Study of deuterated molecules in the PDR around the UCHII region Mon R2

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Photo-dominated regions (PDRs) are ubiquitous environments where chemistry and heating are driven by UV photons from nearby O & B stars. The massive star forming region Mon R2 is the closest (830 pc) ultracompact (UC) HII region associated with a PDR. We are carrying out a spectral line survey of the PDR associated with Mon R2 using both ground and space based facilities, with the aim of investigating the chemistry of the molecular gas around the UCHII region and the possible variations due to the different local physical conditions. The last year we performed an unbiased spectral survey at 1, 2 and 3 mm, and discovered an unexpectedly rich chemistry. More than thirty different species (including isotopologues and deuterated compounds) were detected. Here we present the results of deuterated molecules, we derive the deuteration in the region and compare it with hot cores, dark clouds, and other PDRs.

The Mon R2 star forming complex

Mon R2 is a massive star forming region in the Monoceros molecular cloud (see Figure 1), located at a distance of only 830 pc. It contains the closest UCHII region (ionized by a B0 star; Downes et al 1975, Wood & Churchwell 1989) which is associated with a PDR. Its angular size (~22", corresponding to 0.1 pc) makes Mon R2 the only UCHII region (plus PDR) that can be resolved by single-dish millimeter telescopes, thus being an ideal target for the study of the chemical and physical properties of the PDRs.

Mon R2 comprises several PDRs that can be spatially resolved in both the mm and IR domains. In addition to the PDR associated with the UCHII region, there is a low-UV PDR located to the north of it, which is probably the consequence of an external illumination of the molecular cloud (Pilleri et al 2013).

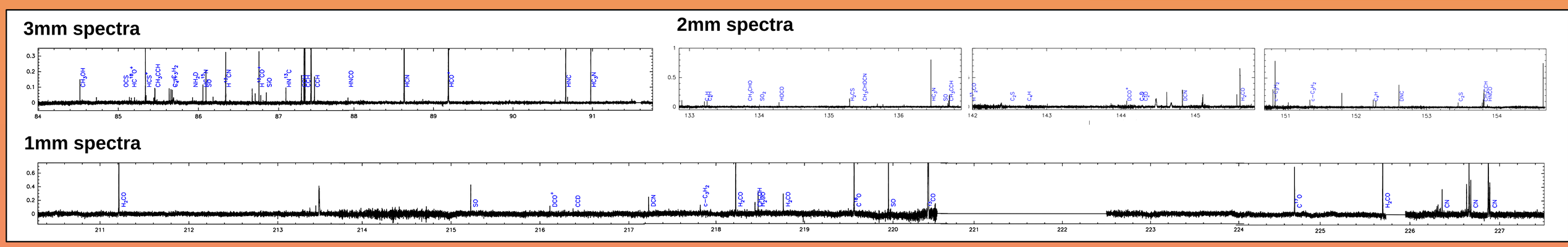
Fig.1: Monoceros molecular cloud

Observations

The IRAM 30m telescope (Granada, Spain) was used to carry out a large spectral survey at 1, 2 and 3 mm toward Mon R2. On January 2012, we performed 2'x2' maps of the region, obtaining an unbiased 64 GHz spectral survey at 1 mm (202.3-265.2 GHz), with a spectral resolution of 0.25 km/s, and an angular resolution of 10". On July 2012, single-pointed spectral surveys at 2 and 3 mm were done toward two interesting positions: IF (0",0") and MP2 (0",40"). All the observations were carried out using the FTS200 backend.

Results, analysis and comparison with chemical models

Fig. 2: Part of the observed 3, 2 and 1 mm spectral survey.



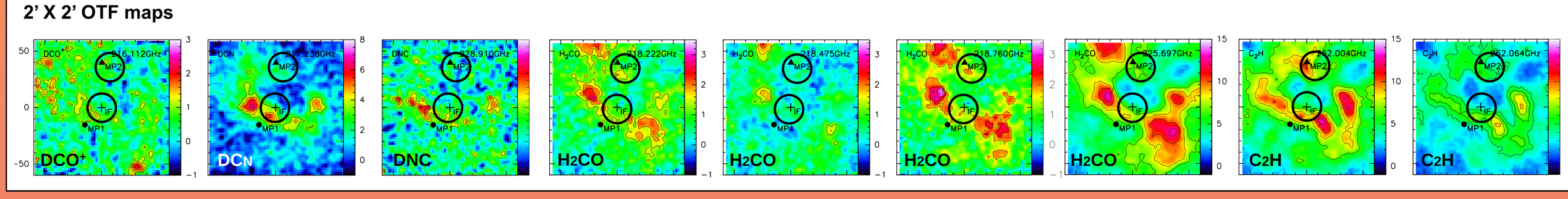
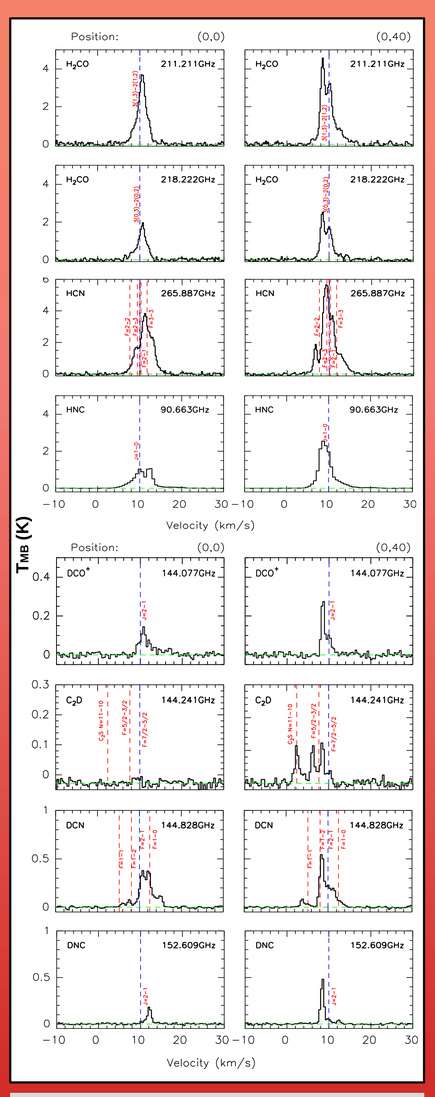


Fig. 3: Integrated line intensity maps of different species. The spatial distribution is quite similar for all the molecules: arc structure surrounding the cometary shape of the UCHII region.



Two velocity components. The component at 10-12 km/s is associated with the main PDR (0",0"). The one at 8.5 km/s is associated with the second low-UV PDR (0",40").

The [HCN]/[HNC] ratio is high, in agreement with model predictions for a dense and warm UV-irradiated region.

Deuteration is high in both PDRs, with some differences for species like C2H and H2CO. Deuteration in the IF PDR is lower than deuteration in the northern low-UV PDR.

Fig. 4: Spectra toward IF and MP2 positions.

Table 1: Column densities toward IF position.

(0,0) Specie	T_{rot} (K)	N (10^{12} cm^{-2})
C_2D	19	3.09
	38	4.63
DCN	44	2.09
DNC	45	0.091
DCO^+	19	0.111
	38	0.166
HDCO	19	0.351
	38	0.616
NH_2D	19	0.389
	38	0.607
C_2H	30	158.00
$H^{13}CN$	14	2.0
$HC^{15}N$	22	0.38
$HN^{13}C$	19	0.176
	38	0.309
$H^{15}NC$	19	0.057
	38	0.100
$H^{13}CO^+$	16	0.96
$HC^{18}O^+$	16	0.129
H_2CO	55	67.1
$H_2{}^{13}CO$	19	< 10.2
	38	< 3.10

Table 2: Comparison of fractional abundances

	Mon R2 (This work)	Ori Bar (Clump 3) (Parise + 2009)	TMC1 (Turner + 2001)	IRAS 16293 (Lis + 2002)
$H^{13}CN/HN^{13}C$	10	2.5	0.9–1.5	—
DCN/HCN	0.02	0.01	0.008	0.01
DNC/HNC	0.01	< 0.01	0.01	—
DCO^+/HCO^+	0.2×10^{-2}	0.6×10^{-3}	0.01	0.7×10^{-2}
C_2D/C_2H	0.03	< 0.11	0.03–0.06	—
$HDCO/H_2CO$	$(0.3–0.9) \times 10^{-2}$	0.6×10^{-2}	0.05	0.15

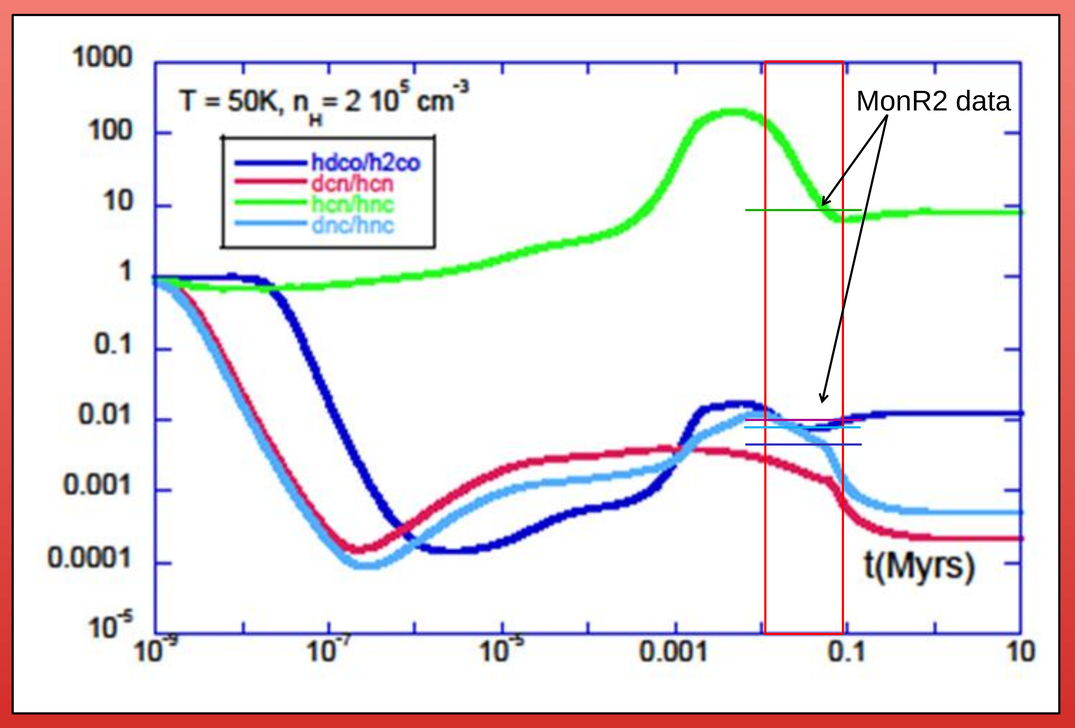


Fig. 5: First comparison between observations and chemical models (see Roueff et al 2007, our updated version takes into account time evolution). Great agreement between observations and model, assuming an age of 0.01-0.1 Myr for Mon R2. The chemistry is controlled by gas-phase reactions via CH_2D^+ and C_2HD^+.

Summary of the main results

We have performed an unbiased spectral survey at 3mm, 2mm, and 1mm, towards the PDR associated with Mon R2. More than 30 molecular species detected in the PDR. The spatial distribution shows a PDR with a cometary shape around the central UCHII region. A second low-UV PDR is found to the north of the main PDR. The high [HCN]/[HNC] ratio is in agreement with model predictions for a dense and warm UV-irradiated region. The low [HDCO]/[H_2CO] and [DCO^+]/[HCO^+] ratios indicate that deuteration in Mon R2 is different to that found in dark clouds (cold objects) and hot corinos (hot objects). The chemistry in Mon R2 is similar to the chemistry of the PDR Orion Bar. A first comparison of observations and models suggests that the chemistry in Mon R2 (warm object) is controlled by gas-phase reactions via CH_2D^+ and C_2HD^+.

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