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


^ Division of Radiophysics, CSIRO, P.O. Box 76, Epping, N.S.W. 2121.
^ Department of Chemistry, Monash University, P.O. Box 92, Clayton, Vic. 3168.

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$_3$OH) and formaldehyde (H$_2$CO) 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 $\lambda = 36$ 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$_2$CO and H$_2$CS. 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 ($\lambda = 35.9$ cm) in emission in Sgr B2 and Sgr A. We report here the detection of the $3_1-3_1$ A-branch transition at $\lambda = 6.0$ 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 5005.37 ± 0.5 MHz. During the present work, the rest frequency was measured at Monash University in a conventional microwave absorption cell, and the result obtained was 5005.32 ± 0.01 MHz.

![Graph showing observed spectrum of Sgr B2](image)

Fig. 1. Showing (a) the observed spectrum of Sgr B2 near 5005 MHz, with the broad profile formed by a blend of the 3₁−3₁, A-branch transition of methanol at 5005.32 MHz and H137β at 5005.033 MHz, superimposed with the expected H137β profile (dashed curve) scaled from that of H109α with 20% of its intensity; and (b) the result of subtracting the expected H137β 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 3₁−3₁, 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 H137β recombination line at 5005.033 MHz. The measured profile of Sgr B2, displayed in Fig. 1a, shows a very broad line which is a blend of the 3₁−3₁ methanol line and H137β. Gardner et al. (1970) have studied the H137β line in many HII regions and have shown that the intensity ratio of H137β to H109α ranges from 0.10 to 0.28, with an average value of 0.2. To remove the H137β line from Fig. 1a, therefore, we measured the H109α line (ν = 5008.923 MHz) in Sgr B2 and then drew the dashed curve in this figure with the same width as the H109α line and 20% of its intensity, centred on the frequency of H137β. When this curve is subtracted from the observed profile in Fig. 1a we are left with the profile shown in Fig. 1b, 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. 1b 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 1₄−1₄, A-branch emission in Sgr B2, as discussed by Radford (1972). Barrett et al. (1972) also infer that the 1₀−0₀, A-branch transition of methanol in Sgr B2 occurs at a velocity of about 55 km s⁻¹.
The $3_{1} \rightarrow 3_{1}$ A-branch transition was not seen in Sgr A ($T_{a} < 0.08$ K) although Ball et al. (1970) found the $1_{1} \rightarrow 1_{1}$ A-branch line in emission in that source.

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 $2_{1} \rightarrow 2_{1}$ doublet at 2502.86 MHz (Lees et al. 1972).

Acknowledgments

The authors wish to acknowledge the assistance of Mr. J. G. Crofts in making the laboratory measurement of the methanol line. The microwave spectroscopy at Monash University is supported by the Australian Research Grants Committee.

References


Manuscript received 15 August 1974