SUB-MILLIMETRE OBSERVATIONS OF SiCC IN IRC 10216

L.W. AVERY[1], T. AMANO[1], M.B. BELL[1], P.A. FELDMAN[1], J.W.C. JOHNS[1], J.M. MACLEOD[1], H.E. MATTHEWS[2], D.C. MORTON[1], J.K.G. WATSON[1], B.E.TURNER[3], S.S. HAYASHI[4], G.D. WATT[2], and A.S. WEBSTER[5]
[1]Herzberg Inst. of Astrophysics, NRC, Ottawa, K1A0R6, Canada
[2]Joint Astronomy Center, 665 Komohana St., Hilo, HI 96720, U.S.A.
[3]National Radio Astronomy Obs., Charlottesville, VA 22901, U.S.A.
[4]National Astronomical Obs., Osawa 2-chome, Mitaka, Tokyo 181, Japan
[5]Royal Observatory, Blackford Hill, Edinburgh, EH9 3HJ, Scotland

ABSTRACT. We have used the James Clerk Maxwell Telescope to observe 11 lines of SiCC with excitation energies up to 330 K above the ground state in IRC 10216. An excitation analysis indicates T_{rot} = 43 ± 5 K within a given Ka ladder and T_{exc} = 160 ± 50 K between Ka ladders. The column density of SiCC is estimated to be 3 x 10^{15}cm^{-2}, more than an order of magnitude higher than previous estimates.

1. Introduction

In 1984 Thaddeus et al. assigned nine unidentified millimetre-wavelength lines to the ring molecule SiCC in the circumstellar envelope of the carbon star IRC 10216. For transitions between levels, J_{KaKc}, characterized by the same value of Ka, they found T_{rot} = 10 K, while lines arising in different Ka ladders yielded T_{exc} = 140 K. Transitions within a Ka ladder can occur by both collisional and rapid radiative deexcitation. However, the "cross-Ka ladder" radiative transitions are only weakly permitted, so that the relative population distributions between the Ka ladders depends more strongly upon collisions. For these reasons Thaddeus et al. (1984) argued that the high cross-Ka ladder excitation temperature should reflect the kinetic temperature in the star's atmosphere.

2. Data

We report observations with the James Clerk Maxwell Telescope (JCMT) of 11 high-frequency SiCC lines in IRC 10216. The range of excitation energies covered by these new detections is from 70 K to 330 K above the ground state, considerably higher than the transitions discussed by Thaddeus et al. (1984). The data are summarized in Table 1 where S is the quantum mechanical line strength and E/k the excitation energy of the line in K (Gottlieb et al. 1989). T_R^* is the line radiation temperature corrected for both atmospheric and telescope losses, and also forward spillover and scattering. The JCMT beamwidth (FWHM) is 16 arcsec at 345 GHz and 21 arcsec at 240 GHz.

3. Analysis

We have combined our observations with the lower excitation data used by Thaddeus et al. (1984) to carry out an extended excitation analysis, using a source diameter of 20 arcsecs (Cernicharo et al. 1989). Our results confirm that a markedly different value of excitation temperature is found within a given Ka ladder compared to that between Ka ladders. For our JCMT lines we find average values of T_{rot} = 43 ± 5 K within a given Ka ladder, and 160 ±

P. D. Singh (ed.), Astrochemistry of Cosmic Phenomena, 399–400.

50 K across Ka ladders. Evaluation of the total column density, as described by Thaddeus et al. (1984), using these temperatures leads to N[SiCC] ≈ 3 x 10^{15} cm^{-2}.

TABLE 1. SiCC TRANSITIONS DETECTED

Freq (MHz)	T_R^*(K)	Transition	S	E/k (K)
232534	1.0	$10_{2,9}$-$9_{2,8}$	9.6	70
234534	0.4	$10_{8,3}$-$9_{8,2}$	3.6	187
		$10_{8,2}$-$9_{8,1}$	3.6	187
235713	0.7	$10_{6,5}$-$9_{6,4}$	6.4	132
		$10_{6,4}$-$9_{6,3}$	6.4	132
259433	0.5	$11_{6,6}$-$10_{6,5}$	7.7	145
		$11_{6,5}$-$10_{6,4}$	7.7	145
342805	0.6	$15_{2,14}$-$14_{2,13}$	14.7	141
344906	0.9	$16_{0,16}$-$15_{0,15}$	15.9	144
346110	0.75	$14_{2,12}$-$13_{2,11}$	13.7	132
350280	0.25	$15_{10,5}$-$14_{10,4}$	8.3	328
		$15_{10,6}$-$14_{10,5}$	8.3	328
352437	0.4	$15_{8,8}$-$14_{8,7}$	10.7	260
		$15_{8,7}$-$14_{8,6}$	10.7	260
354790	0.6	$15_{6,10}$-$14_{6,9}$	12.6	206
354798	0.6	$15_{6,9}$-$14_{6,8}$	12.6	206

4. Conclusions

The 11 high frequency SiCC lines we have observed in IRC 10216 permit an extended excitation analysis to be carried out. We find that the excitation temperature within a given Ka ladder is 43±5 K, considerably higher than the result of 10 K (Thaddeus et al. 1984) based on wider-beam, lower-frequency data. Population distributions between different Ka ladders correspond to T_{exc} = 160±50 K between ladders. Such values seem too high to be characteristic of kinetic temperatures, and may reflect infrared excitation of the molecule. The column density of SiCC is estimated to be 3 x $10^{15}cm^{-2}$, more than an order of magnitude higher than previous estimates.

5. References

Cernicharo, J., Gottlieb, C.A., Guélin, M., Thaddeus, P. and Vrtílek, J.M. 1989, Ap.J. **341**, L25.

Gottlieb, C.A., Vrtílek, J.M. and Thaddeus, P. 1989, Ap.J. **343**, L29.

Thaddeus, P., Cummins, S.E., and Linke, R.A. 1984, Ap.J. **283**, L45.