Strong irradiation of low-mass protostars in Corona Australis

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Abstract

Very young low-mass protostars are deeply embedded in cold gas and dust. These early stages of star formation often show an interesting and varied chemistry, e.g. with complex organic molecules or long carbon-chain molecules in the inner regions. The effect on the physics and chemistry from nearby luminous stars remains poorly understood.

We find unexpectedly high temperatures in the R CrA region, but also in other protostars in CrA. Models suggest that the Herbig Be star R CrA is the dominant heat source in this star-forming region. Thus, also intermediate-mass stars have large effects on the physical properties in such regions. ALMA observations of H_2CO can be used to trace such heating also in more distant regions.

Young objects in the R CrA region

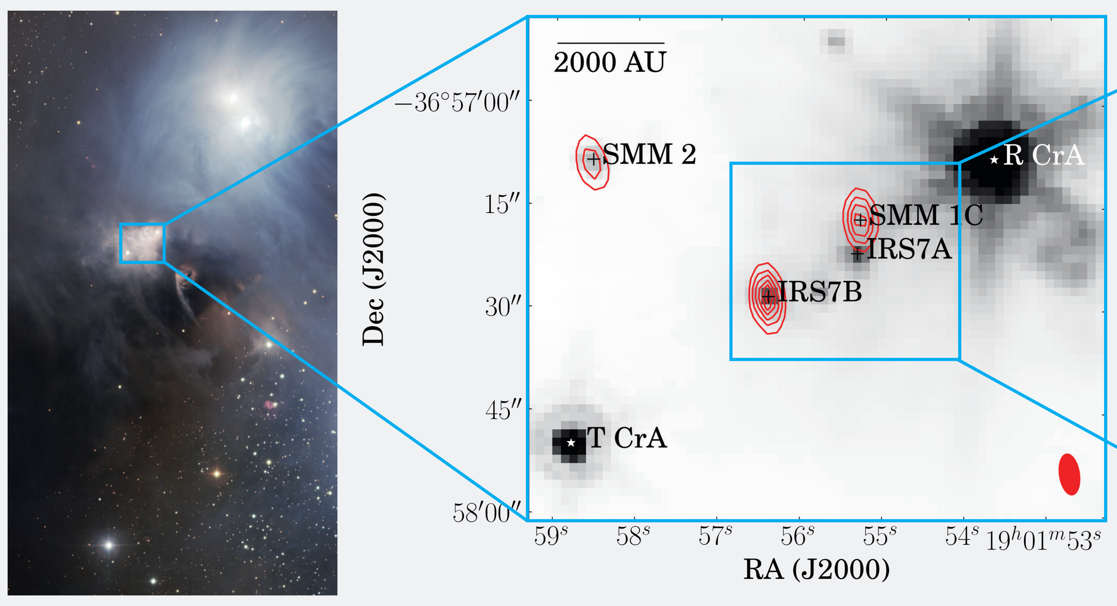

Figure 1: Left: *Optical image of the CrA region. Credit: ESO.* Right: *SMA continuum at 223 GHz (red contours) and Spitzer 4.5 μm image of the R CrA region.*

R Coronae Australis IRS7

R CrA IRS7 is a small group of Young Stellar Objects (YSOs) at a distance of 130 pc.
The region contains a handful of young stars in different stages, including:

- SMM 1C: Class 0
- IRS7B: Class 0/I
- IRS7A: Class 0/I
- R CrA: Herbig Be

APEX observations

R CrA heating on larger distances

In an APEX survey of 17 YSOs in the CrA star-forming region, we found that the H_2CO rotational temperature relates to the distance to R CrA. Dust radiative transfer modelling confirms R CrA as the dominant heating source assuming that $L_{\mathrm{R\ CrA}} = 166 L_\odot$ (Bibo et al. 1992) and a molecular cloud density of 10^3 cm^{-3}.

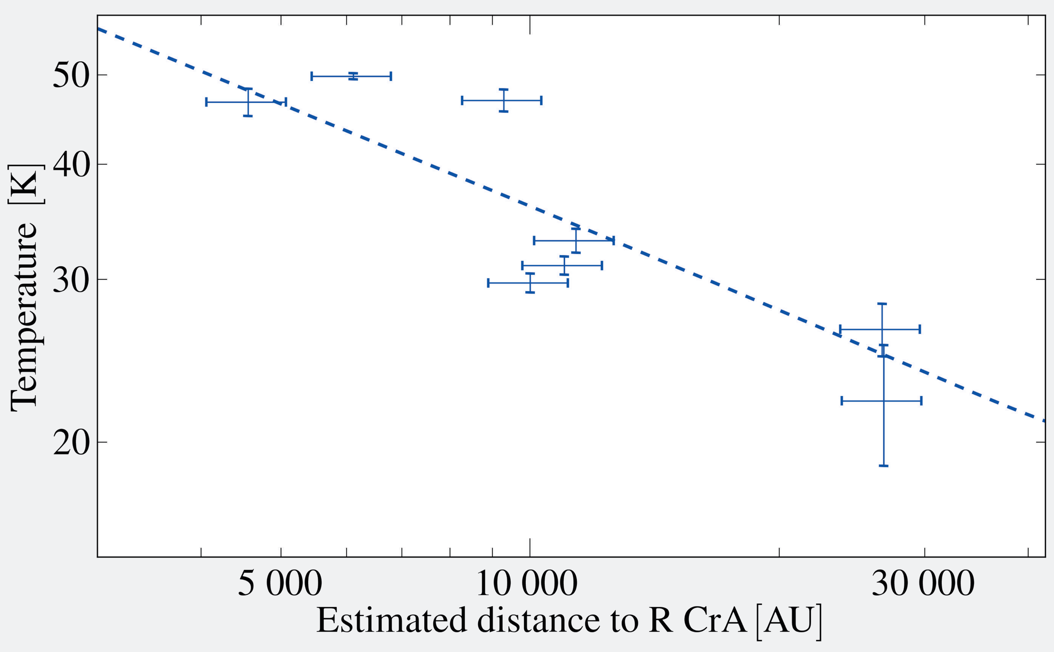

Figure 5: *Rotational H_2CO temperatures of YSOs as function of distance to R CrA, and Transphere model fit. One outlier and eight non-detections are not included.*

Questions?
Johan Lindberg will be happy to tell you more about this poster.

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References:
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Dullemond, C. P., et al. 2002, A&A, 389, 464
Green, J. D., et al. 2013, ApJ, 770, 123
Jørgensen, J. K., et al. 2006, A&A, 449, 609
Lindberg, J. E. & Jørgensen, J. K. 2012, A&A, 548, A24

ALMA Cycle 0 observations

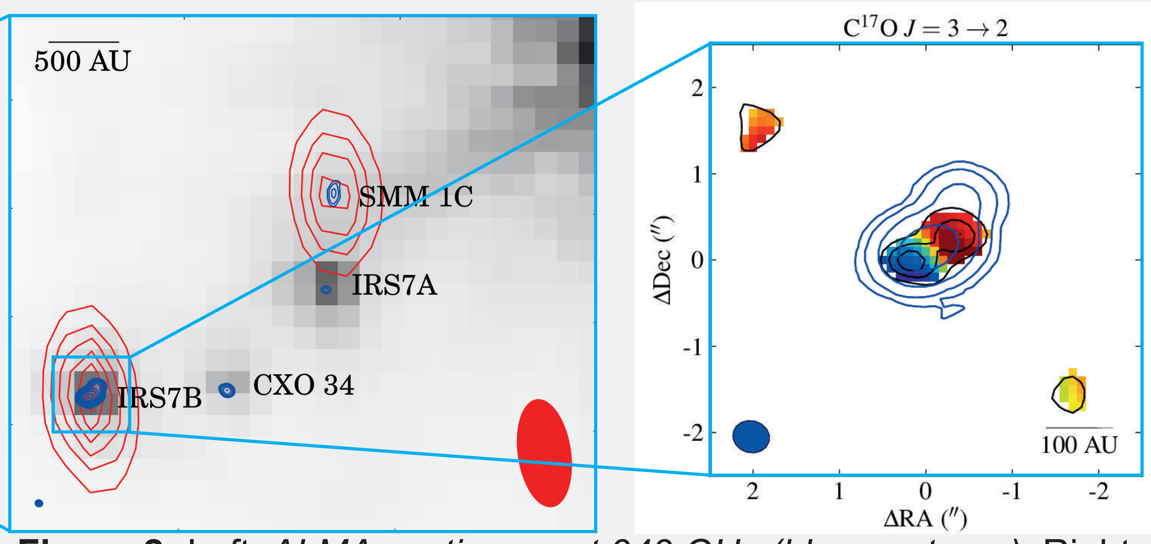

Figure 2: Left: *ALMA continuum at 343 GHz (blue contours).* Right: *$C^{17}O$ 3→2 moment 0 (black contours) and moment 1 (colour) maps. The difference in velocity between the peaks is 10 km/s.*

Several CH_3OH lines were detected on large scales. More complex species were significantly non-detected.
We also find a Keplerian disc in the $C^{17}O$ 3→2 line on 100 AU scales (Figure 2). The lack of complex organic molecules could be explained either by the presence of a disc or by irradiation from R CrA.
Finally, IRS7A and CXO 34 were for the first time detected in sub-mm continuum.

SMA observations

High temperatures in protostellar cores...

Interferometry data with ~400 AU resolution from the SMA was combined with short-spacing data from the APEX telescope (Lindberg & Jørgensen 2012). The large-scale H_2CO temperatures are much higher than what is normally expected in protostellar envelopes. Rotational temperatures are generally higher than 50 K (Figure 3). Non-LTE modelling shows temperatures of at least 40-50 K in two long (>6000 AU) ridges around the YSO region.

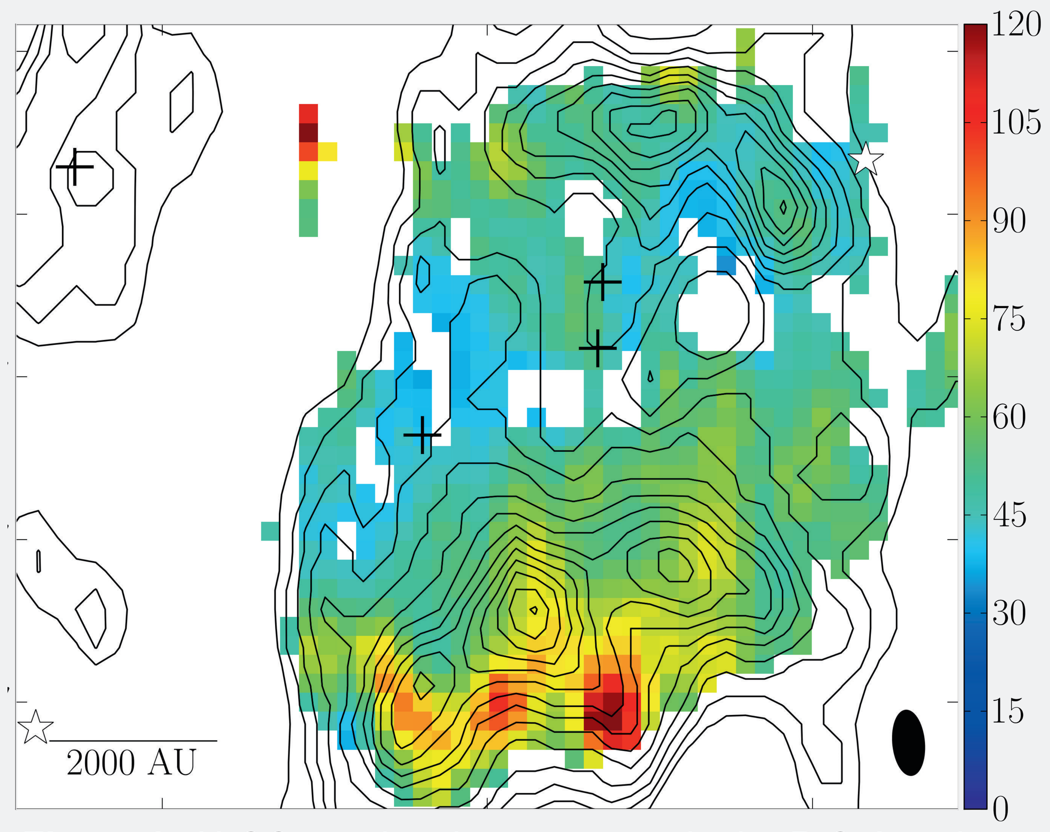

Figure 3: *H_2CO rotational temperature in the R CrA region (colour) and H_2CO $3_{03}\to 2_{02}$ integrated intensity (contours). The highest temperature peaks are likely optical depth effects.*

...caused by external heating

One-dimensional radiative transfer modelling (*Transphere*, Dullemond et al. 2002) shows that the central object cannot cause temperatures higher than ~20 K at 1000 AU scales – in agreement with Jørgensen et al. (2006) – but that external heating from R CrA could be responsible for the high temperatures.
We also find that R CrA can heat the whole envelope to temperatures above 20 K even without a central source, meaning that CO would mostly be present in the gas phase.

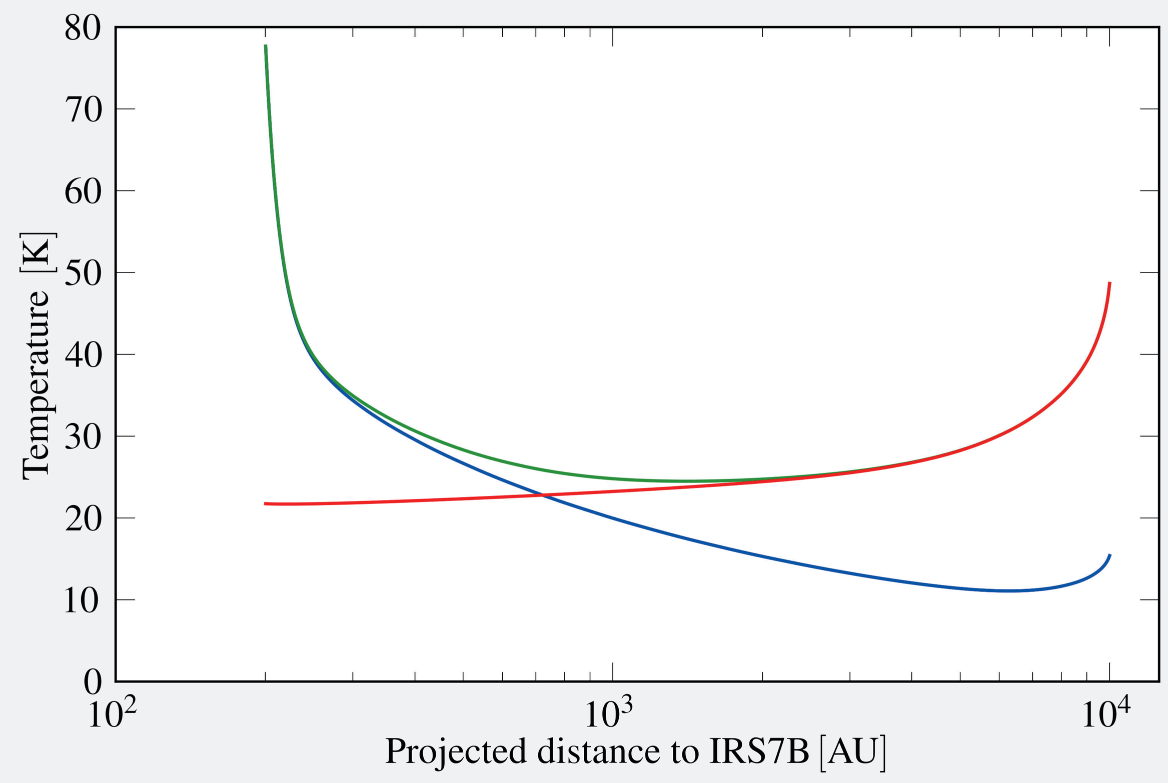

Figure 4: *1D radiative transfer model of the temperature in an envelope around IRS7B (blue), with external heating from R CrA (green), and with external heating but with no central source (red).*

Herschel observations

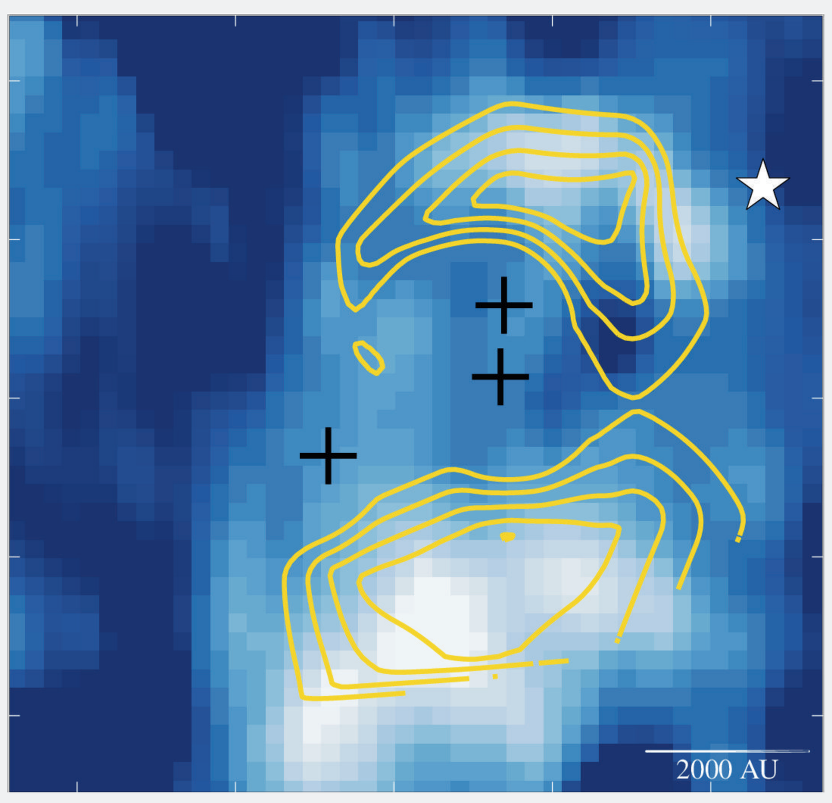

Figure 6: Herschel *120 μm extended continuum emission (yellow contours) and H_2CO 3_{03}-2_{02} line emission (bluescale). Contours start at 35 Jy and are then in steps of 5 Jy. The* Herschel *resolution is limited by the PACS spaxel size of 9.4″×9.4″.*

The *Herschel* Programme DIGIT (Dust, Ice and Gas in Time; PI: N. Evans) used the PACS spectrometer to observe the CrA region. By deconvolution we separated the point-source and extended emission. Considerable extended continuum and line emission was found.
The molecular excitation temperatures in the compact and extended emission were found to be similar, and also agree with those in isolated embedded protostars (e.g. Green et al. 2013).
The ratios between [O I], OH, and H_2O line fluxes indicate PDR-like activity.
In Figure 6, the extended continuum emission at 120 μm is compared to the H_2CO line emission discussed above. (Lindberg et al., subm.)

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