Observing GMC-Scale Star-Formation in M33

Thomas G. Williams*, Walter K. Gear, Matthew W. L. Smith

*williams@mpia.de

Read the full papers!

arXiv: 1806.01293

MNRAS: 479, 297

arXiv: 1812.06103

MNRAS: 483, 5135

The Star-Formation Law at GMC Scales

The star-formation law relates the surface density of total gas with star-formation rate (SFR), in the form [1,2]

$$\Sigma_{\rm SFR} \propto \Sigma_{\rm gas}^{N}$$

with N~1.4. However, more recent work has shown that molecular gas drives star-formation more than the total gas [3], and that at high-resolution, the classic 'Kennicutt-Schmidt' relation breaks down [4,5]. Local Group galaxy M33 is an ideal test bed for these high-resolution studies, as it is nearby (840kpc away [6]), and actively star-forming across its disk [7], with a high star-formation efficiency.

We have combined archival data from a variety of both ground- and space-based observatories with new, deep, high-resolution SCUBA-2 observations to probe the star-formation law at the scales of individual star-forming regions (giant molecular clouds, or GMCs; 100pc) in a pixel-by-pixel fashion, and investigated the scale dependence on the star-formation relation.

Key Results

When we fit to individual pixels at various spatial scales, we see a strong scale dependence on the fitted Schmidt index (Fig. 1). At these sub-kpc regions, a stronger correlation between molecular gas than our other gas tracers is seen.

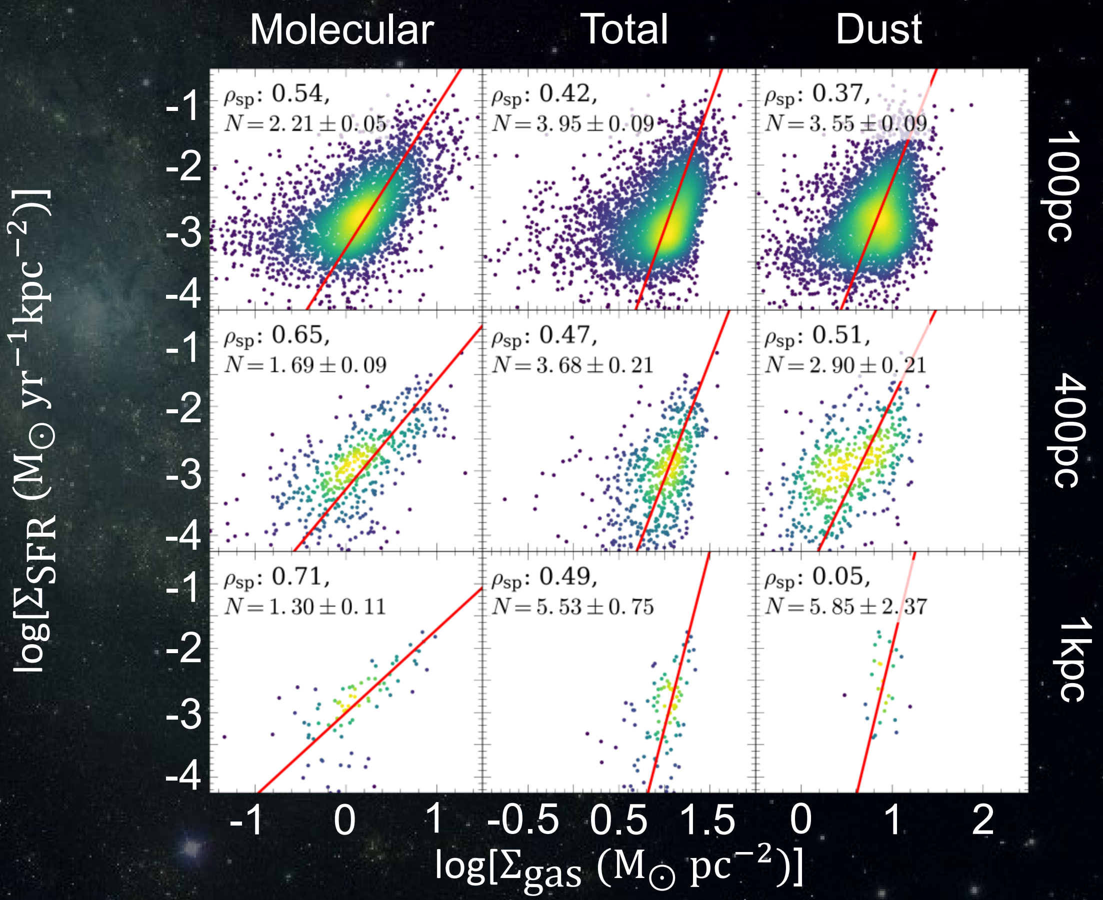

Fig. 1: Surface density of gas and SFR for our three gas tracers (molecular, total gas and total gas from dust) for a variety of spatial scales. In each case, we highlight the Spearman correlation coefficient and the slope of the fitted Schmidt index, *N*.

A Dust-Selected GMC Catalogue

Stars, ultimately, are believed to form in the dense molecular gas inside molecular clouds [8,9]. These clouds are often identified using CO, as cold molecular hydrogen is impossible to trace; how well CO traces the bulk molecular gas, especially in low-metallicity environments, is a matter of some debate [10].

In this work, we take an alternative approach, instead using the cold dust continuum emission, which has been shown to be linked to the molecular gas of a galaxy [11,12,13]. Our new SCUBA-2 observations allow us to probe the peak of the cold dust SED at resolutions of 70pc, similar to the size of some of the larger GMCs.

Key Results

We find a total of 165 clouds, which have sizes from 46-280pc, and a median size of 105pc. They have dust temperatures between 17 and 32K, somewhat higher than in the diffuse ISM, due to their ongoing star-formation. The cloud masses range from 10^4 to 10^7 $M_\odot$, and form massive clouds significantly less efficiently than in other nearby galaxies (such as the MW and M31).

Comparing the location of these clouds with earlier CO surveys (Fig. 2), we find that in the centre of the galaxy we have a good correspondence between our clouds and these earlier studies. However, at large galactocentric radii (>4kpc), there are a dearth of CO clouds which we do not see in the dust. This may be due to a larger fraction of CO-dark gas at larger distances, and CO being a poorer tracer of the molecular gas in these low-metallicity environments.

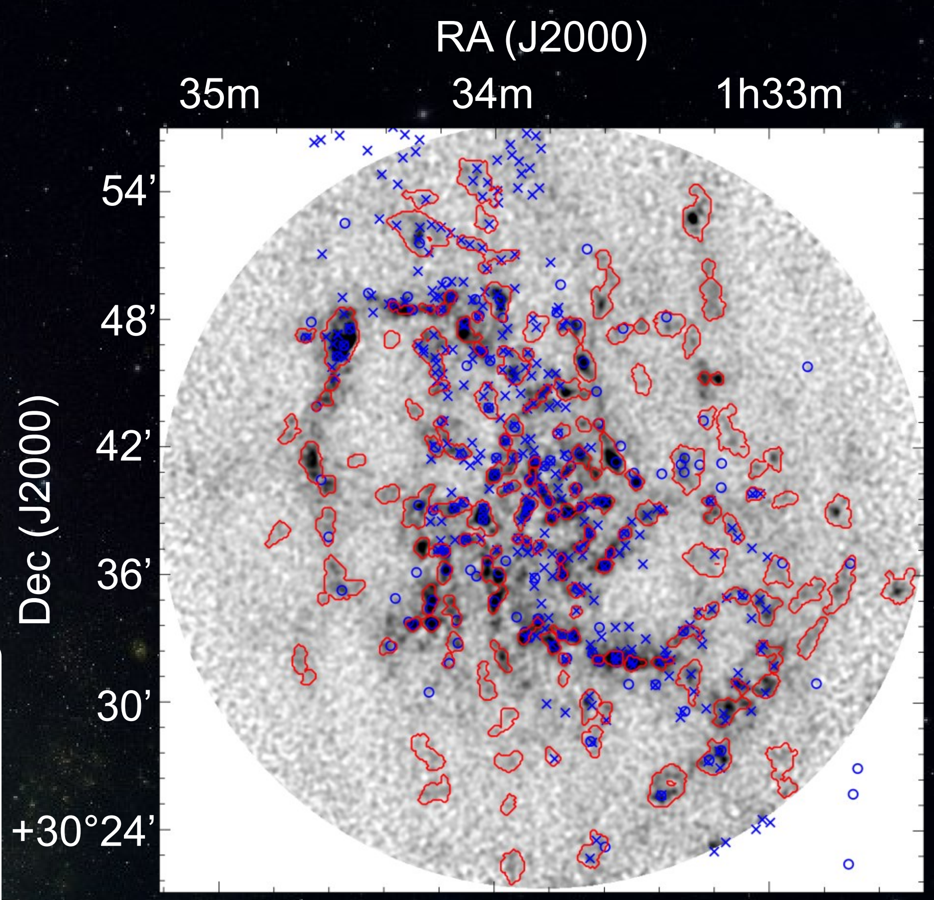

Fig. 2: Comparison between earlier GMC studies of M33, overlaid on the SCUBA-2 450μm data. The red contours show our dust-selected GMCs, the blue crosses from CO(2-1) data [14], and the blue circles from CO(1-0) observations [15].

Take-Home Messages: The Star-Formation Law at GMC Scales

- Correlations between **molecular** gas and SFR remain strong down to 100pc regions.
- There is a strong scale dependence on the Schmidt index, highlighting the evolutionary diversity of star-forming regions within the galaxy!

Take-Home Messages: A Dust-Selected GMC Catalogue

- M33 is forming GMCs significantly more inefficiently than other local spiral galaxies.
- The dust continuum emission may offer a more representative view of the molecular gas content, particularly in low-metallicity environments.

References

[1] Schmidt , 1959, ApJ, 129, 243, [2] Kennicutt 1998, ARA&A, 36, 189, [3] Bigiel et al., 2008, AJ, 136, 2846, [4] Onodera et al., 2010, ApJ, 722, L127, [5] Boquien et al., 2015, A&A, 578, A8, [6] Madore & Freedman, 1991, PASP, 103, 933, [7] Heyer et al., 2004, ApJ, 602, 723, [8] André et al., 2010, A&A, 518, L102 [9] Lada et al., 2010, ApJ, 724, 687, [10] Krumholz et al., 2008, ApJ, 689, 865, [11] Hildebrand 1983, QJRAS, 24, 267, [12] Magdis et al. 2012, ApJ, 760, 6, [13] Eales et al. 2012, ApJ, 761, 168, [14] Gratier et al., 2012, A&A, 542, A108, [15] Engargiola et al. 2003, ApJS, 149, 343.