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Protostellar chemistry dominated by external irradiation

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Abstract. Submillimetre observations of externally irradiated low-mass protostellar envelopes show that the gas temperature in the envelopes is dominated by the external irradiation. Detailed studies of the protostar IRS7B in Corona Australis also show that the chemistry is strongly affected by the irradiation, depleting the abundances of complex organic molecules.

Keywords. stars: formation, ISM: molecules, astrochemistry, radiative transfer

1. Introduction

The low-mass protostars in the R CrA cloud in the Corona Australis star-forming region ($d = 130$ pc) are externally irradiated by the intermediate-mass protostar R CrA, which heats the envelopes to $T \gtrsim 30$ K (Lindberg & Jørgensen 2012).

We conducted spectral line surveys with the ASTE telescope and the APEX telescope† of the Class 0/I protostar IRS7B, irradiated by R CrA. More details on these two surveys are given by Watanabe *et al.* (2012) and Lindberg *et al.* (2015), respectively.

We also used APEX to observe three H_2CO lines around 218 GHz towards 56 protostellar envelopes in the CrA and Ophiuchus star-forming regions. The observations were used to measure the rotational temperature of H_2CO, which is a good tracer of the kinetic temperature (Mangum & Wootten 1993).

2. Line survey

In the APEX and ASTE surveys of IRS7B, we detected spectral lines from 22 different molecular species, of which the most complex were CH_3CHO, CH_3CCH, CH_3CN, and CH_3OH. The absolute abundance of CH_3OH in IRS7B is found to be only a few $\times 10^{-9}$, two orders of magnitude lower than the CH_3OH abundance in the hot corino source IRAS 16293-2422 (Cazaux *et al.* 2003). Furthermore, the abundance of several other organic molecules (such as HCOOH, CH_3CN, CH_3OCH_3, and CH_3OCHO) relative to CH_3OH is at least an order of magnitude lower in IRS7B than in IRAS 16293-2422. We propose that a long-term elevated temperature in the protostellar envelopes caused by external irradiation from R CrA has led to

† This work is based on observations with the Atacama Pathfinder EXperiment (APEX) telescope. APEX is a collaboration between the Max Planck Institute for Radio Astronomy, the European Southern Observatory, and the Onsala Space Observatory.

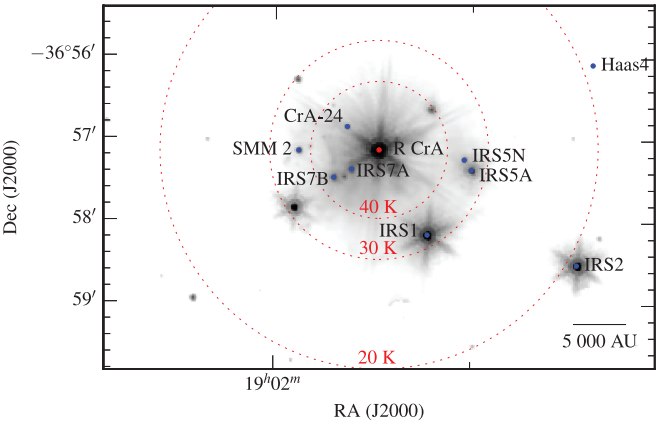

Figure 1. H_2CO temperatures measured in the protostellar envelopes near the luminous Herbig Be star R CrA.

large-scale evaporation of CO from the dust grains, inhibiting formation of complex organics. Gas-phase formation of certain complex organic species will also be inhibited due to the low CH_3OH abundance (Charnley 1997).

3. H_2CO and c-C_3H_2 surveys

In our survey of H_2CO and c-C_3H_2 in Corona Australis, we find H_2CO rotational temperatures ranging between 19 K and 45 K; even higher temperatures are found in two outflow components Lindberg *et al.* (2015). The difference in temperature is well-correlated with the distance to the luminous R CrA, and matches with a simple 1-D *Transphere* (Dullemond *et al.* 2002) radiative transfer model of the heating from R CrA. This star heats the gas in the star-forming region on scales of $\sim 30\,000$ AU. The c-C_3H_2 temperature is, however, found to be 9–17 K in all sources.

The same trend is seen in the Ophiuchus star-forming region (Lindberg et al., in prep.). We identify the Herbig Be star S 1 and the B2 star HD 147889 as the primary heating sources of the embedded protostars in the ρ Oph A and ρ Oph B clouds, where we find H_2CO temperatures up to 40 K. The hot corino source IRAS 16293-2422, however, shows the highest H_2CO temperature in the sample, 73 K, but this emission is thought to originate in the hot inner envelope, with internal irradiation causing the high temperature.

References

Cazaux, S., Tielens, A. G. G. M., Ceccarelli, C., et al. 2003, *ApJL*, 593, L51
Charnley, S. B. 1997, in IAU Colloq. 161: Astronomical and Biochemical Origins and the Search for Life in the Universe, ed. C. Batalli Cosmovici, S. Bowyer, & D. Werthimer, 89
Dullemond, C. P., van Zadelhoff, G. J., & Natta, A. 2002, *A&A*, 389, 464
Lindberg, J. E. & Jørgensen, J. K. 2012, *A&A*, 548, A24
Lindberg, J. E., Jørgensen, J. K., Watanabe, Y., et al. 2015, *A&A*, in press (arXiv:1509.02514)
Mangum, J. G. & Wootten, A. 1993, *ApJS*, 89, 123
Watanabe, Y., Sakai, N., Lindberg, J. E., et al. 2012, *ApJ*, 745, 126

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