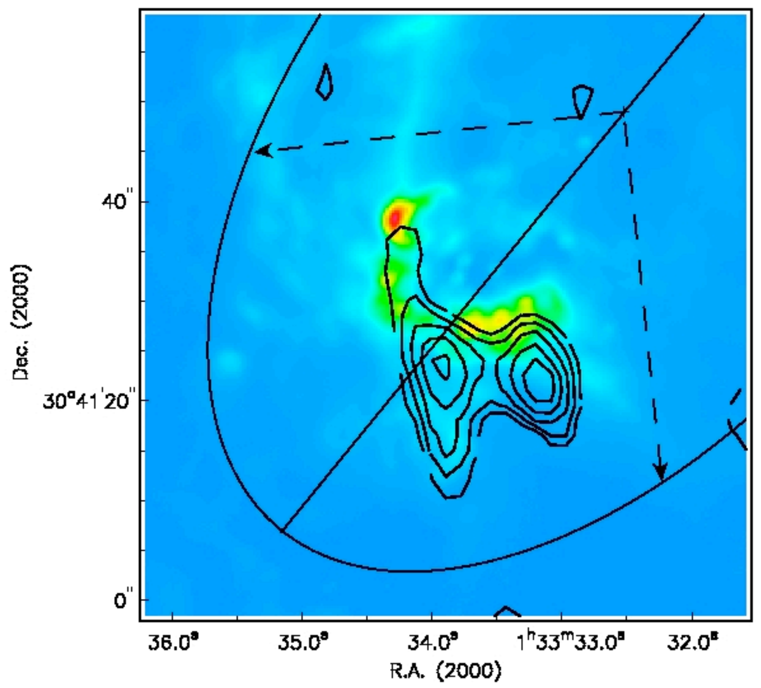
Hα (color) plus FUV emission contours at (5, 10, 20, 40, 60, 80, 95)% of the maximum 24μm intensity (5%=6-20σ)

NGC 595: Comparison with CO emission

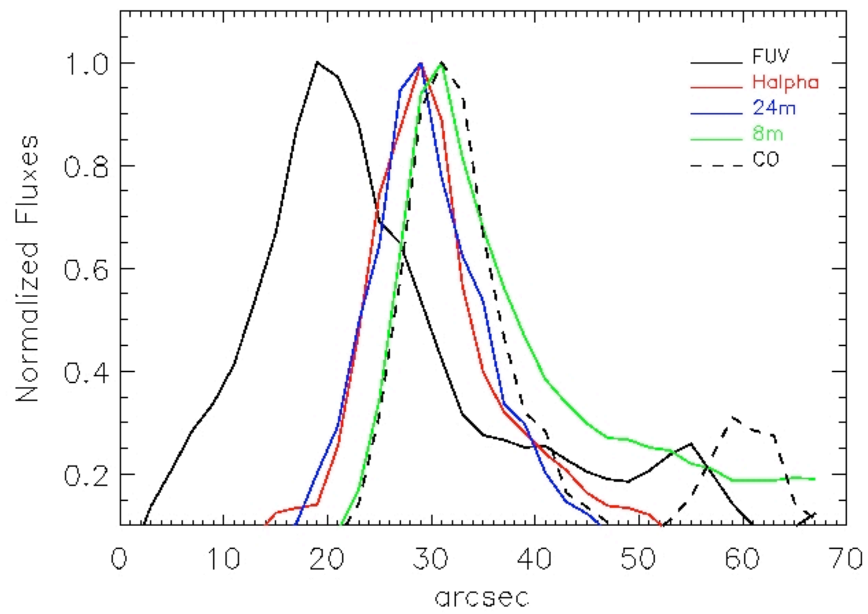


CO data from Wilson & Scoville (1992)

NGC 595



- Integration zone for the radial profiles. The location of the center and the dashed lines (45deg from the major axis of the ellipse) were chosen to include the Hα emission of the shell. Ellipticity derived assuming i=56deg for M33.



- Radial profiles of FUV, Hα, 24μm, 8μm and CO emission distribution for NGC 595. Rings of 2¨width, integrated fluxes normalized to the maximum value in each ring. Distances along the major axis.

- From the center position to the outer radii a ***layered structure emission*** is clearly seen: FUV is located at the inner part of the ellipse, then at larger radii there is emission at Hα and 24μm, both following the same distribution, and slightly further out we find the 8μm and CO emission distribution.

Integrated fluxes and star formation

- The ¨classical¨ SFR calibrations assume a constant SFR over a time scale of 100Myr (Kennicutt 1998, Calzetti et al. 2007; Iglesias-Páramo et al. 2006) , typical ages for our HII regions are ~4Myr and the observable parameters suggest in general an instantaneous burst of SF
- Star formation calibrations for an instantaneous burst, Salpeter IMF, mass limits 0.1-100Msun and Z=0.02. At τ~4Myr we find:

$$SF(H_\alpha)(M_{sun}) = 1.29 \times 10^{-34} L(H_\alpha) \qquad SF(FUV)(M_{sun}) = 1.64 \times 10^{-21} L(FUV)$$

- Use the empirical relations between Hα-24μm (Calzetti et al. 2007) and Hα-8μm (Calzetti et al. 2005) and then obtain SF(24μm) and SF(8μm), respectively.

$L(H\alpha)_{corr} = L(H\alpha)_{obsr} + 0.031 \times L(24)$

Table 3. Star Formation for the selected H II regions in M33

Region	SF(8 μm)[a] 10^4 M$_\odot$	SF(24 μm)[b] 10^4 M$_\odot$	SF(Hα^{corr})[c] 10^4 M$_\odot$	SF(com)[d] 10^4 M$_\odot$	SF(FUV^{corr})[e] 10^4 M$_\odot$	SF(24 μm)/SF(Hα^{corr})	SF(com)/SF(Hα^{corr})	SF(Hα^{corr})/SF(FUV^{corr})
NGC 588	0.065	0.970	9.366	6.862	10.563	0.104	0.733	0.887
NGC 592	0.188	1.494	4.543	3.975	20.667	0.329	0.875	0.220
IC131	0.101	0.610	4.196	3.814	4.091	0.145	0.909	1.026
IC131-West	0.180	1.863	3.307	3.626	4.657	0.563	1.097	0.710
NGC 595	1.782	11.158	32.086	22.415	14.914	0.348	0.699	2.151
NGC 604	7.159	28.428	56.065	56.872	54.482	0.507	1.014	1.029

Lower by a factor 0.1-0.6

Better relation

- SF(8μm) is much lower than the SF predicted from the extinction-corrected Hαluminosity.

- The 24μm emission gives lower values of the SF than the SF(Hα): gives evidence of the low dust content within these HII regions.

- SF derived from the *combined* luminosities represents 70-100% of the SF(Hα)

-SF(Ha) and SF(FUV) agree well within the uncertainties assuming an age of 4Myr for the HII regions

What to do next?

- Extend this approach to a larger sample of HII regions in M33: check whether the morphology of the region changes the results shown here (as it is the case of IC131-West).

- Compare 24μm with dust emission at longer wavelengths (not done here due to the low resolution of SPITZER data: ~60pc at 70μm and ~150 pc at 160μm) but HERSCHEL will offer the opportunity to do it.

- Check whether the correlation between the CO emission and the 8μm emission also holds in other HII regions in M33 where CO data are available.

- Any ideas, comments and suggestions for future plans are very welcomed!