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DISTRIBUTION OF H_2CO, CO, AND EXTINCTION IN THE DARK CLOUD B5

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ABSTRACT

We have made observations of the dark cloud, B5 in the transitions of H_2CO, $J = 1_{10} \leftarrow 1_{11}$, and $2_{12} \rightarrow 1_{11}$. We compared the H_2CO result with the observational results of CO and with the visual extinction. There exists an overall correspondence of molecules and extinction. However, a detailed agreement is lacking. We discussed the kinematics and the spatial relationship of molecules and extinction in this cloud.

I. INTRODUCTION

Even though it is generally known that molecules and dust are associated and correlated in space, details of their relation have not yet been resolved. In general, there are two theories on the formation of the H_2CO molecule. One is the gas-phase reaction (Herbst and Klemperer 1973), and the other is the reactions within and on the dust grains (Greenberg *et al.* 1979; Williams and Hartquist 1984). However, both of these theories have some weakness which has to be justified.

In order to determine the details of the relationships between H_2CO and other molecules as well as of the visual extinction, we have observed B5 in the transitions of $J = 1_{10} \leftarrow 1_{11}$, and $2_{12} \rightarrow 1_{11}$ of H_2CO. We compared the intensities and kinematics of these spectral lines. Also the H_2CO results are compared with the distribution of CO emission and visual extinction which is obtained with the star counting method.

II. OBSERVATIONS

The ortho H_2CO $J = 1_{10} \leftarrow 1_{11}$ (6 cm) transition has been observed in absorption against the 2.7 K background with the 100-m Bonn-Effelsberg radio telescope in Germany. The spectra were obtained with a single-channel cooled parametric amplifyer. We used the 1024 channel autocorrelation spectrometer with a bandwidth 1638.5 kHz. The resolution per channel was 1.6 MHz or 0.189 km s^{-1}. The beamsize of the telescope is about 2.6′ and the main-beam efficiency is 0.7 at 4.83 GHz. The system temperature was about 30 K at the cold sky. The integration time was 20 to 30 minutes. The data were taken employing the frequency switching method.

Observations of the $J = 2_{12} \rightarrow 1_{11}$ transitions of H_2CO in a region of approximately 10′ × 10′ around IRS1, using the NRAO* 12-m millimeter-wave radio telescope at Kitt Peak, Arizona, were made (see Hogerheijde, 1993). The HPBW of the antenna is 45″ at the frequency of the observed transition. The receiver used is the 2-mm SIS heterodyne mixer. The 100 kHz and 30 kHz filterbanks and the Hybrid Spectrometer (HySpec) were used. Each filterbank consists of 256 channels. The 100 kHz filterbank was split into two parts of 128 channels which were used in parallel mode and the 30 kHz filterbank was used in series mode.

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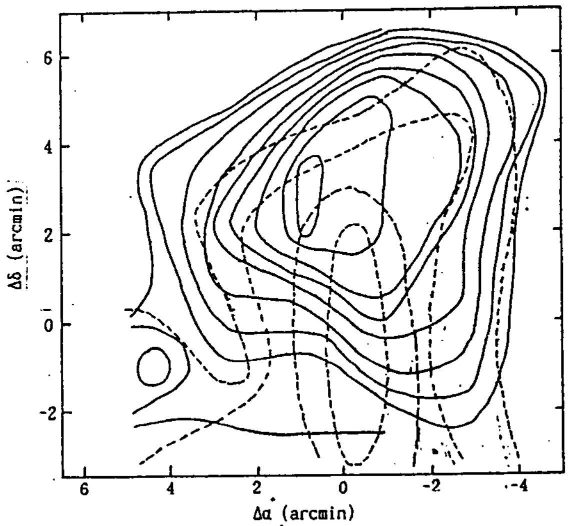

Fig. 1.— Contour map of $\int T_A dv$ of the 6-cm H_2CO absorption line (solid line) superposed on the distribution of A_v (dashed line) in B5. The map offsets are with respect to $\alpha_{1950} = 03^h44^m28.7^s$ and $\delta_{1950} = +32°44'30''$. The contour level of $\int T_A dv$ starts from 0.06 K km s^{-1} increasing with 0.01 K km s^{-1} and that of A_v starts from 3.0 mag increasing with 1.0 mag towards the cloud center.

III. RESULTS AND DISCUSSION

In Figure 1, we presented the integrated intensity map of the 6-cm H_2CO absorption line, $\int T_A dv$, superposed on the extinction distribution derived from the data of Cernicharo and Bachiller (1984). They performed star counts on the prints of the Palomar Obser-

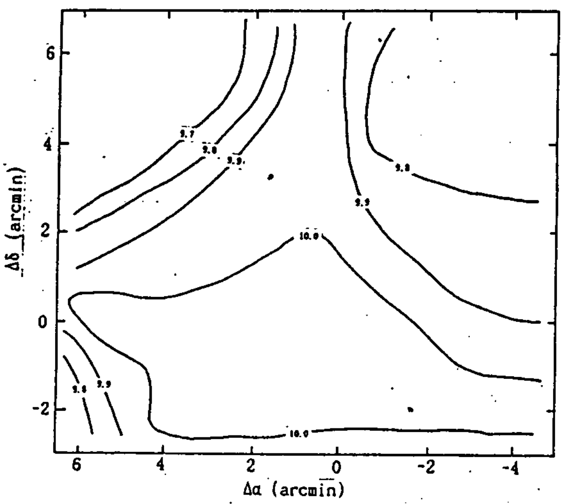

Fig. 2.— Contour map of the radial velocity of 6-cm H_2CO absorption line in B5. The map offsets are the same as Fig. 1. The contour unit is km s^{-1}.

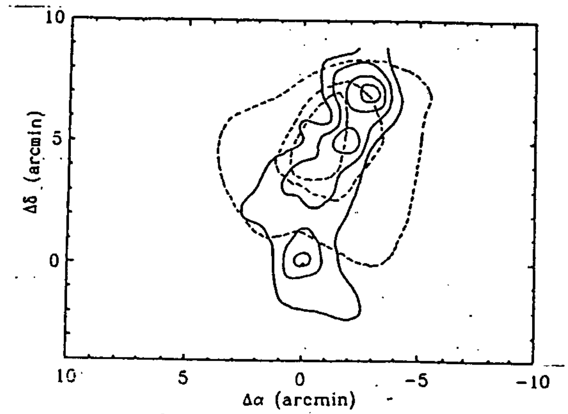

Fig. 3.— Contour map of $\int T_A dv$ of 2-mm H_2CO emission (solid line) superposed on the map of $\int T_A dv$ of 6-cm H_2CO absorption (dashed line) towards the B5 core. Map offsets are with respect to IRS1. Contour levels of the solid line start from 0.30 K km s^{-1} increasing with 0.3 K km s^{-1}. Three contour levels of the dashed line are 7, 12, and 13 K km s^{-1} increasing toward the cloud center.

vatory Sky Survey (POSS). The resolution of the star counts was 2.50 arcminutes.

The high extinction region generally falls within the boundary of the molecular cloud. However, the maxima of both contours do not coincide. The H_2CO intensity peak is shifted about 3′ north of the extinction peak. This discrepancy is quite unexpected and contrary to many other similar studies.

The integrated intensity the distribution is similar to that of the antenna temperature of H_2CO $1_{10} \leftarrow 1_{11}$ (6 cm) absorption line with coinciding peaks at $\alpha(1950) = 03^h44^m32^s$ and $\delta(1950) = +32°47'30''$ and having a similar shape. The FWHM distribution of the 6-cm H_2CO absorption line shows no systematic trend. However, there appear two distinct maxima which have no correlation with the line intensity. Near the position of the antenna temperature peak, the FWHM decreases to a minimum value of 1.1 km s^{-1}.

The radial velocity distribution of the 6 cm H_2CO line is given in Figure 2. It shows that the velocity distribution is nearly uniform ranging from 10.2 to 9.7 km s^{-1}. It has a small gradient of 0.05 km s^{-1} from the north to south direction.

In Figure 3, we compared the integrated intensity of the H_2CO $2_{12} \rightarrow 1_{11}$ emission line with that of the H_2CO $1_{10} \leftarrow 1_{11}$ absorption line. The spatial distribution of the two transitions is clearly dissimilar, the 6 cm ($1_{10} \leftarrow 1_{11}$) absorption has nearly a circular shape while the the 2 mm ($2_{12} \rightarrow 1_{11}$) emission has an elongated shape. However, the area of the two intensity peaks is generally coinciding. The discrepancy could be the beasize effect.

The antenna temperature distributions of the $C^{18}O$ $J = 1 \rightarrow 0$ emission (Fuller *et al.*1991) and H_2CO 6-cm absorption show a similar spatial distribution with both peaks at the same position in-between the H_2CO $2_{12} \rightarrow 1_{11}$ peaks, and coinciding with the northern NH_3 clump of Benson and Myers (1989).

The emission of the H_2CO $2_{12} \rightarrow 1_{11}$ is peaked towards the young outflow source B5 IRS1. The spatial distribution is also similar to the CS $J = 2 - 1$ emission (Fuller *et al.* 1991), which indicates that the same process is causing the emission. The emission peaks of H_2CO $2_{12} \rightarrow 1_{11}$ appears not to be coinciding with that of the H_2CO $1_{10} \leftarrow 1_{11}$ (6 cm) absorption.

Excitation calculations carried out by Jansen *et al.*(1996) suggest that the position difference of peaks in emission and absorption is a density effect. The $1_{10} \leftarrow 1_{11}$ goes from absorption to emission around an H_2 number density of 10^5 cm^{-3}. The $C^{18}O$ $J = 1 \rightarrow 0$ emission (Fuller *et al.* 1991) has about the same spatial distribution as the H_2CO 6 cm absorption, and they peak at the same positon (2′ north of IRS1). The northen clump of the NH_3 emission (Benson and Myers 1989) and the extinction peak (Cernicharo and Bachiller 1984) are at this position too. This can be explained by a column density peak at this position. The sourthern NH_3 clump coincides with IRS1.

The H_2CO $2_{12} \rightarrow 1_{11}$ emission clearly shows the northwestern extention which Fuller *et al.* (1991) found in $C^{18}O$ and CS. Due to better sampling in our case, it turns out that the northwestern extension is much more prominent than found by Fuller *et al.*(1991). In fact, the northwest feature is stronger than the emission around IRS1. Furthermore, the emission is distributed in two clumps. In addition, the line profiles in this region differ greatly from gaussians, and appear to be double lines in some cases.

The nature of the northwest feature is not very clear. One possible explanation is that it is caused by the infrared source IRS4, which is located about 8′ to the northeast. Goldsmith *et al.* (1986) have suggested that IRS4 has created a cavity around itself of about 4′ (-0.4 pc) diameter. The material around this cavity shows velocity offsets of about 2 km s^{-1}, with blueshifted material on the western side. Although the northwest feature is 5′ away from the edge of the cavuty, it might be related to it. Goldsmith et al. give a spectrum of ^{12}CO at about 4′ north of the northwest feature, showing a similar velocity structure as found in H_2CO and CS in the northwest feature.

We can conclude from this study that the different transitions of H_2CO occur from the same general region, but there is shown no detailed correspondence. A similar conclusion can also be applied to ^{13}CO and CS. The overall shape of the different molecular clouds is similar, but peaks occur at different positions. The 6 cm H_2CO absorption generally matches better to the visual extinction than any other molecules or molecular transitions.

REFERENCES

Benson, P.J. & Myers, P.C. 1989, ApJS, 71, 89.

Cernicharo, J. & Bachiller, R. 1984, A&A, 58, 327.

Fuller, G.A., Myers, P.C., Welch, W.J., Goldsmith, P.F., Langer, W.D., Campbell, B.G., Gulloteau,S. & Wilson, R.W. 1991, ApJ, 376, 135.

Goldsmith, P.F., Langer, W.D., & Wilson, R.W. 1986, ApJ, 303, L11.

Greenberg, J.M., Minn, Y.K. & Tielens, A.G.G.M. 1979, A&A, 78, 100.

Herbst, E., & Klemperer, W. 1973, ApJ, 185, 505.

Hogerheijde, M. 1993, Verslag van Het Reductiepracticum.

Jansen, D.J., van Dishoeck, E.F., & Black, J.H. 1996, in prep.

Williams, D.A. & Hartquist, T.W. 1984, MNRAS, 210, 141.