GAS TEMPERATURES IN ORION B NORTH

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Abstract

We present observations of two formaldehyde transitions towards 14 clumps in the Orion B North complex; the ratio of these transitions is an indicator of the kinetic temperature of the molecular gas. The spectra show narrow-line components with temperatures 20–30 K, and broader components with rather higher temperatures.

1. Introduction

Formaldehyde (H_2CO) is a slightly asymmetric rotor whose rotational ladders are linked by collision only, making it an excellent probe of the physical conditions (kinetic temperature and volume density) of high-density gas (Mangum & Wooten 1993). In particular, by observing the $J = 3 - 2$ transitions of the $K_a = 2$ and $K_a = 0$ ladders of para-H_2CO, namely $3_{0\,3} - 2_{0\,2}$ (218.2222 GHz) and $3_{2\,2} - 2_{2\,1}$ (218.4756 GHz), and taking the ratio of intensities, it is possible to find the kinetic temperature. This line ratio has the advantage that most calibration uncertainties cancel out, since the frequencies are almost identical.

2. Observations and Data Reduction

Observations were carried out at the JCMT in 2000 August and September, using receiver RxA3 and the autocorrelation spectrometer with a frequency resolution of 189 kHz or 0.26 $\mathrm{km\,s^{-1}}$. Calibration spectra were taken towards NGC 2071 IR every few hours; the peak values of gaussian fits to these spectra were consistent to $\sim 2\%$ (rms).

Fourteen clumps in Orion B were observed, as shown in Figure 1(taken from Mitchell et al. 2001), with total integration times ranging from 0.5 to 2.25 hours. The spectra (Figures 2 and 3) were reduced by subtracting polynomial baselines, and are given on the T_A^* scale, taking no account of the coupling between the telescope beam and the source size.

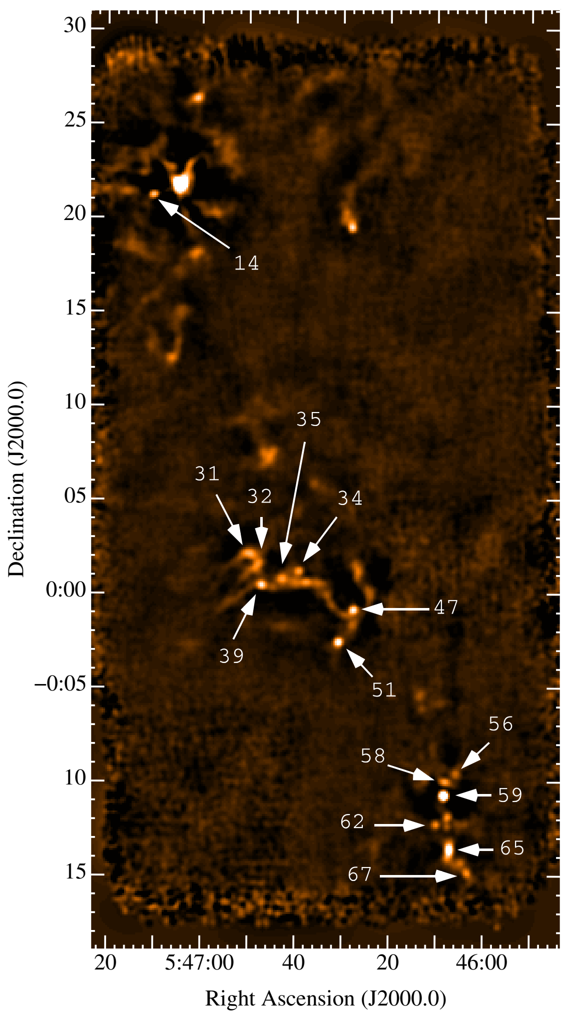

Figure 1. Map of 850 micron continuum emission from Orion B North; the clumps observed in formaldehyde are labelled — they all have the prefix OriBsmm.

3. Results and Discussion

Many of the sources have narrow (but resolved) components ($< 1\mathrm{km\,s^{-1}}$) in the 218.22 GHz line; in some cases (e.g. OriBsmm31) the line contains only a narrow component. These narrow components are largely weak or absent in the 218.48 GHz spectra, suggesting that the narrow-line emission arises in comparatively cool gas. This narrow-line emission is accompanied by weaker broad emission in many of the 218.22 GHz spectra. Despite the

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Table 1. Gaussian fits to formaldehyde spectra of all sources, ratios of fitted line peaks, and LTE temperature estimates. Most sources are represented by the sum of more than one gaussian component.

Source	Peak T_A^*/K	FWHM/km s^{-1}	Peak T_A^*/K	FWHM/km s^{-1}	Line ratio	LTE temperature/K
	$3_{2\,2} - 2_{2\,1}$		$3_{0\,3} - 2_{0\,2}$			
OriBsmm14	0.73	0.74	0.09	0.83	8.6	30
	0.26	2.88	< 0.05		> 5.2	< 45
OriBsmm31	1.30	0.53	0.16	0.47	8.3	31
OriBsmm32	1.20	0.62	< 0.09		> 12.8	< 26
OriBsmm34	0.66	0.61	< 0.05		> 13.2	< 26
	0.19	1.65	0.05	1.28	3.6	68
OriBsmm35	1.02	0.75	< 0.05		> 20.4	< 20
	0.40	1.81	0.07	1.50	5.4	44
OriBsmm39	1.09	1.41	0.13	1.17	8.3	31
OriBsmm47	0.87	0.74	< 0.04		> 20.1	< 20
	1.03	1.25	0.08	1.26	13.4	25
OriBsmm51	0.83	0.82	< 0.08		> 10.4	< 28
	0.47	6.39	0.09	6.71	5.0	47
OriBsmm56	0.43	0.65	< 0.05		> 8.6	< 32
OriBsmm58	0.77	1.35	< 0.09		> 8.7	< 30
OriBsmm59	0.61	0.80	< 0.1		> 6.1	< 39
	0.36	1.92	< 0.08		> 4.3	< 55
OriBsmm62	0.37	1.06	< 0.05		> 7.3	< 35
OriBsmm65	0.72	1.54	0.07	1.07	9.9	29
	0.31	3.86	0.12	3.42	2.6	130
OriBsmm67	0.32	0.67	< 0.1		> 3.2	< 82
	0.09	3.03	< 0.02	3.21	> 5.5	< 43

low signal-to-noise, the 218.48 GHz lines appear to be comparatively broad; it may be possible to identify these higher-frequency lines with the broad components of the 218.22 GHz transition. This would imply that the broad components arise in warmer gas, giving rise to comparatively low line ratios (218.22/218.48).

The lines can be fitted with a combination of gaussians of different FWHM. The fitted gaussians are given in Table 1, together with the estimated line ratios and hence kinetic temperatures. Eight of the sources can be fitted by the sum of two gaussians in the 218.22 GHz transition, while the other 6 are well-fitted by single gaussians. In the 218.48 GHz transition, only one source (OriBsmm65) can be fitted with two gaussians, but 8 of the rest can be fitted with single gaussians; these single components can be identified with components in the lower-frequency line with similar linewidths. For those lower-frequency line components that cannot be identified with higher-frequency fits, upper limits to the the 218.48 GHz emission can be estimated from the spectra. The line ratio is given by the ratio of the fitted peak antenna temperatures, and the derived temperatures are based on the LTE solutions tabulated in Table 4 of Mangum & Wooten 1993; we suggest that they are accurate to about 5K.

These temperature estimates and limits bear out the qualitative analysis above — the narrow line components have temperatures of about 20–30 K, while the higher temperatures are confined to the broader components.

4. Implications for FIRST

A key focus for FIRST science will be the characterisation of clumps within the interstellar medium by their far-infrared spectral energy distribution, usually modelled by a single-temperature greybody. These formaldeyde results show that there are multiple temperature components present within a 20″ beam. It will therefore be necessary to use multiple-temperature greybody fits. Ground-based observations of formaldehyde and similar molecules may be very useful in constraining the temperature structure of the gas, although the temperature coupling between gas and dust is expected to be density-dependent.

Acknowledgements

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References

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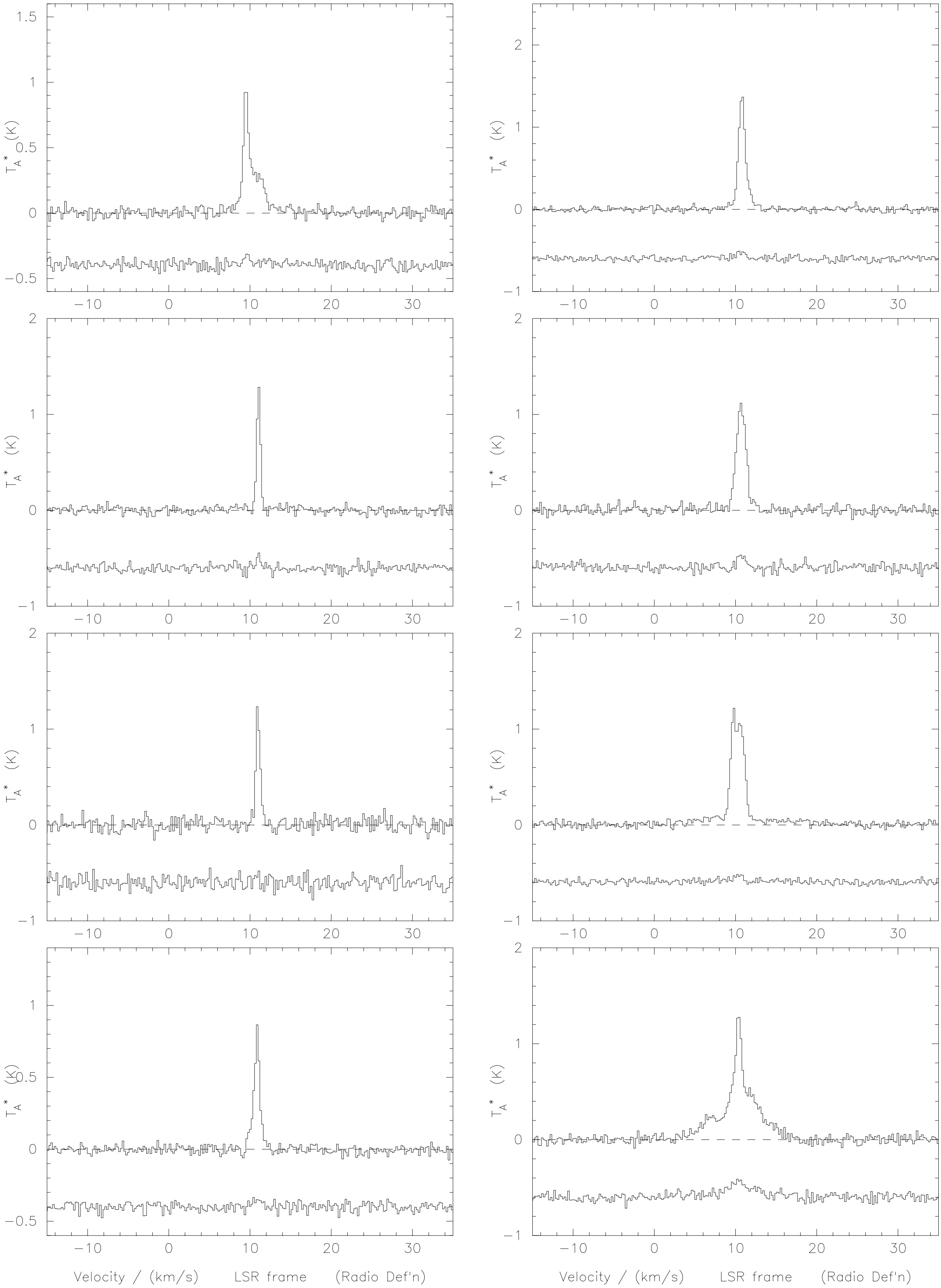

Figure 2. H_2CO spectra towards target clumps in NGC 2071 and 2068. Each spectrum shows the relatively strong 218.2222 GHz line and the 218.4756 GHz line offset below it. The clumps are: Left (top to bottom) — OriBsmm14, 31, 32, 34; Right (top to bottom) — OriBsmm35, 39, 47, 51.

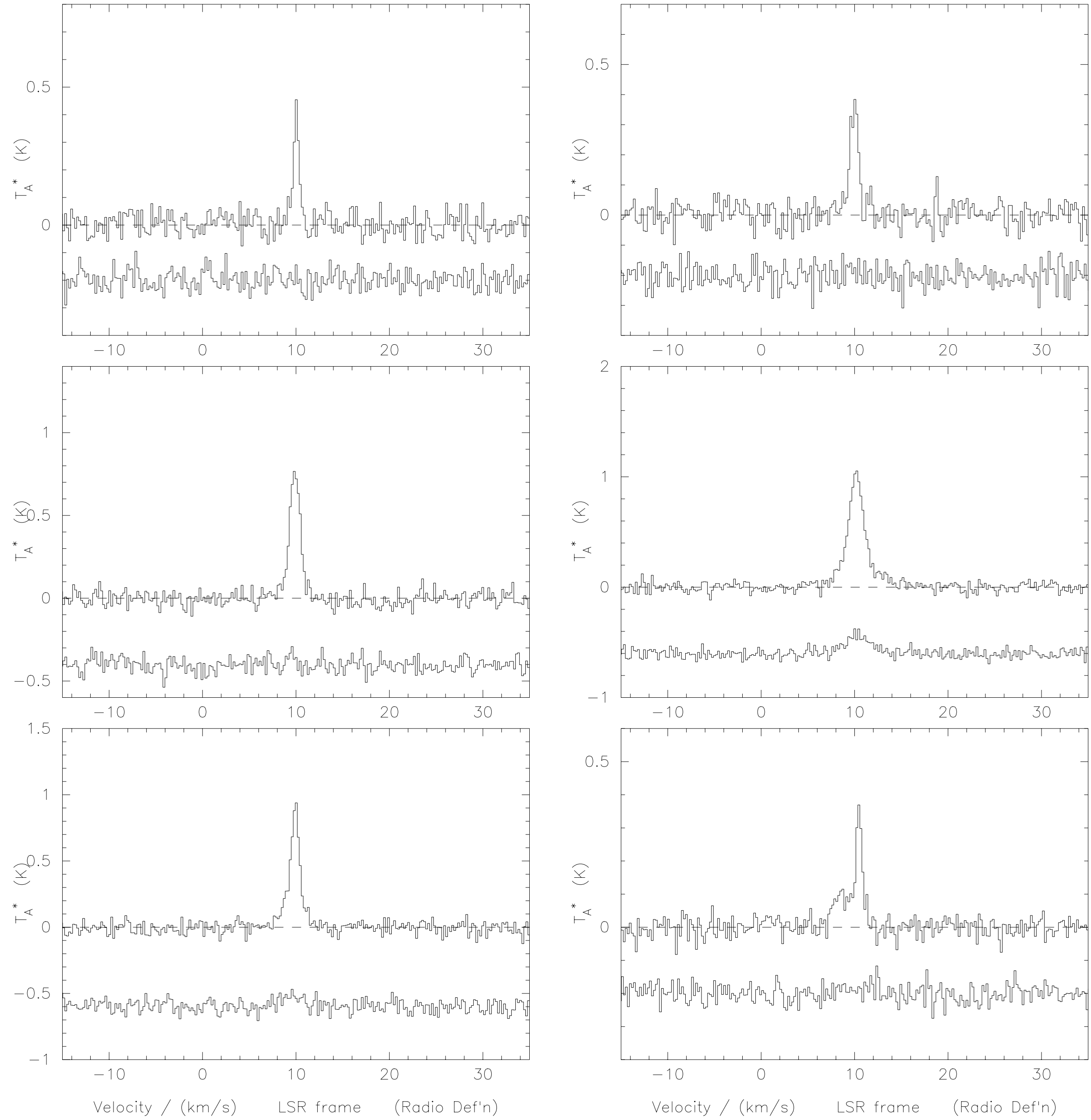

Figure 3. As Fig 2 for target clumps in the HH24–26 region. The clumps are: Left (top to bottom) — OriBsmm56, 58, 59; Right (top to bottom) — OriBsmm62, 65, 67.