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Letter to the Editor

Formaldehyde Emission from DR21 (OH)

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Summary

The discovery of H_2CO emission from the $2_{11}-2_{12}$ K-doublet line at 14.5 GHz is reported. The emission is centered at $\alpha = 20^h37^m13.8^s$, $\delta = +42^\circ11'55''$ (1950.0), which is within 15" of the position of the OH and H_2O emission source DR21(OH). The extent of the line emitting source is $\lesssim$30". From excitation considerations, we believe that this emission has a quasi-thermal origin. If the region is similar to OMC-1 the size would be ∿10". We have estimated source parameters for sizes of 30" and 10" assuming that the shape is spherical and that an H_2 density of $\geq 10^6$ cm^{-3} is required to produce H_2CO emission in the 14.5 GHz line.

Key words: Molecular Lines – Star Formation

Introduction

The $1_{10}-1_{11}$ and $2_{11}-2_{12}$ K-doublet lines of H_2CO at 4.83 GHz and 14.5 GHz are normally found in absorption, even against the microwave background. The refrigeration of the K-doublets is attributed to the effects of collisions with H_2 molecules. According to the calculations of Garrison et al. (1975), the refrigeration of the 14.5 GHz line is quenched for $n(H_2) \gtrsim 10^6$ cm^{-3}. Such high densities are expected in regions of star formation. Although there are many such regions, only a few sources of 14.5 GHz H_2CO line emission have been found so far. Presumably, this is the case because the line-emitting regions have a small physical size. At distances more than 500 pc, these sources will subtend a small angle and the combination of this with the prevalent absorption will prevent a detection. The use of a large telescope will emphasize the emission from small regions, and might allow us to detect more sources, if accurate positions for candidates are known. We have made a systematic search for emission sources, and in this letter we describe the results for DR21(OH), also known as W75S. This source is near OH and H_2O maser emission regions, and is 3' north of the compact HII region DR21.

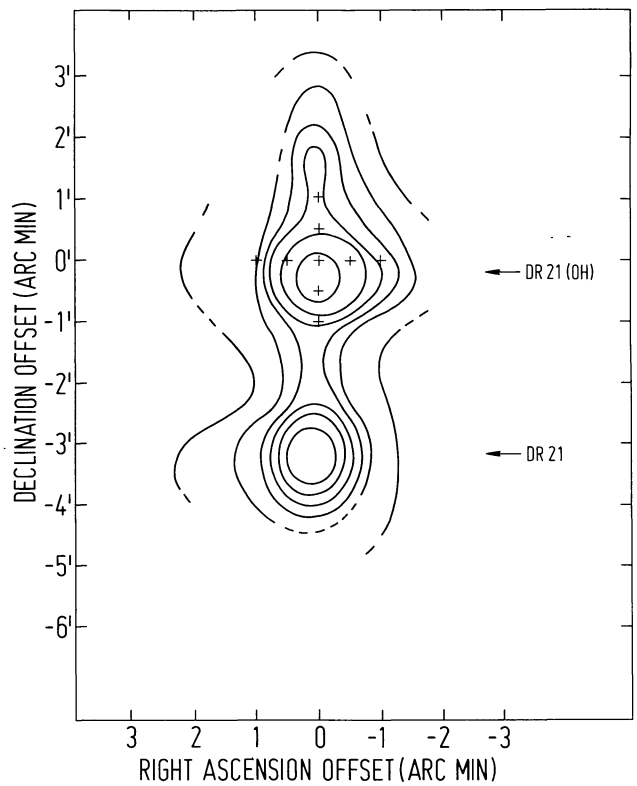

Fig. 1. The crosses indicate the positions where our spectra were measured. The offsets, spaced by 30" and 60" in α and δ, are measured with respect to the H_2CO emission center at $\alpha_{1950.0} = 20^h37^m13.8^s$, $\delta_{1950.0} = 42^\circ12'10''$ (Genzel and Downes 1977). The contours show the distribution of 1 mm emission measured by Werner et al. (1975). The resolution used for the 1 mm and H_2CO measurements was 1'.

Observations and Results

The observations were made using the 100-m telescope. At 14.488 GHz, the rest frequency of the $2_{11}-2_{12}$ line, the full width to half power of the telescope is 1'. The main-beam brightness temperature scale was established by continuum cross scans through the peaks of the calibration sources NGC7027 and DR21. From Baars et al. (1977), the flux densities of these sources were taken to be 6.1 and 19.5 Jy, respectively. The receiver included a cooled, single channel parameter amplifier and gave a system noise on cold sky of ∿140 K. Spectra were obtained with a 384 channel autocorrelator. The bandwidth used was 2.5 MHz; this gives a channel spacing of 0.13 km s^{-1} at the line rest frequency. The observations were made employing position switching; the reference position was 7 minutes of time west of the (0,0) position $\alpha = 20^h37^m13.8^s$, $\delta = +42^\circ12'10''$ (1950.0). (The (0,0) position refers to the center of the H_2O emission (Genzel and Downes 1977)). We also measured spectra at 8 positions spaced 30" and 1' north, east, south and west of the peak. These are indi-

Send offprint requests to: T. L. Wilson cated by crosses, which are superimposed on the 1 mm continuum map of Werner et al. (1975) in Fig. 1, also made with a 1' beam. Repeated checks of the positions of the nearby continuum sources DR21 and NGC7027 indicated that the pointing accuracy is ∿5". In Fig. 2 we show the spectra spaced at 30" on a line in declination, at the right ascension of the peak position. The spectra from the east and west offset positions have less integration time, and are similar to those at the north and south offset points; for this reason we have not included these in Fig. 2.

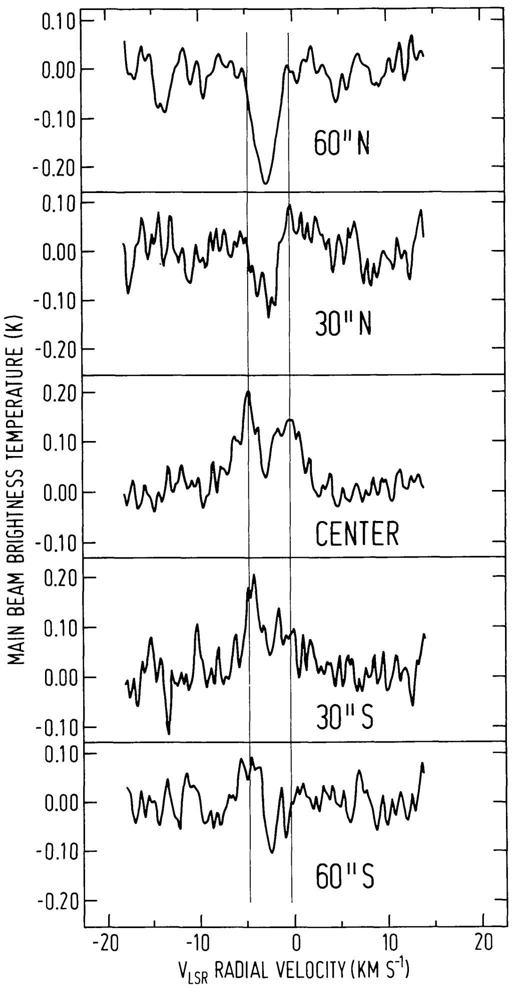

Fig. 2. The H_2CO spectra measured at offsets from $\delta_{1950.0}$ = +42°12'10". All spectra shown were taken at $\alpha_{1950.0}$ = $20^h37^m13.8^s$. The profiles were gaussian smoothed to a velocity resolution of 0.4 km s^{-1}. The two thin vertical lines mark the velocities of the two emission line peaks at the center position.

The central profile shows two emission peaks; between these peaks, the emission drops to nearly zero, at a radial velocity near that of N-S absorption maximum. The east-west profiles show a similar absorption. The most plausible interpretation of the profiles shown in Fig. 2 is as follows. Each profile is the sum of a single broad emission line (from a spatially compact region) and a narrower absorption component from a more extended region. On this basis, we made two component gaussian fits (one for emission, one for absorption) to the profiles. The fit results are given in Table 1. Although the formal errors in Table 1 are reasonably small and the results are consistent with our assumption, the fits to two blended lines can have larger uncertainties than are indicated by the fit uncertainties. The presence of residual emission to all sides of the central position suggests that the source is slightly extended (we estimate a size of ≲30"), and displaced ∿15" to the south. Our best estimate of the peak is α = $20^h37^m13.8^s$, δ=+42°11'55" (1950.0). The peak emission line brightness temperature, corrected for the beam dilution, if the source and beam are gaussian shaped, is ≳1.2 K.

Table 1: Gaussian Fit Results

Position[a)] Offset (arc sec)	Peak Main-Beam Brightness Temperature (K)	Full Width of Half Power (km s^{-1})	Radial velocity (km s^{-1})
(0, 60)	−0.23 ± 0.02	2.4 ± 0.3	-3.0 ± 0.1
(0, 30)	−0.11 ± 0.02	2.1 ± 0.6	-2.8 ± 0.2
(0, 0)	+0.31 ± 0.05	5.2 ± 0.3	-2.8 ± 0.1
	−0.25 ± 0.05	2.6 ± 0.3	-2.7 ± 0.1
(0,-30)	+0.32 ± 0.13	3.8 ± 0.4	-3.0 ± 0.1
	−0.26 ± 0.13	2.1 ± 0.4	-2.7 ± 0.1
(0,-60)	+0.08 ± 0.01	2.7 ± 0.9	-4.6 ± 0.4
	−0.13 ± 0.02	1.0 ± 0.3	-2.6 ± 0.1

Errors are one standard deviation, obtained from gaussian fit

a) relative to α = $20^h37^m13.8^s$, δ = +42°12'10" (1950.0)

Discussion

The only known source of non-thermal (maser) H_2CO emission is NGC7538. At 4.8 GHz the derived peak brightness temperature is ≳10^5 K for the 1_{10}-1_{11} line (see e.g. Rots et al., 1981). However, our observations (unpublished) have failed to detect the 2_{11}-2_{12} line in NGC7538. This suggests that the excitation of H_2CO in DR21(OH) is quasi-thermal, as in Orion (see e.g. Wilson et al., 1980). On this basis the H_2 density is ≥10^6 cm^{-3}.

The distance to the DR21 region is rather uncertain but a value of 3 kpc is commonly assumed. We list source parameters for sizes of 10" and 30" in Table 2. The 30" value is our measured upper limit while the 10" value is based on an analogy with the Orion Molecular Cloud, where most of the emission is from a 1' region. At the assumed distance of DR21(OH), such an Orion-like region would have a size of 10".

For a 30" size, the column density of H_2 would nearly equal the upper limit from model calculations based on IR measurements of dust emission (Harvey et al., 1977). If the cloud is uniform, spherical, and in equilibrium, we can use the Virial theorem (Mihalas and Routley, 1968) to estimate the mass. From the size and linewidth, the Virial theorem also gives a mass of 2000 $M_\odot$. This agreement may be fortuitous however since the equilibrium required by the Virial theorem is the exception in regions of star formation. For a 10" diameter region, the cloud of 80 $M_\odot$ is much smaller than the 700 $M_\odot$ required by the Virial theorem for stability.

Table 2: Estimated Source Parameters

Angular Size (")	Linear Size (pc)	Column Density[a)] of H_2 $\times 10^{24}$ cm^{-2}	Mass of cloud[b)] ($M_\odot$)
30"	0.44	1.4	2×10^3
10"	0.15	0.4	8×10^1

a) Assuming an H_2 density of 10^6 cm^{-3}
b) For spherical, uniform source, of H_2 density 10^6 cm^{-3}

Given the gas temperature and density, we can estimate the scale of fragment sizes from the Jeans criterion. The derived dust temperature, averaged over a 30" region (Harvey et al., 1977), is 35 K. However, there may be cool foreground material and this temperature is a lower limit to the temperature of the dense gas located deeper in the cloud. If we assume that the kinetic temperature of the dense gas is 70 K, as in OMC-1, and take 10^6 cm^{-3} for the H_2 density, we find that the Jeans criterion predicts that the length and mass of a stable clump are 5×10^{-2} pc (= 3" at 3 kpc) and 3 $M_\odot$, respectively. Since our measurements favor a size larger than 3", the emission may arise in a few clumps.

Is the gas we observe contracting or expanding? If contracting, the object is presumably in a cocoon star phase; if expanding, the star has been on the main sequence long enough to break up the cocoon and cause expansion. Our observations cannot differentiate between these two possibilities. However, the presence of a Type I OH maser indicates that at least one young star, and a radio continuum source are probably present (see e.g. Habing and Israel, 1979), although at present there is no published detection of such a source. According to Harvey et al. (1977), the far IR measurements give a total luminosity of 5×10^4 $L_\odot$; they find that if there is only one exciting star, it must be later than type O9. Since the amount of ionized gas must be small, it is possible that the excitation is provided by a few stars later than type B0. If a main-sequence star is present, this region may be similar to the Orion Molecular Cloud, and we may be observing gas outflow (see e.g. the discussion of Scoville 1981).

Our interpretation of the results is the following: The H_2CO in the lower density gas produces the observed absorption. The distribution of this gas probably follows the contours of the 1 mm continuum emission in Fig. 1. Embedded in this lower density gas is the hotter, high density region which gives rise to the H_2CO emission. The H_2CO emission line is probably from a region where star formation is now taking place.

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