Astrophysical Masers:
Unlocking the Mysteries of the Universe
Proceedings IAU Symposium No. 336, 2017
A. Tarchi, M.J. Reid & P. Castangia, eds.

doi:10.1017/S1743921318000364

Chemical differentiation in the inner envelope of a young high-mass protostar associated with Class II methanol maser emission

T. Csengeri[1], S. Bontemps[2], F. Wyrowski[1], A. Belloche[1], K. M. Menten[1], S. Leurini[1] and the SPARKS team

[1]Max Planck Institute for Radioastronomy, Auf dem Hügel 69, 53121 Bonn, Germany
email: `csengeri@mpifr.de`

[2]OASU/LAB-UMR5804, CNRS, Université Bordeaux, allée Geoffroy Saint-Hilaire, 33615 Pessac, France

Abstract. We present a case study of a single high-mass protostar associated with an infrared quiet massive clump selected from the ATLASGAL survey. The thermal dust emission reveals a single collapsing object associated with a prominent molecular outflow. We detect bright emission from a torsionally excited state transition of CH_3OH offset from the protostar that is well explained by shocks at the transition from the infalling envelope onto an accretion disk.

Keywords. stars: formation, ISM: kinematics and dynamics, ISM: molecules

---

1. The SPARKS of high-mass star formation

Whether high-mass star formation proceeds as a scaled-up version of low-mass star formation is an open question in today's astrophysics. The SPARKS project (Search for high-mass protostars up to kpc scales with ALMA) targets at high angular resolution with ALMA 35 of the complete sample of the highest surface density infrared quiet massive clumps selected from the ATLASGAL with $M_{\rm clump} > 650 M_\odot$ up to 5 kpc (Csengeri *et al.* 2017a, Csengeri *et al.* 2017b). The achieved $0.6''$ resolution allows us to study the properties of individual collapsing envelopes on ∼2000 au physical scales with a statistical approach. Towards a handful of sources we obtained, however, a considerably higher angular resolution of $0.16''$ corresponding to 400 au scales at a distance of 2.5 kpc. We obtained an instantaneous spectral coverage of 7.5 GHz in a frequency range between 333.2 to 337.2 and 345.2 to 349.2 GHz which gives an insight into the molecular composition of the gas in the immediate vicinity of high-mass protostars.

2. Case study of a single high-mass protostar: AGAL 328.25

SPARKS discovered the largest sample of the youngest known precursors of high-mass stars (Csengeri *et al.* in prep). We present here our results towards one object associated with the ATLASGAL clump, AGAL 328.25, located at 2.5 kpc (Fig 1 a). We identify a compact object that stays single down to our resolution of ∼ 400 au corresponding to a massive envelope (Fig 1 b). The highest velocity CO (3–2) emission reveals a prominent bipolar outflow (Fig 1 c), and the bright Class II methanol maser emission associated with the dust continuum suggests the presence of en embedded high-mass protostar (Fig 1 d).

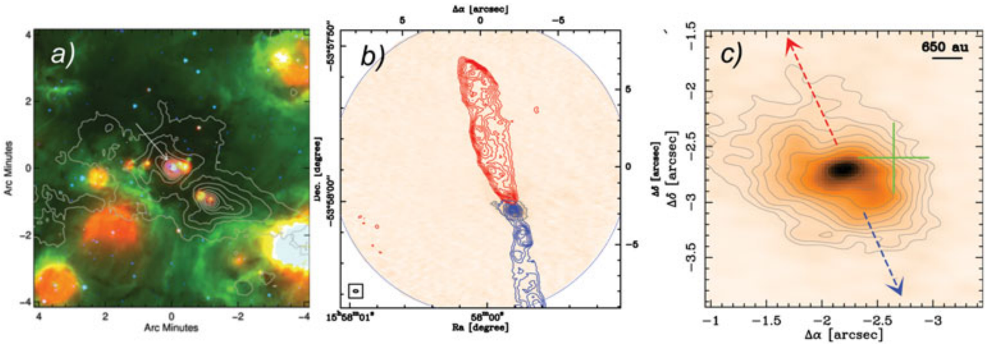

Figure 1. a) Three-color composite image from the Spitzer/GLIMPSE and MIPSGAL surveys (blue: 4.5 μm, green: 8 μm, red: 24 μm, see the on-line version of the figure). Contours show the 870 μm emission from ATLASGAL (Schuller *et al.* 2009, Csengeri *et al.* 2014). The arrow marks the dust continuum peak of the source. b) Line-free continuum emission at 345 GHz measured by the ALMA 12m and 7m array. The high velocity contours from CO (3–2) reveal a prominent bipolar outflow. c) Zoom on the central protostar. The dashed arrows show the direction of the CO outflow. The cross marks the position of the Class II methanol maser from Green *et al.* (2012). Its size shows the estimated accuracy of the maser position.

3. Bright CH_3OH emission offset from the protostar

We detect a rotational transition of CH_3OH in the $v_t = 1$ state at 334.42 GHz with a high signal-to-noise ratio (Fig. 2). The upper energy level of this transition is at 315 K, which either requires high methanol column density and temperature, or an infrared radiation field at 50 μm to populate this state. Interestingly, the emission drops towards the peak of the continuum, and its spatial morphology shows two prominent emission peaks *offset* from the continuum. These peaks spatially coincide with a spiral structure seen in the dust emission, and their kinematics is consistent with rotational motions. A rotational diagram analysis suggests high methanol column densities at the emission peaks.

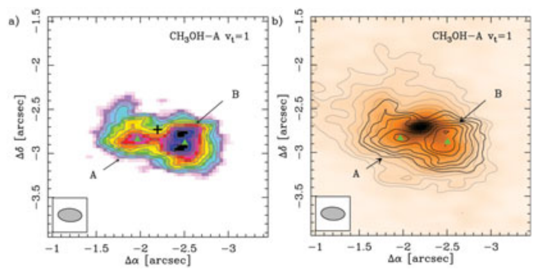

Figure 2. *a)* Integrated intensity map of the rotational transition of CH_3OH in its $v_t = 1$ state at 334.42 GHz. Triangles mark the positions where the spectra have been extracted for the rotational diagram analysis. *b)* Color scale shows the line-free continuum at 345 GHz (see the on-line version of the figure). The contours are the same as on the left.

4. A shock dominated inner envelope

Based on its spatial distribution and kinematic pattern, we associate the observed CH_3OH emission with the inner envelope. The increased CH_3OH abundance can be well explained by shocks that are expected to be associated with the transition from the infalling envelope to an accretion disk with a smaller inward motion. This suggests a physical structure that is qualitatively similar to low-mass Class 0 protostars.

References

Csengeri, T., Urquhart, J., Schuller, F. *et al.* 2014, *A&A*, 565, 75

Csengeri, T., Bontemps, S., Wyrowski, F. *et al.* 2017, *A&A*, 601, 60
Csengeri, T., Bontemps, S., Wyrowski, F. *et al.* 2017, *A&A*, 600, L10
Green, J. A., Caswell, J. L., Fuller, G. A. *et al.* 2012, *MNRAS*, 420, 3108
Schuller, F., Menten, K. M., Contreras, Y. *et al.* 2009, *A&A*, 504, 415