Chemical diversity in massive star formation

H. Beuther[1], Q. Zhang[2], T.K. Sridharan[2], E.A. Bergin[3]

[1]*MPIA Heidelberg/Germany;* [2]*CfA Cambridge/USA;* [3]*Uni. Michigan, Ann Arbor/USA* email contact: beuther@mpia.de

Abstract: Synthesizing Submillimeter Array (SMA) observations conducted over the last few years toward four massive star-forming regions in different evolutionary stages, we identify several characteristics important for the chemical evolutionary sequence. For example, $C^{34}S$ is observed mainly at the core-edges and not toward their centers because of temperature-selective desorption and successive gas-phase chemistry reactions. Most nitrogen-bearing molecules are only found toward the hot molecular cores and not the earlier evolutionary stages, indicating that the formation and excitation of such complex nitrogen-bearing molecules needs significant heating and time to be fully developed.

Introduction

The four high-mass star-forming regions were observed with the SMA in a spectral setup covering 2×2 GHz around 338 and 348 GHz, respectively. From an evolutionary point of view, they cover two prototypical Hot Molecular Cores (HMCs, Orion-KL and G29.96) and two younger High-Mass Protostellar Objects (HMPOs) in a pre-HMC phase. The basic properties of the sample are listed in Table 1.

While Figure 1 presents the spectra toward all four regions, Figure 2 shows shows a modeling approach for this dataset highlighting important line ratios. Furthermore, Figure 3 presents images of selected molecular species.

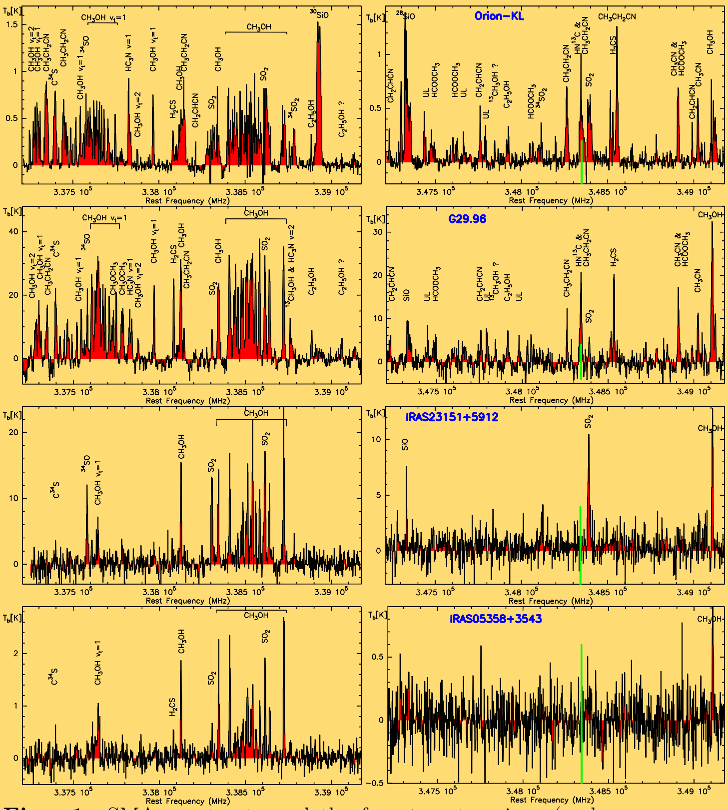

Fig. 1: SMA spectra toward the four target regions (each row corresponds to one source). All data-cubes were smoothed to the same spatial resolution of ~5700 AU. The green line marks the position of an interesting nitrogen-bearing molecular line.

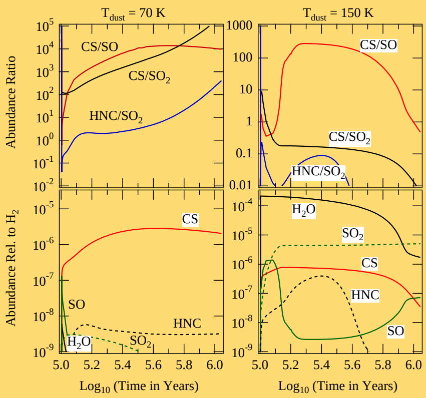

Fig. 2: Results from the chemical modeling. The top-row shows interesting abundance ratios vs time for two different temperatures, whereas the bottom row presents the corresponding absolute abundances with respect to H_2.

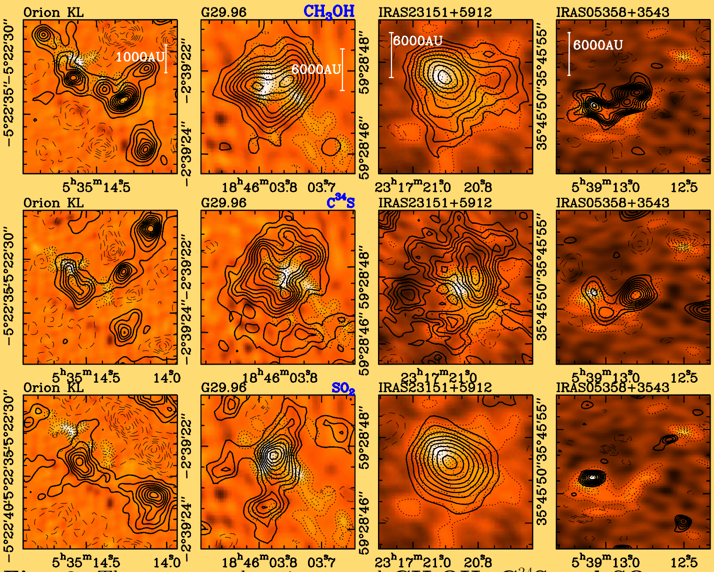

Fig. 3: The contours show integrated $\mathbf{CH_3OH}$, $\mathbf{C^{34}S}$ **and** $\mathbf{SO_2}$ maps (from top to bottom) overlaid on the submm continuum emission (862 μm). Full lines show positive emission, dashed lines negative features due to the missing flux.

Main results

- The HMCs show far more molecular lines than the pre-HMCs (Fig. 1). This is independent of the luminosity because IRAS 23151 has the same luminosity as Orion-KL and G29.96 (Table 1).
- While the ground state CH_3OH lines are observed toward all regions, the torsionally excited $v_t = 1$ lines are observed only toward the HMC sources (Fig. 1). This can be explained with on average larger temperatures there.
- While the SO_2 line near 348.35 GHz is found toward all sources, the neighboring $HN^{13}C/CH_3CH_2CN$ line blend is detected only toward the HMCs but not toward the pre-HMCs (Fig.1., green line). This indicates that nitrogen-bearing molecules are either released from the grains only at higher temperatures, or they are daughter molecules which need some time during the warm-up phase to be produced in gas-phase chemical networks (Fig. 2).
- In all sources $C^{34}S$ is weak toward the submm continuum peaks and stronger in the outskirts. This is because sulphur reacts quickly with OH to SO and SO_2 which then peak toward the centers (Fig. 3).
- A general result is that different molecules have to be used to investigate similar physical properties at different evolutionary stages. For example, $C^{34}S$ may be a good disk tracer at early evolutionary stages whereas nitrogen-bearing molecules are usually better suited for more evolved evolutionary stages (Exceptions exist, e.g., IRAS 20126, Cesaroni et al. 2005, A&A 434, 1039.).

	Orion-KL	G29.96	IRAS 23151	IRAS 05358
$L\,[L_\odot]$	10^5	9×10^4	10^5	$10^{3.8}$
d [pc]	450	6000	5700	1800
$M_{gas}\,[M_\odot]$	140	2500	600	300
T_{rot} [K]	300	340	150	220
Type	HMC	HMC	pre-HMC	pre-HMC

Table 1: Source parameters. The SMA data were first published in Beuther et al 2005 (ApJ 632, 355), Beuther et al. (2007, A&A 468, 1045) Beuther et al. (accept. at A&A) and Leurini et al. (subm. to A&A).