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MOLECULAR COMPLEXITY IN THE STAR FORMING REGION W43-MM1

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Abstract. The study of the distribution of molecules in star forming regions helps to constrain the chemical models. The "mini-starburst" region associated to W43-MM1 includes a number of massive pre-stellar and proto-stellar cores candidates (e.g. Motte et al. 2018; Nony et al. 2018). It is an important sample of molecular cores at various evolutionary stages and moreover, it may contain the most massive cold core known in the whole Galaxy. We present high spatial resolution data from ALMA Cycle 2 and Cycle 3. We first introduce the technique we developed to substract automatically the continuum in large regions of molecular emission in order to study weak emission lines. Then we present the current state of our comparison of the molecular composition of the cores in W43-MM1, in particular between two high-mass cores of similar masses and sizes.

Keywords: ISM, massive star formation, continuum, complex molecules

1 Introduction

In the past ten years, large efforts were made to improve our understanding of the formation of high-mass stars. In the "core-fed" or "core-accretion" models, high-mass stars form in a similar way to the low-mass stars through a prestellar core. Imaging cold, high-mass star-forming clouds is needed to reach a consensus on the existence of a high-mass prestellar core phase. W43-MM1, located at 5.5 kpc from the Sun (Zhang et al. 2014), turned out to be one of the youngest and richest clusters of high-mass cores at different evolutionary stages in the Milky Way. Thus, it is an important sample to search for a high-mass prestellar core candidate. The molecular content of the star-forming region is a powerful tool to understand the dynamics and the physical properties of the cloud. It also gives some clues about the chemistry of the interstellar medium.

2 Data

Observations were carried out in Cycle 2 (project #2013.1.01365.S) and Cycle 3 (#2015.1.01273), with ALMA 12 m and ACA 7 m arrays. W43-MM1 was imaged in band 6 (between 216 and 234 GHz) with a 78"x53" (2.1 pc x 1.4 pc) mosaic composed of 33 fields with the 12 m array and 11 fields with ACA. The total bandwidth is 4 GHz observed in 6 bands centered on lines of interest and 2 continuum bands, with a spectral resolution ranging from 122 to 976 kHz and a spatial resolution of $\sim$0.5" (2400 AU). The region includes numerous sources, with different velocities and molecular contents.

We developped an automatic technique to subtract the continuum using, for each pixel, the distribution of channel intensities. The distribution is composed of a gaussian part associated to the noise and a tail toward high intensities due to the molecular emission. An Exponentially Modified Gaussian (EMG) is well suited to represent such a distribution (see Fig. 1). The continuum level corresponds to the peak of the gaussian

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part. Our method is adapted from the one presented by Jørgensen et al. (2016) and also used by STATCONT (Sanchez-Monge et al. 2017). STATCONT is appropriate to different types of regions, while using EMG is faster but only usable for spectra without absorption. To estimate the error on the obtained value, we used synthetic spectra with lines parameters based on our observations. We estimated the relative error on the continuum value depending on 3 parameters (the rms value, the real continuum level and the maximum of emission of the molecular lines). Typical values from our observations reveal an error <1% for the main cores (see Fig. 1). The resulting continuum map of W43-MM1 is presented in Fig. 2.

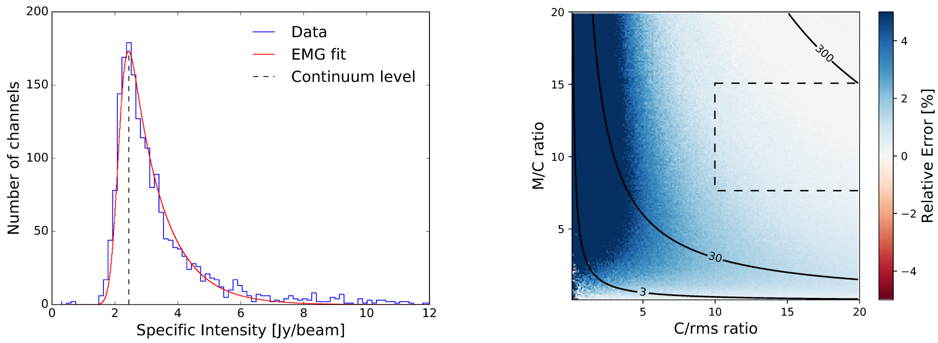

Fig. 1. Left: Distribution of brightness in one pixel (blue) and EMG fit (red). **Right:** Estimation of the relative error on the continuum level. Tests are made with different rms, real continuum level C and maximum of emission of molecular line M ratios. The contours represent the M/rms ratio. As an example, the dotted box corresponds to the ratios in the region of core #3 and the relative error on the determination of the continuum level is thus less than 1%. This figure is the mean of 20 synthetic spectra for each ratio.

3 Two nearby high-mass cores with a different molecular content

In W43-MM1, Motte et al. (2018) identified 131 continuum cores using the *getsources* algorithm, including 13 high-mass protostellar cores with masses from 16 to 100 $M_{\odot}$. Nony et al. (2018) focus on two different cores at the end of the main filament. Core #3 and #6 have the same mass (60 $M_{\odot}$) and the same size (1300AU), but while core #3 displays outflows and an important molecular signature, core #6 shows no sign of outflow (Fig. 2) and few emission lines (Fig. 3). In that sense, while core #3 is identified as a hot core, core #6 seems to be a good high-mass prestellar core candidate.

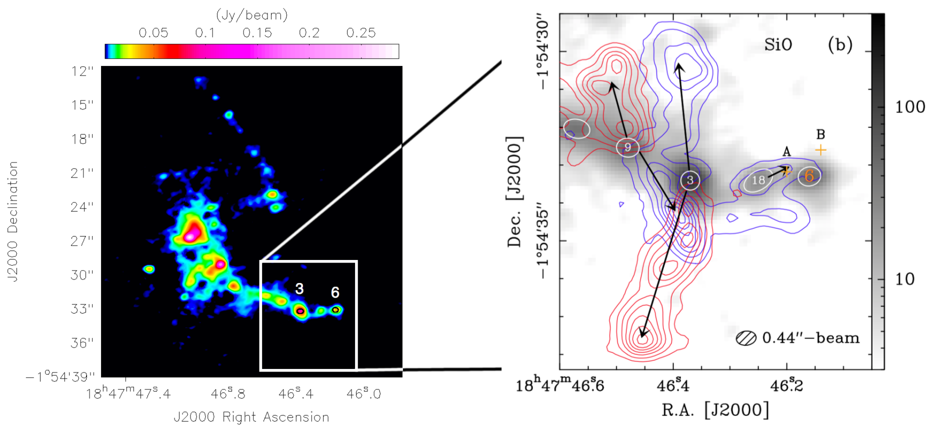

Fig. 2. Left: Continuum map of W43-MM1. **Right:** Zoom on cores #3 and #6 (from Nony et al. 2018). Continuum is in greyscale and contours represent integrated SiO(5-4) emission (60-90 $km.s^{-1}$ in blue, 104-134 $km.s^{-1}$ in red).

We used rotational diagrams (e.g. Goldsmith & Langer 1999) to derive the column density N and temperature T for the detected molecules. In core #3, we identified 80% of the lines and assigned them to 25 molecules and isotopologues, but only 10 molecules have enough transitions to apply the rotational diagram method. In core

#6, 17 out of the 25 molecules are detected and only methanol, CH_3OH, acetaldehyde, CH_3CHO and methyl formate, CH_3OCHO, have enough transitions to allow for a rotational diagram. Despite the huge uncertainty for core #6, it seems that the temperature of core #6 is colder (∼40K) than that of core #3 (∼170K) (see Fig. 4). Another difference is that the lines are narrower in core #6 (3km/s) than in core #3 (5km/s).

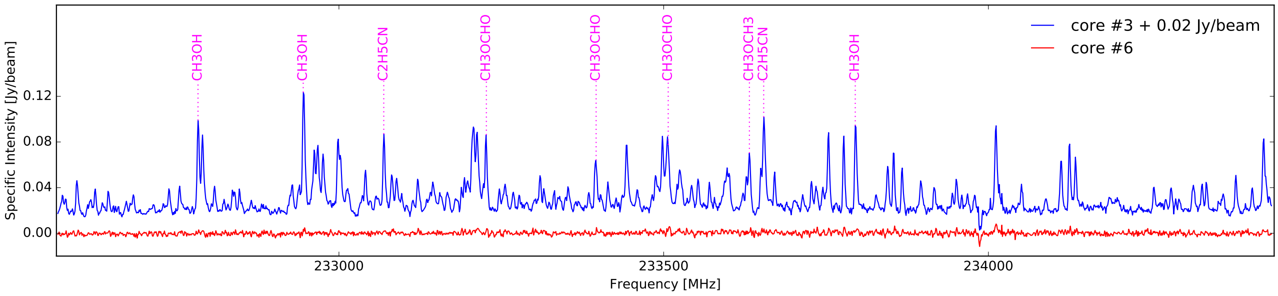

Fig. 3. Spectra intregrated over the continuum core #3 (blue) and core #6 (red). Continuum band obtained from ALMA Cycle 2.

	Core #3		Core #6	
Molecule	Tex [K]	N x10^{15} [cm^{-2}]	Tex [K]	N x10^{15} [cm^{-2}]
CH_3OH *	302 ± 60	8000 *	39 †	? *
$^{13}CH_3OH$	210 ± 43	120 ± 20	1 transition	
$CH_3{}^{18}OH$	161 ± 52	29 ± 4	**not detected**	
CH_3CHO	150 ± 60	11 ± 1	30 ± 15	4 ± 2
CH_3OCH_3	145 ± 8	190 ± 20	1 transition	
C_2H_5OH	91 ± 8	47 ± 7	**not detected**	
CH_3OCHO	195 ± 25	180 ± 20	74 †	6 †
$^{13}CH_3CN$	131 ± 62	0.9 ± 0.2	**not detected**	
HC(O)NH_2	180 ± 60	2.5 ± 0.6	**not detected**	
C_2H_5CN	206 ± 15	9 ± 1	**not detected**	

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**	

Fig. 4. Left: Molecules in core #3 with enough detected transitions to obtain N and T with a rotational diagram. In core #6, a rotational diagram was only possible for CH_3OH, CH_3CHO and CH_3OCHO. **Right:** Other molecules detected in core #3. Molecules in bold are not observed in core #6. Optically thick molecules are marked by * and a huge uncertainty is signposted by †.

4 Conclusions

W43-MM1 may contain a good high-mass prestellar core candidate, because no outflow is observed towards core #6 and it appears colder than a nearby hot core with the same mass, which suggests a younger evolutionary stage of core #6. We are currently taking into account all the detected lines in a new model to confirm the identity of this core. The identified lines can be used to map the distribution of the molecules, and will serve as a starting point to compare with the other cores of the region.

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