THE CN MOLECULE
AND
THE COSMIC BACKGROUND RADIATION TEMPERATURE

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We have remeasured the rotational temperature of the CN molecule ground state in the direction of the star ζ Ophiuchi using the ESO 1.4 meter CAT telescope and associated Coudé Echelle Spectrograph. These measurements determine: a) a very precise value of cosmic background radiation (CBR) temperature at λ2.64 mm, b) a new value for the intrinsic line width of the CN absorption lines, and c) a measure of the CBR temperature at λ1.32 mm. We present each of these results briefly here and refer the reader to the paper of Crane et al. (1986) for further details of our results and to the review of Thaddeus (1972) and the paper of Meyer and Jura (1985) for more details of the technique.

The intrinsic linewidth of the observed absorption lines is an important parameter in determining the relative number of molecules in the various rotational levels. This linewidth is used to determine the degree of saturation of the lines and hence the true relative state populations. We have observed the absorption lines in the B $^2\Sigma^+$ - X $^2\Sigma^+$ system of the CN molecule at 3875 Å with a spectral resolution of up to 156,000 (see Figure 1). The observed lines had a measured width (FWHM) of 31.8±0.3 mÅ and the instrumental width (FWHM) was 24.8±0.3 mÅ. This allowed us to determine the intrinsic linewidth of the R(0) line of 19.0±0.5 mÅ (Crane et al., 1986). This value is substantially smaller than the value of 28 mÅ determined previously (Hegyi et al., 1972) and implies a change in the final CBR temperature of -0.05°K compared to that which would be found using 28 mÅ. We believe the value presented here is to be preferred.

The CBR temperature at λ2.64 mm can be determined from the relative strength of the R(1) or P(1) line to the R(0) line of the CN rotational levels. The ratios of the observed equivalent widths of the lines, corrected for saturation using the linewidth information, provide a measure of the excitation temperature of the CN levels. This temperature corresponds to the CBR temperature only if there are no local mechanisms in the observed interstellar cloud which can also excite the rotational levels. In the ζ Oph cloud, electron collisions appear to be the only local excitation mechanism (Thaddeus, 1972). Estimating the electron density and calculating the collisional excitation rate, this mechanism could excite the CN levels by 0.06±0.04°K (Meyer and Jura, 1985). Table 1 summarizes our CN measure of the CBR at λ2.64 mm. The final CBR temperature from the data in Table 1 is T_{CBR} = 2.74±0.05°K. We note that the uncertainty is dominated by the electron excitation uncertainty (0.04°K) and not by the errors in the optical absorption lines (0.025°K).

The value for the CBR temperature at λ2.64 mm derived here should be compared to the longer wavelength microwave radiometer measurements of the CBR temperature of 2.73±0.04°K (Smoot et al., 1985) and to the balloon bolometer measurements of 2.78±0.11°K (Peterson et al., 1985) at wavelengths of λ3.5 mm to λ 1.0 mm. Analyzing the equivalent widths of Meyer and Jura (1985) for ζ Oph using our saturation correction yields T_{CBR} = 2.61±0.05°K. We believe our results are more likely correct since they were obtained at higher resolution and through smaller air masses.

In addition to the CBR temperature at λ2.64 mm, the CN rotational levels are also sensitive to the CBR temperature at λ1.32 mm. The ratio of the R(2) line to either the R(1) or P(1) line of the absorption system discussed previously yields a measure of the CBR temperature after correction for saturation. Unfortunately, the R(2) line is very weak and has so far only been detected with large errors. Table 2 summarizes our result for the CBR temperature at λ1.32 mm. In this case, no correction for electron collisions is needed. Our final value in this case is T_{CBR} = 2.75 (+0.24; -0.29) °K.

The CN technique for determining the CBR temperature yields extremely precise values at specific wavelengths. Since the technique is so different from the microwave radiometer and bolometer experiments, it serves both to verify and to strengthen these results. Future work should provide improvements in the CN results at both λ1.32 mm and λ 2.64 mm.

References

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Table 1. Summary of CN Results at λ2.64 mm

Lines	Equivalent Widths (mÅ)	T	ΔT_{sat}	ΔT_{elec}	T_{CBR}
$\frac{R(1)}{R(0)}$	$\frac{2.420\ (51)}{7.646\ (91)}$	2.956 (31)	-0.159 (3)	-0.060 (40)	2.737 (50)
$\frac{P(1)}{R(0)}$	$\frac{1.254\ (67)}{7.646\ (91)}$	3.015 (71)	-0.197 (3)	-0.060 (40)	2.758 (82)

Table 2: Summary of CN Results at λ1.32 mm

Lines	Equivalent Widths (mÅ)	T	ΔT_{sat}	T_{CBR}
$\frac{R(2)}{R(1)}$	$\frac{0.072\ (26)}{2.420\ (51)}$	2.78 (+0.26; -0.30)	-0.03	2.75 (+0.25; -0.29)
$\frac{R(2)}{P(1)}$	$\frac{0.072\ (26)}{1.254\ (67)}$	2.75 (+0.27; -0.31)	-0.01	2.74 (+0.27; -0.30)

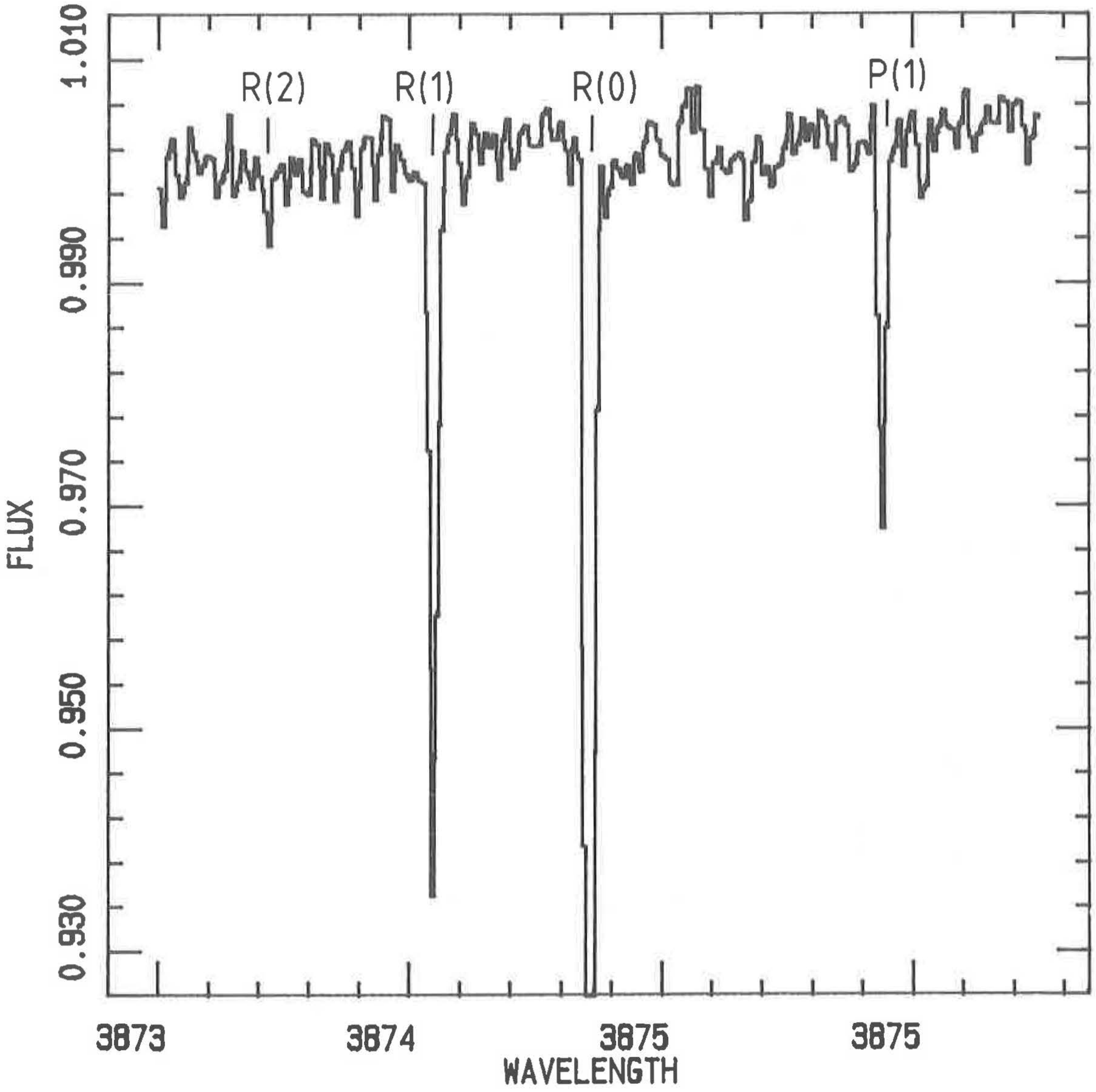

Figure 1. CN spectrum showing lines at the observed wavelengths. This is a single night of data representing 3.5 hours of observations. The R(0) line depth is 0.785.