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Detection of the 3_1–3_1(A) Transition of Methanol in Sagittarius B2

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Abstract

The 3_1–3_1 A-branch transition of methanol has been observed in emission in Sgr B2. A laboratory determination of the rest frequency of 5005·32 MHz indicates that the radial velocity of the line in Sgr B2 is 57 km s^{-1}.

Introduction

Methanol (CH_3OH) and formaldehyde (H_2CO) are likely to be the most useful molecules for studying the excitation of interstellar molecules and for probing the density and temperature of the dense molecular clouds. Transitions of methanol have been detected at over 20 wavelengths spanning the range from λ = 36 cm to 1·8 mm (see the summary in Fig. 1 of Kutner *et al.* 1973). Because of the large number of transitions observed, the rotational excitation of methanol could be determined better than that of any other interstellar molecule.

Millimetre-wave observations show that the kinetic temperatures T_K of dense molecular clouds are low, in the range 5–90 K. For collisional excitation we would expect the rotational excitation temperatures to be less than or equal to T_K. The molecules should then be seen in absorption at long wavelengths, where the background continuum temperature of the associated HII regions greatly exceeds the measured values of T_K. However, most molecules detected at long wavelengths are seen in emission against the hot continuum background. The only exceptions to this are OH, CH (Robinson *et al.* 1974), H_2CO and H_2CS. The emission seen in all other molecules has provoked suggestions that the energy levels are inverted and that maser amplification is occurring (see Gottlieb *et al.* 1973; Fourikis *et al.* 1974). Confirmation of these suggestions has been lacking because the excitation of linking steps on the rotational ladder is unknown.

Because so many millimetre-wave transitions of methanol can be observed, it appears to be an excellent candidate for the study of the excitation of the long-wave *K*-doublet transitions. Ball *et al.* (1970) have observed the 1_1–1_1 A-branch transition of methanol (λ = 35·9 cm) in emission in Sgr B2 and Sgr A. We report here the detection of the 3_1–3_1 A-branch transition at λ = 6·0 cm in emission in Sgr B2.

Determination of Rest Frequency

The rotational spectrum of methanol has been studied in detail by Lees *et al.* (1972). They calculated that the rest frequency of the 3_1–3_1 A-branch transition would be $5005 \cdot 37 \pm 0 \cdot 5$ MHz. During the present work, the rest frequency was measured at Monash University in a conventional microwave absorption cell, and the result obtained was $5005 \cdot 32 \pm 0 \cdot 01$ MHz.

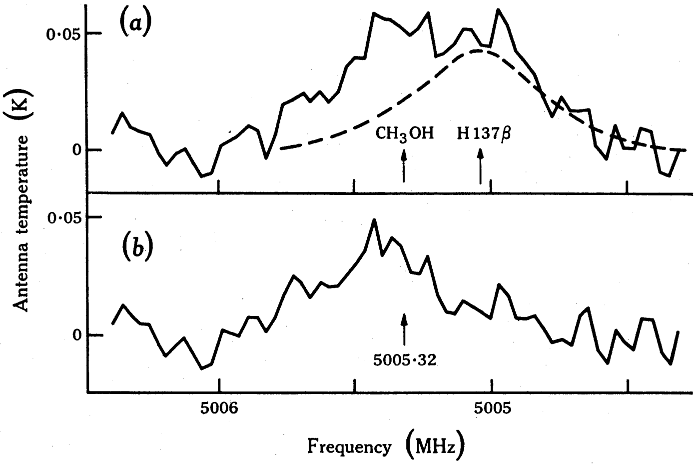

Fig. 1. Showing (*a*) the observed spectrum of Sgr B2 near 5005 MHz, with the broad profile formed by a blend of the 3_1–3_1 A-branch transition of methanol at 5005·32 MHz and H 137β at 5005·033 MHz, superimposed with the expected H 137β profile (dashed curve) scaled from that of H 109α with 20% of its intensity; and (*b*) the result of subtracting the expected H 137β profile in (*a*) from the measured points. The frequency scale is labelled with the rest frequencies corresponding to a radial velocity of the Sgr B2 molecular cloud of 62 km s^{-1}. The 3_1–3_1 A-branch transition of methanol remaining in (*b*) is displaced to lower velocity by about 5 km s^{-1} (80 kHz).

Astronomical Observations

Observations of Sgr B2 were made in November 1972 with the Parkes 64 m telescope equipped with a 6 cm cryogenic parametric amplifier (system noise 90 K) and a 64-channel spectrometer with a filter bandwidth of 33·0 kHz.

The methanol line at 5005·32 MHz is adjacent to the H 137β recombination line at 5005·033 MHz. The measured profile of Sgr B2, displayed in Fig. 1*a*, shows a very broad line which is a blend of the 3_1–3_1 methanol line and H 137β. Gardner *et al.* (1970) have studied the H 137β line in many HII regions and have shown that the intensity ratio of H 137β to H 109α ranges from 0·10 to 0·28, with an average value of 0·2. To remove the H 137β line from Fig. 1*a*, therefore, we measured the H 109α line (ν = 5008·923 MHz) in Sgr B2 and then drew the dashed curve in this figure with the same width as the H 109α line and 20% of its intensity, centred on the frequency of H 137β. When this curve is subtracted from the observed profile in Fig. 1*a* we are left with the profile shown in Fig. 1*b*, with a width equivalent to 27 km s^{-1}. The frequency scale has been drawn on the assumption that the radial velocity of the molecular cloud in Sgr B2 is 62 km s^{-1}. Although the signal to noise ratio is low, the profile in Fig. 1*b* appears to be higher in frequency than 5005·320 MHz by about 80 kHz. Such a displacement would put the radial velocity of the line at 57 km s^{-1}. This is consistent with the low velocity (54 km s^{-1}) found for the 1_1–1_1 A-branch emission in Sgr B2, as discussed by Radford (1972). Barrett *et al.* (1972) also infer that the 1_0–0_0 A-branch transition of methanol in Sgr B2 occurs at a velocity of about 55 km s^{-1}.

The 3_1–3_1 A-branch transition was not seen in Sgr A ($T_a < 0 \cdot 08$ K) although Ball *et al.* (1970) found the 1_1–1_1 A-branch line in emission in that source.

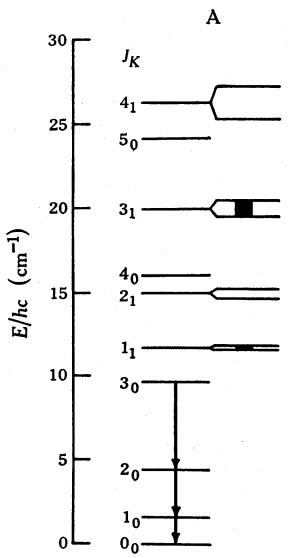

Fig. 2. Lowest energy levels of the A branch of methanol. The observed centimetre-wave transitions are shown by bars and the millimetre-wave transitions by arrows.

Discussion

The lowest A-branch energy levels of methanol are shown in Fig. 2, with the lines observed to date marked by bars and arrows. Despite the large number of millimetre-wave lines of methanol detected (see Kutner *et al.* 1973), very few have been A-branch transitions. Before significant progress can be made in understanding the excitation of the centimetre-wave transitions, observations are required of the $3_1 \rightarrow 2_1$ transitions at $\lambda = 2$ mm and the $2_1 \rightarrow 1_1$ transitions at $\lambda = 3$ mm. (The $3_1 \rightarrow 2_1$ A-branch lines were at the ends of the range searched by Kutner *et al.* but were not detected by them.) It would also be valuable to have observations of the 2_1–2_1 doublet at $2502 \cdot 86$ MHz (Lees *et al.* 1972).

Acknowledgments

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