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Molecular Line Maps of the Galactic Centre Circumnuclear Disc

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Abstract. Prelimary results are discussed for a long-term programme carried out with the James Clerk Maxwell 15m Telescope, to map the structure and dynamics of the Circumnuclear Disc at the Galactic Centre in a wide range of millimetre and submilletre wavelength molecular line transitions

1. Observations and Data Reduction

The data were obtained with the 15 metre James Clerk Maxwell Telescope (JCMT) at Mauna Kea, Hawaii at various times between 1987 and 1994. The beam sizes of the observations in this study ($\sim$ 10 - 23 arc seconds) corresponded to linear resolutions of $\sim$ 0.4 - 0.8 pc (15 arc seconds $\approx$ 0.62 pc), and the map centres are located at the position of SgrA*: α_{1950} = $17^h42^m29^s.3$, δ_{1950} = -28°59′19″.

2. History of the Galactic Plane Mapping Project

The first observations during commissioning of the JCMT in 1987 in the CO J=2-1 and 3-2, CS J= 7-6 , HCN J= 4-3 lines showed the $C^{18}O$ and ^{13}CO isotopes to be surpisingly weak, whereas observations of the HCN J= 4-3 and CS J= 7-6 lines showed them to be relatively intense. Mapping was hard work in those days when system temperatures were typically 3000 - 10,000 K. A more extensive series of maps were followed in 1988 by a spectral scan of the 330 - 357 GHz window towards three bright spots which had been identified on the rim of the CND, supplemented by more speculative targeted searches in the 220 - 270 GHz window for species such as H_2O, O_3 etc. Between 1989 and 1994, fully sampled maps over an area about 2 x 2 arc minutes were made for all the lines seen in the spectral survey which had antenna temperatures greater than about 1 K. These maps were supplemented by deeper observations in key isotopomers between 1990 and 1995, and the programme was completed by April 1996 with the acquisition (after years of being beaten by Mauna Kea weather !) of maps in the CO J=4-3 and $^3P_1$ - $^3P_0$ atomic carbon lines maps, and a larger area ($4' \times 8'$ along the galactic plane) in the CO and ^{13}CO J= 3-2 lines. The final key piece of work remaining to be completed is the ISO high resolution spectral survey, which is contained within the SWS and LWS Guaranteed time programmes.

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Lines which have been studied (with maps available for the majority) include ^{13}CN N= 2-1 (217.142 GHz), $C^{18}O$ J= 2-1 (219.560 GHz), ^{13}CO J= 2-1 (220.398 GHz), CN N= 2-1 (226.632 GHz), CN N= 2-1 (226.875 GHz), CO J= 2-1 (230.538 GHz), $C^{34}S$ J= 5-4 (241.016 GHz), CH_3OH 5_0 - 4_0 E (241.700 GHz), CH_3OH 5_{-1} - 4_{-1} E (241.767 GHz), CH_3OH 5_0- 4_0 A^+ (241.791 GHz), CS J= 5-4 (244.936 GHz), SO 6_6 - 5_5 (258.255 GHz), C_2H (260.03 GHz), $H_{13}CO^+$ J= 3-2 (260.256 GHz), SiO J= 6-5 (260.518 GHz), HCN J= 3-2 (265.816 GHz), ^{13}CO J= 3-2 (330.588 GHz), SO 3_3 - 3_2 (339.341 GHz), CN (340.035 GHz), CN (340.248 GHz), CH_3OH 13_1 - 13_0 A^- (342.730 GHz), CS J= 7-6 (342.883 GHz), SO 8_8 - 7_7 (344.310 GHz), $H^{13}CN$ J= 4-3 (345.340 GHz), CO J= 3-2 (345.796 GHz), $H^{13}CO^+$ J= 4-3 (346.999 GHz), SiO (347.331 GHz), HCN J= 4-3 (354.505 GHz), HCO^+ J= 4-3 (356.734 GHz), CO J= 4-3 (461.041 GHz), CI $^3P_1$ - $^3P_0$ (492.161 GHz)

A complete discussion of these data are beyond the scope of this short paper, however, it is possible to summarise some general conclusions.

(1) The chemistry of the CND is on the whole photon dominated excitation - rather than collisionally dominated as in many dense molecular cores.

(2) Some species are very under-abundant. There are however some chemical indicators we have detected, such as SiO, which may suggest high temperature, or shock activity - but recent detection's of this species in absorption against $SgrB_2$ may suggest that our understanding of the relationship of SiO to shocked material should be treated with caution.

(3) Many lines, even dominant isotopomers, are optically thin, and gross variations of line shapes from isotope to isotope as well as species to species can complicate the analysis. Many of the problems encountered in the 3 mm window, where line of sight self absorption in lower J-transitions can have significant effects on the line profiles, are minimised by observing in the higher rotational transitions - which require a higher excitation environment.

(4) Most main isotopes - as well as main lines (with the exception of CO) - are optically thin. The CO isotopes are surprisingly weak - beam-matched data suggest an environment with $n_{H2} \sim 10^5$ - 10^6 cm^{-3} and $T_{kin} \sim 200$ - 300 K.

(5) The ring dynamics are traceable in all molecular species - even CO. The CND's structure may be better described by group of co-rotating filaments within a loose ring structure, than an coherent body. This complicates simple kinematic modelling with inclined rotating rings. Strong non-circular motions are however seen, particularly to the SW of the centre perhaps indicative of an infall - or outflow activity.

(6) There are suggestions of larger scale collapse outside the ring, and strong kinematic activity at the edge of the SW streamer, matching the velocities of material in the ionised fingers - where probably some shock or tidal stripping activity is happening.

(7) The atomic gas CI, has a different distribution to molecular material - although some high velocity gas in associated with the CND.

(8) There is little evidence evidence of a chemically distinct rim along the HII region interface.

(9) The CND's mass depends strongly on the filling factor - but is probably $\sim$ 250 - 500 $M_\odot$, with a filling factor $\sim$ 3 - 10 percent.

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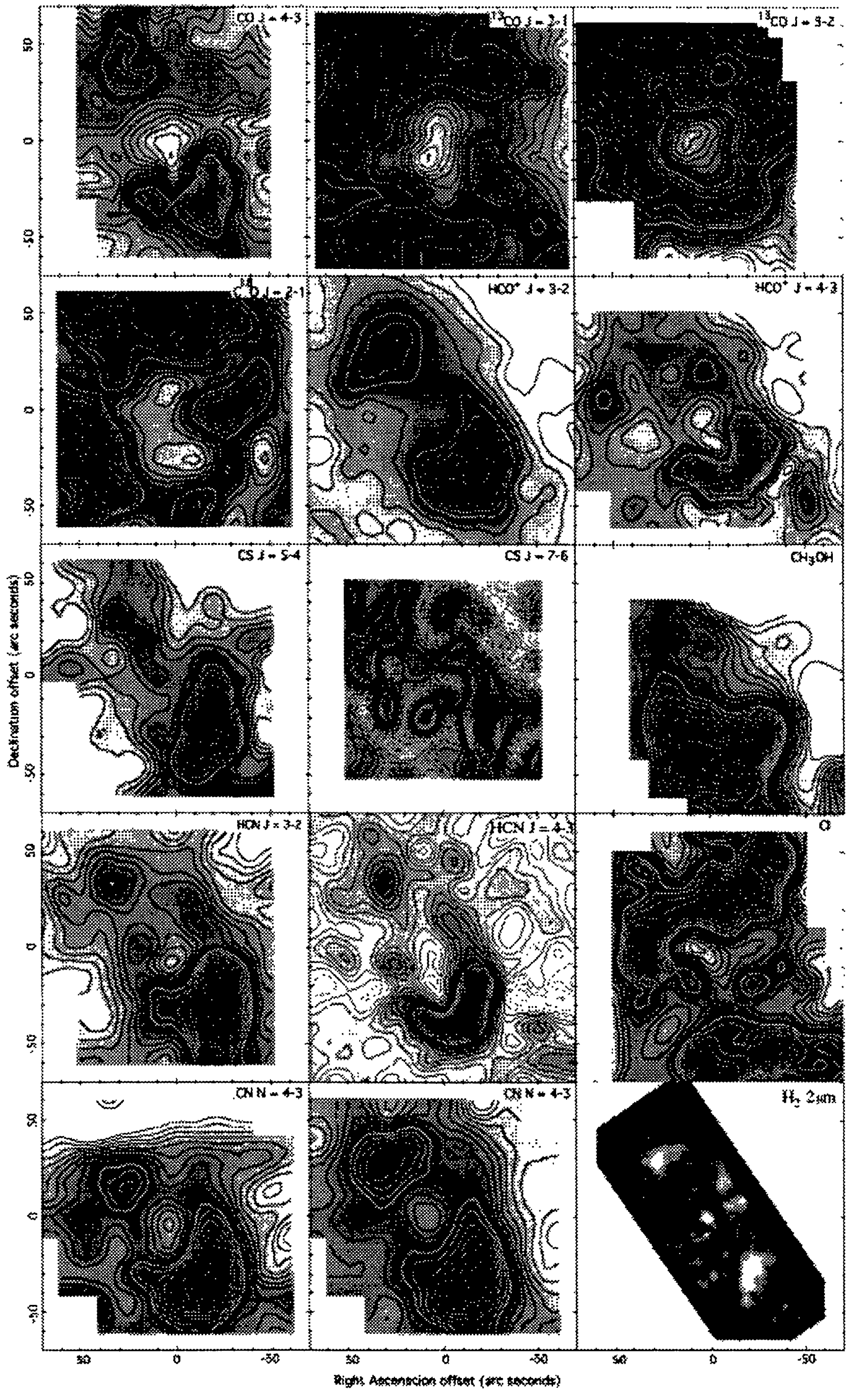

Figure 1. Maps showing the integrated emission for the area around the Galactic Centre, integrated between −120 and +120 km s^{-1}. The beamsize varies between ≈ 20 arc seconds at the lower frequencies to ≈ 9 arc seconds at the CO 4-3 and atomic carbon frequencies

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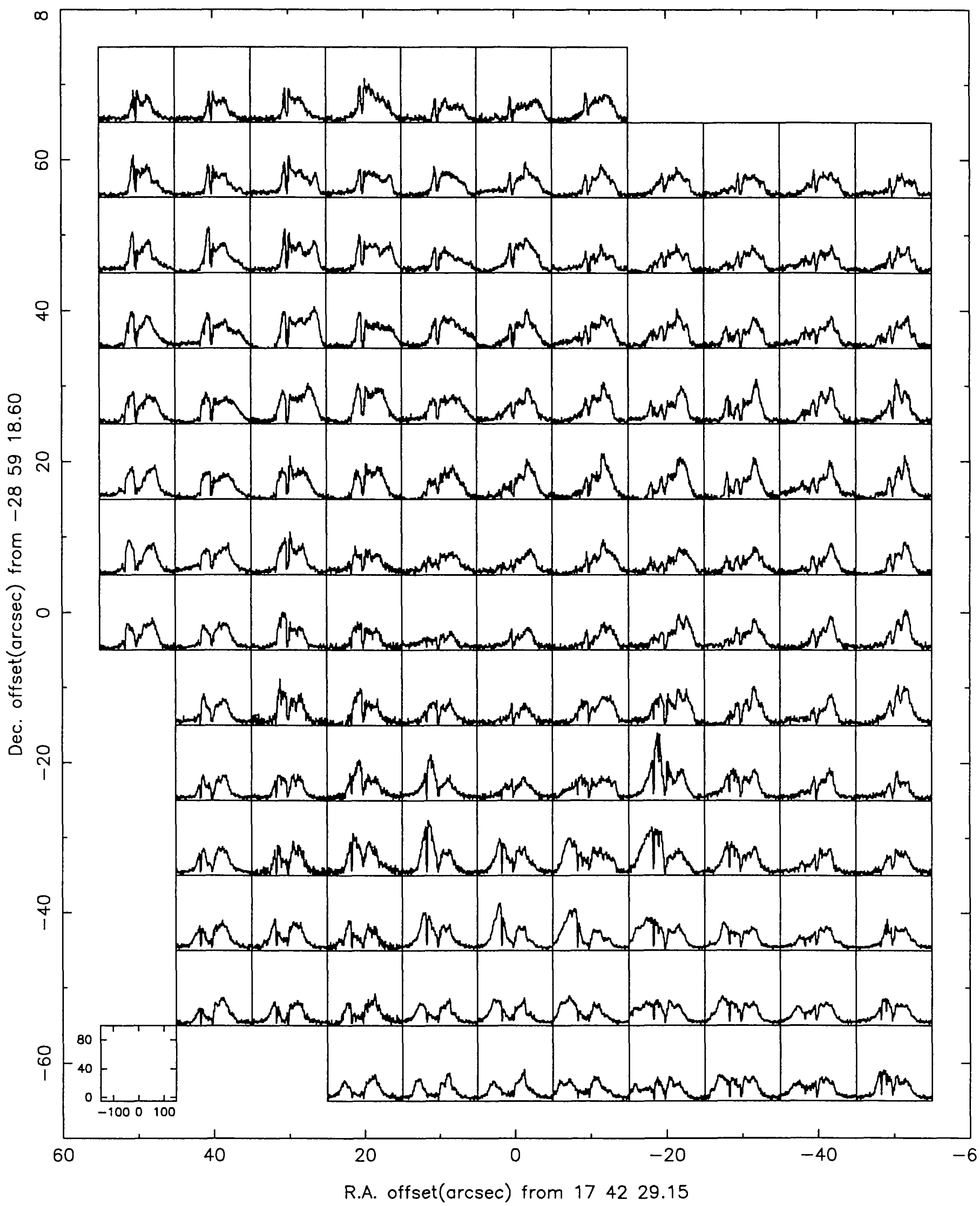

Figure 2. CO $J=$ 4-3 map of the region around the Circumnuclear Disc. These spectra are 10 second integrations at each position, with only linear baselines subtracted

(10) A comparison of the line shapes of $C^{18}O$ and ^{12}CO toward selected positions shows that they often differ significantly. A detailed analysis shows that the standard conversion formula for the determination of the ^{12}CO column density does not work in the Galactic center region and that the assumption of high optical depth for the ^{12}CO emission is not generally valid there.

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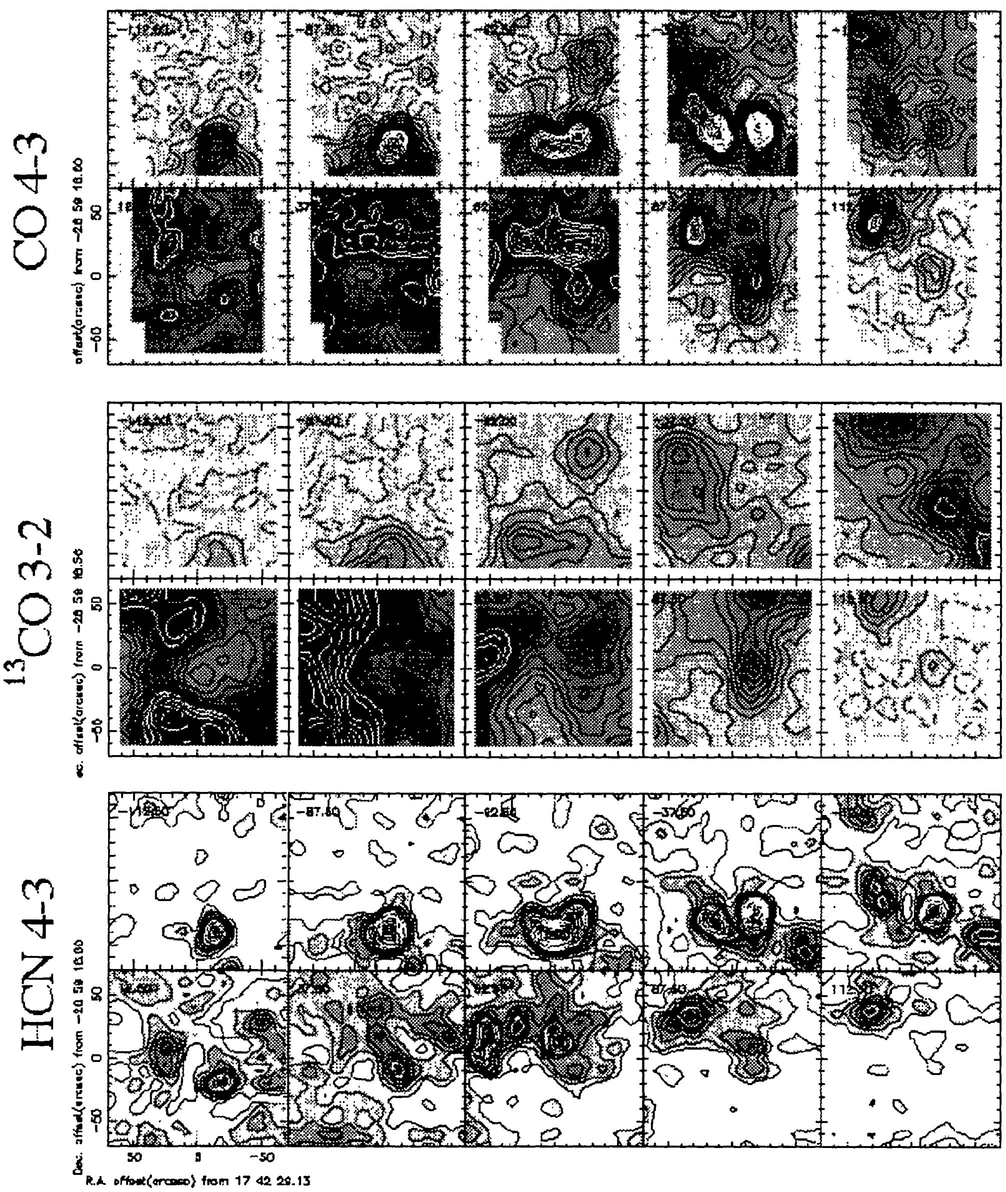

Figure 3. Channel maps for three of the species mapped in this study. It is quite remarkable that the CO line is able to trace the structure of the disk so clearly, despite the fact that it is normally quite saturated in molecular clouds

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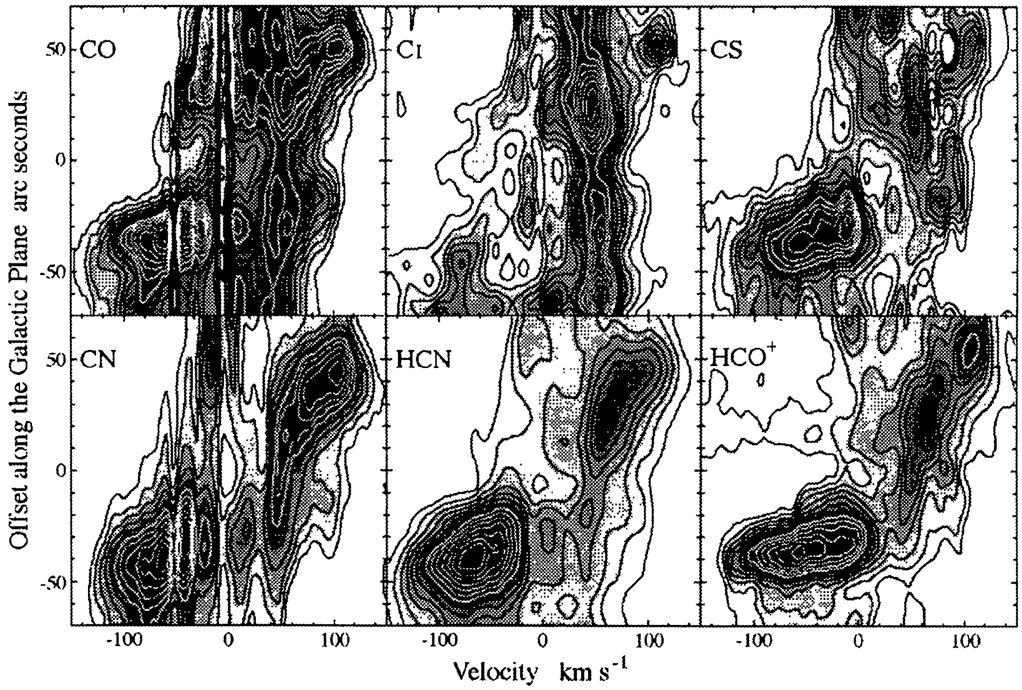

Figure 4. Position velocity maps along galactic longitude, centred on the Galactic Centre. The signature of the ring can be seen ≈ 40 - 50 arc seconds from the central position

3. Acknowledgements

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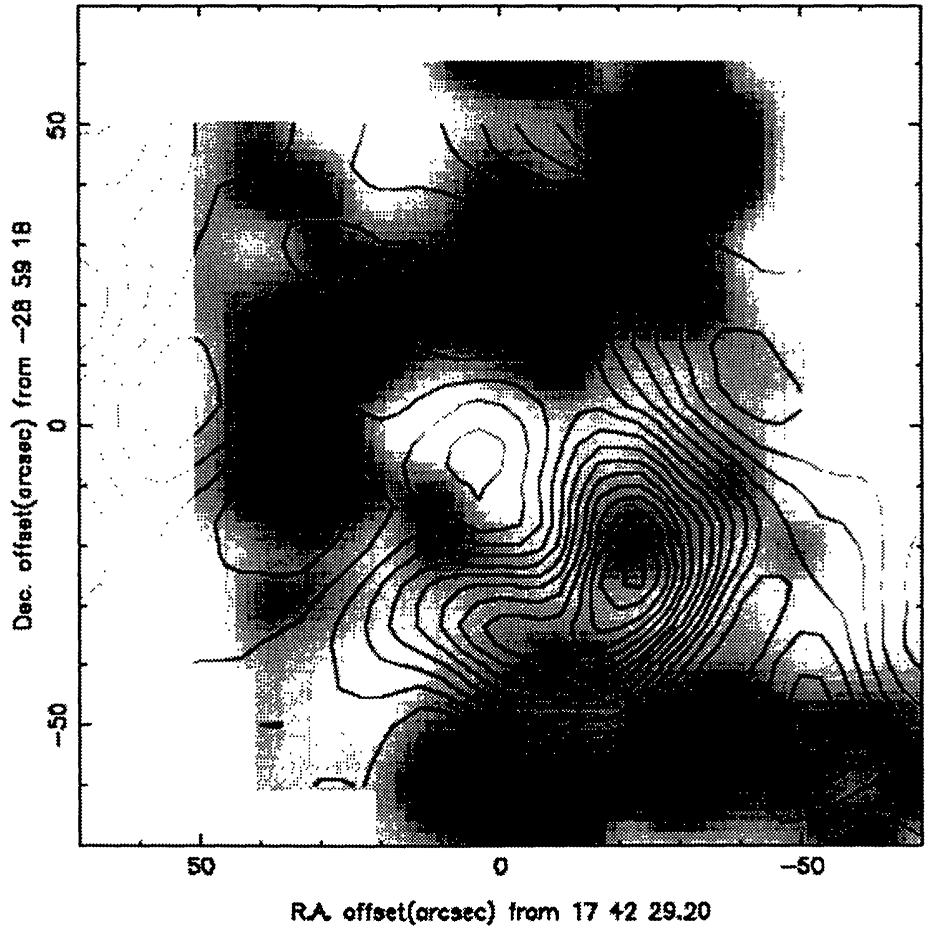

Figure 5. Overlay showing the relative distributions of the HCO^+ distribution (as contours) and atomic carbon (as greyscales). It is notable how the CI in the south of the ring sits further out from the edge of the molecular ring, as indicated by most of the tracers shown in Figure 1

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