# Molecular complexity in the star forming region W43-MM1

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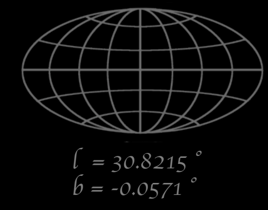
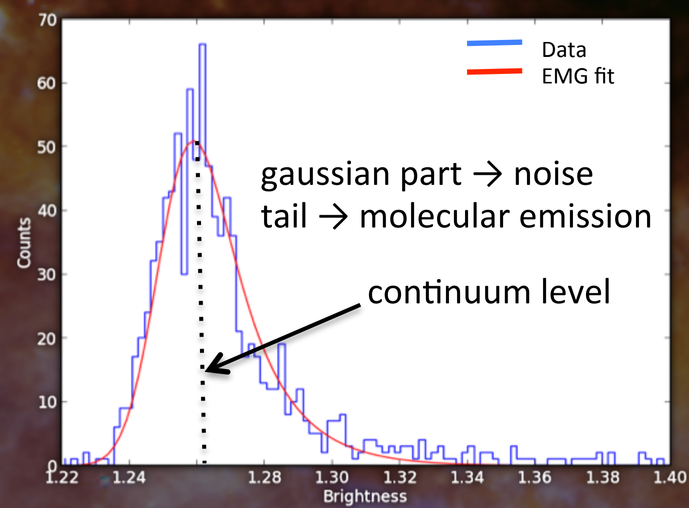



W43-MM1 is a massive star forming region, located at a distance of 5.5 kpc from the Sun in the constellation Aquila, at the edge of the Galaxy bar. It is one of the most active region in the Milky Way regarding star formation and as such is qualified as a "mini-starburst" (SFR ≈ 6000 $M_\odot Myr^{-1}$). It includes an important sample of molecular cores of various masses at various evolutionary stages. It is thus interesting to study the distribution of molecules in the different cores and to search for complex molecules in order to characterize the cores and constrain chemical models. For this, we use 4 GHz of high spatial resolution (0.5" ≈ 2400AU) data mosaic (33 fields) from ALMA+ACA cycle 2/3 at 1.3mm.

## Continuum Substraction Method

We developed a method to substract automatically the continuum in large regions of molecular emission in order to study weak emission lines. The substraction is made on each pixel from the analysis of the flux density distributions, similar to the STATCONT algorithm *(Sánchez-Monge et al. 2017)*. The distribution is well fitted by the Exponentially Modified Gaussian :

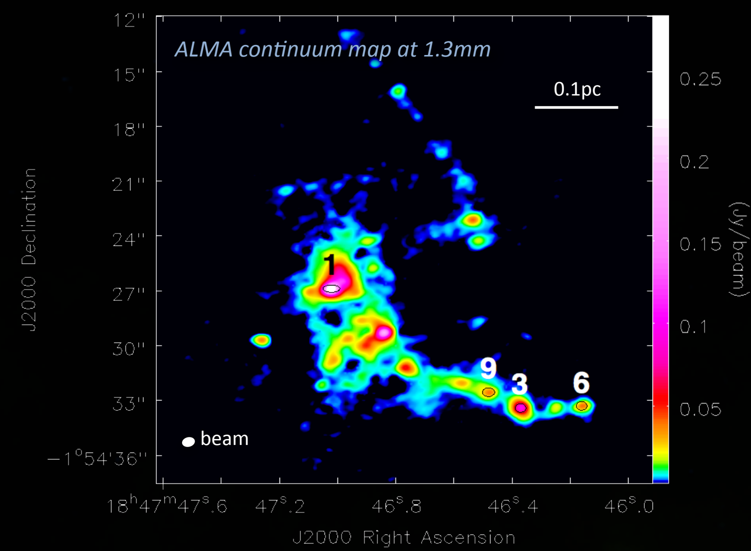
$$f_{EMG}(x) = Ae^{\frac{\lambda}{2}(2\mu+\lambda\sigma^2-2x)} erfc(\frac{\mu+\lambda\sigma^2-x}{\sqrt{2}\sigma})$$



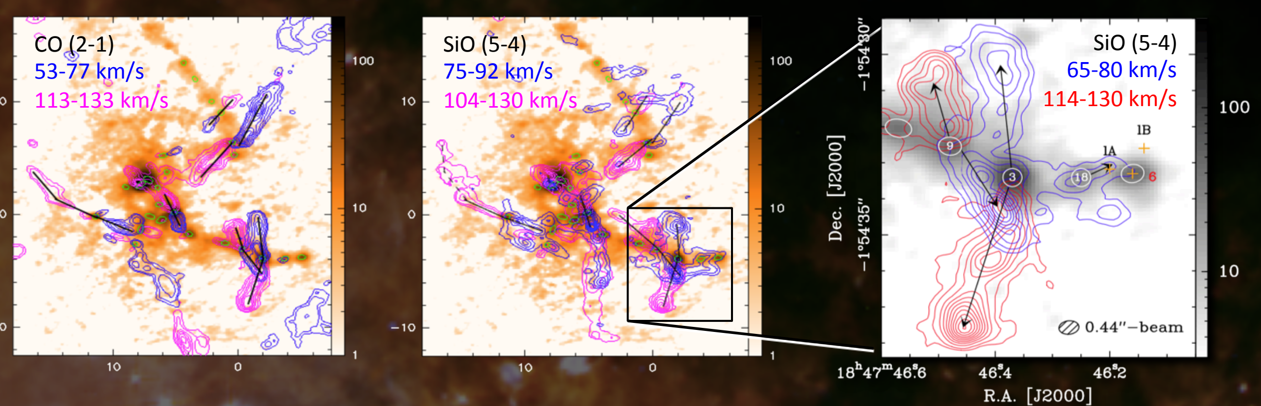

*Example of the distribution of intensities on one pixel.*

## Continuum Emission

The continuum map from ALMA data reveals 131 sources, among them 13 high-mass cores with masses from 16 to 100$M_\odot$, physically characterized by *Motte et al. (2018)*. We focus here on cores #3, 6 and 9 located at the western tip of the main filament. Whereas cores #3 and 6 are both very massive (≈60$M_\odot$), core #6 appears to be much colder than cores #3 and 9 and could be a good high-mass prestellar core candidate *(Nony et al. in prep)*.




## Using outflows to identify protostars




*CO (left) and SiO (middle, right) contours on continuum map.*

Two lines used to trace molecular outflows of protostars : SiO(5-4) and CO(2-1). There is a good agreement between both distributions.

While cores #3 and 9 drive strong bipolar outflows, core #6 seems to lack protostellar outflow.

*From Nony et al. (in prep.)*

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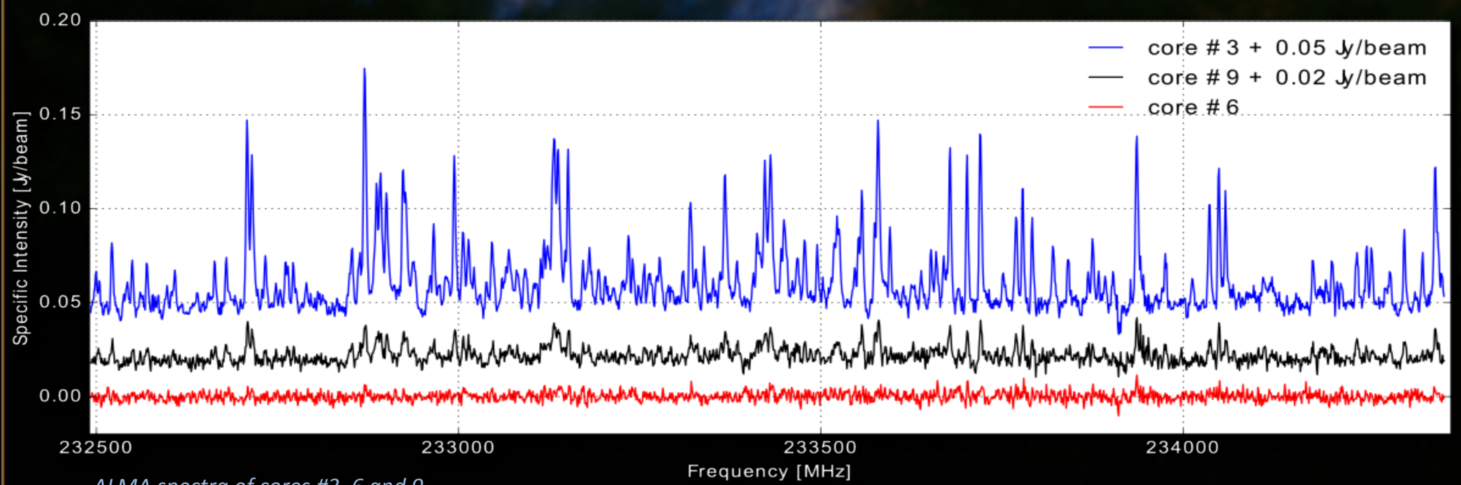
| Core | RA [J2000] | Dec. [J2000] | FWHM [AU] | $S^{int}_{1.3mm}$ [mJy] | $T_{dust}$ [K] | $M_{core}$ $M_\odot$ |
|---|---|---|---|---|---|---|
| 1 | 18:47:47.02 | -1:54:26.86 | 2300 | 592 ± 6 | 74 ± 2 | 102 ± 5 |
| 3 | 18:47:46.37 | -1:54:33.41 | 1200 | 222 ± 2 | 45 ± 1 | 59 ± 2 |
| 6 | 18:47:46.16 | -1:54:33.30 | 1300 | 94 ± 1 | 23 ± 2 | 56 ± 9 |
| 9 | 18:47:46.48 | -1:54:32.54 | 1600 | 87 ± 3 | 50 ± 1 | 18 ± 1 |

*Characteristics of studied cores (3,6,9) in comparison with the main core (1) of W43-MM1.*

## Molecular Complexity

The main cores along the filament, like cores #1 and 3, have a rich molecular content typical of hot cores. In contrast, core #6 display a poor molecular emission. It also stands out from the other cores with narrower lines.




*ALMA spectra of cores #3, 6 and 9.*

| | Core #3 | Core #6 | Core #9 |
|---|---|---|---|
| v [km/s] | 97.1 | 95.7 | 96.5 |
| Δv [km/s] | 4.8 | 3.1 | 5.1 |

*Mean velocity and dispersion of molecular lines.*

80% of the lines in core #3/9 have been identified!

## Molecular Content of cores #3, 6 & 9

Excitation temperatures and column densities are determined using population diagrams *(e.g. Goldsmith and Langer 1999)*. Cores #3 and 9 have a similar molecular content and their temperatures are close, suggesting a similar state of evolution. Whereas the number of lines observed in core #6 is low, we detect several molecules and isotopologues including complex molecules like methyl formate.

| | Core #3 | | Core #6 | | Core #9 | |
|---|---|---|---|---|---|---|
| | Tex [K] | N x$10^{15}$ [$cm^{-2}$] | Tex [K] | N x$10^{15}$ [$cm^{-2}$] | Tex [K] | N x$10^{15}$ [$cm^{-2}$] |
| $CH_3OH$ * | 302 ± 60 | 8000 * | 39 † | ? * | 344 ± 92 | 2000 * |
| $^{13}CH_3OH$ | 210 ± 43 | 120 ± 20 | - | - | 205 ± 42 | 37 ± 8 |
| **$CH_3{}^{18}OH$** | 161 ± 52 | 29 ± 4 | - | - | 92 ± 50 | 3.9 ± 1.4 |
| $CH_3CHO$ | 150 ± 60 | 11 ± 1 | 30 ± 15 | 4 ± 2 | 110 ± 62 | 2.1 ± 0.5 |
| $CH_3OCH_3$ | 145 ± 8 | 190 ± 20 | - | - | 185 ± 40 | 50 ± 10 |
| **$C_2H_5OH$** | 91 ± 8 | 47 ± 7 | - | - | 67 ± 12 | 9 ± 3 |
| $CH_3OCHO$ | 195 ± 25 | 180 ± 20 | 74 † | 6 † | 256 ± 115 | 40 ± 10 |
| **$^{13}CH_3CN$** | 131 ± 62 | 0.9 ± 0.2 | - | - | 154 ± 55 | 0.2 ± 0.1 |
| **$HC(O)NH_2$** | 180 ± 60 | 2.5 ± 0.6 | - | - | 110 ± 40 | 0.5 ± 0.1 |
| **$C_2H_5CN$** | 206 ± 15 | 9 ± 1 | - | - | 190 ± 70 | 1.9 ± 0.4 |

** optically thick : column density estimated using isotopes ratio $^{12}C/^{13}C$≈50 and $^{16}O/^{18}O$≈320*
*† high uncertainty due to the small number of lines observed*
***bold** : not detected in core #6*

Despite the uncertainties, core #6 is a colder core than its protostellar neighbors and seems to be hotter than the filament temperature (23K).

| Other species detected | | | |
|---|---|---|---|
| **CO** | $C^{18}O$ | $H_2CO$ * | $H_2{}^{13}CO$ |
| SiO | **$CH_3COCH_3$** | $^{13}CS$ | **$H_2C^{34}S$** |
| OCS * | $O^{13}CS$ | $OC^{33}S$ | SO |
| DCN | $HC_3N$ | **$C_2H_3CN$** | |

## Conclusion

The two close high-mass cores #3 and 6, with large masses (≈60$M_\odot$), and small diameters (≈1300AU), are the densest cores detected so far. Whereas core #3 appears to be a hot core, core #6 is less evolved and possibly the densest starless core known. Despite it shows no clear sign of protostellar activity, from the molecular content and the derived temperature it could in fact be a young high-mass protostellar core. The modelisation of the source is in progress.