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THE IDENTIFICATION OF THE (0,0) AND (1,0) BANDS OF THE CN RED SYSTEM IN THE SOLAR SPECTRUM

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The Identification of the (0,0) and (1,0) Bands of the CN Red System in the Solar Spectrum

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ABSTRACT—A comparison has been made of the wavelengths of the rotational lines in the (0,0) and (1,0) bands of the CN red system produced in the laboratory with the tabulated wavelengths of lines in the solar spectrum in the neighbourhood of 11,000 A and 9200 A respectively. Some 38 coincidences were established between CN lines and previously unidentified lines of solar or terrestrial origin.

RÉSUMÉ—Nous avons établi une comparaison entre les longueurs d'onde des raies rotationnelles des bandes (0,0) et (1,0) du système rouge CN observé au laboratoire et les longueurs d'onde classées du spectre solaire dans le voisinage de 11,000 A et 9200 A respectivement. Quelque 38 coïncidences ont été établies entre les raies CN et des raies non encore identifiées d'origine solaire ou terrestre.

Introduction

The electronic transition $A^2\Pi - X^2\Sigma$ of the CN molecule produces a system of vibration-rotation bands covering the spectral range from 0.6 to 1.5μ. The most intense bands of this red system are located between 0.7 and 1.0μ but owing to technical difficulties they have scarcely been studied either in solar or stellar spectra. Improved infrared-sensitive emulsions now make it possible to photograph the red system at high spectral resolution. Since the presence of CN is well established in comets, planets, carbon stars, and the sun, a study of the rotational line structure of these bands covers a wide range of astrophysical interests.

Accordingly, spectra at high dispersion were obtained with a grating spectrograph and a laboratory source of CN of the (0,0) and (1,0) bands of the red system, covering the spectral range from 9140 to 11,550 A. A rotational analysis has been carried out on the two bands and these results, including wavelengths and provisional rotational constants, have been published elsewhere (Rigutti 1959). In the present paper the spectrum of the red bands produced in a laboratory source is compared with the tables of lines in the infrared solar spectrum by Babcock and Moore (1947) and previously unidentified lines of solar or terrestrial origin are assigned to the CN molecule.

Observations

The laboratory source of the CN red bands was a D.C. electric arc using carbon or graphite electrodes, either 6mm. or 12 mm. in diameter, operated in air with a current of 7 amperes. A comparison spectrum was obtained with an iron arc operated in air with a D.C. current of 3.5 amperes.

The spectrograph employs a plane reflection grating (ruled 14,400 lines per inch over an area 3 in. x 5 in.) in a modified Littrow mounting with camera and collimator mirrors of 20 foot focal length. The (0,0) band was photographed in the second order with a dispersion of 1.14 A/mm., while the (1,0) band was photographed in the third order with a dispersion of 0.61 A/mm. Nine spectrograms of the (0,0) band were taken on Kodak IZ plates hypersensitized in ammonia, with exposures ranging from 40 to 60 minutes. Four of the nine spectrograms were useful for wavelength measurements. For the (1,0) band ten spectrograms were taken on Kodak IM plates hypersensitized in ammonia, with exposure times ranging from 20 to 60 minutes. Five of the ten spectrograms were useful for wavelength measurements. Glass filters were used to isolate the appropriate orders of the grating: Corning 2540 for the (0,0) band; Corning 5031 and 2030 for the (1,0) band. A slit width of 70 μ was used for all the spectrograms.

No intensity calibration of the plates was attempted because it was found that the intensity of the CN lines depended strongly on the composition and condition of the electrodes in the arc source.

Wavelength measurements were made with a two stage Mann comparator at the Dominion Observatory. The wavelengths for the iron comparison spectrum were taken from the M.I.T. tables (Harrison 1939).

Results and Discussion

Examples of the spectrograms of the (0,0) and (1,0) bands are shown in Figure 1 and Figure 2 respectively. The results are presented in Tables 1 and 2 in which laboratory data are shown on the left and solar data from the tables of Babcock and Moore (1947) are on

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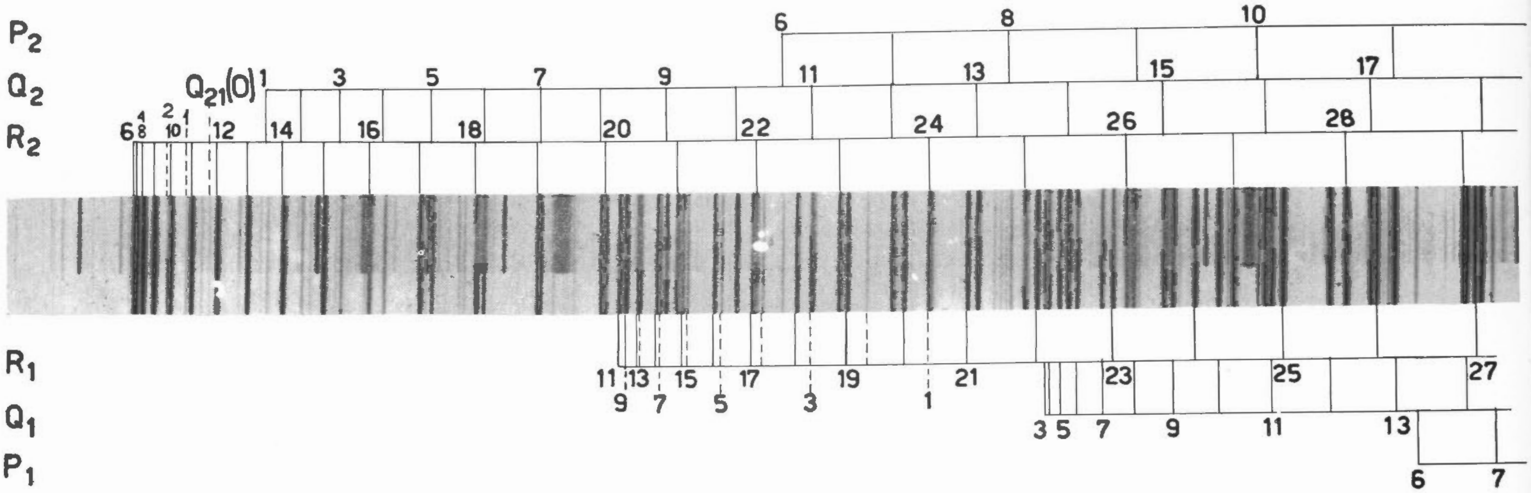

Figure 1. The first part of the (0,0) band of the CN red system in emission from a laboratory source. The R_2 head is at 10925.547 A. Enlargement 2x.

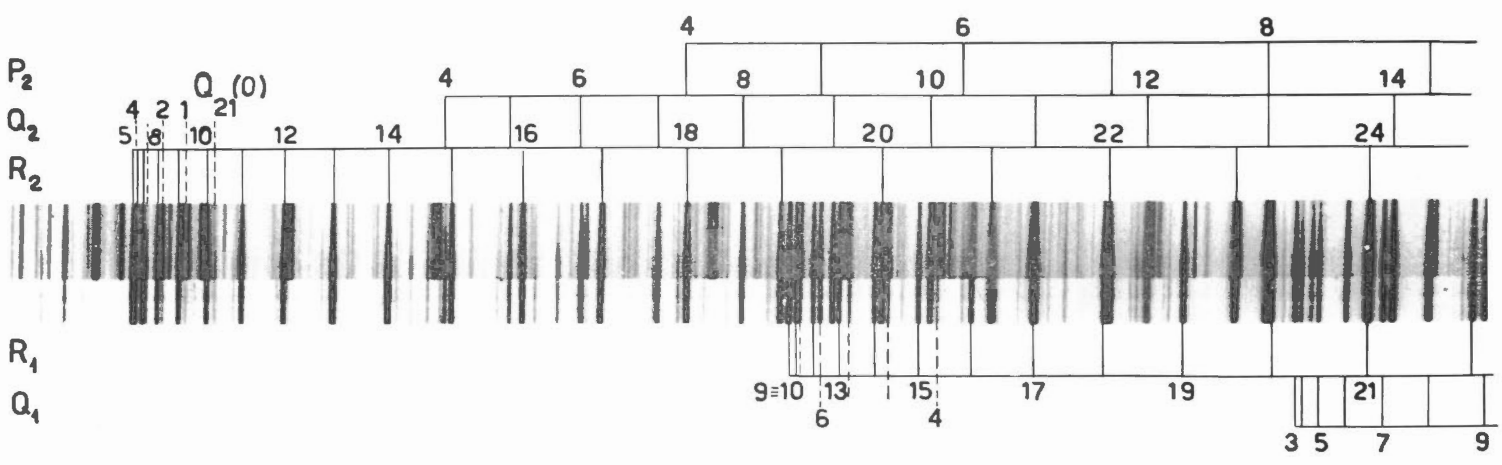

Figure 2. The first part of the (1,0) band of the CN red system in emission from a laboratory source. The R_2 head is at 9140.572 A. Enlargement 2x.

TABLE 1. $A^2\Pi$-$X^2\Sigma$ (0,0) BAND OF CN COMPARED TO THE SOLAR SPECTRUM

Rotational Quantum Numbers						Laboratory		Sun		Sun—Lab. A	Identification by Babcock and Moore (1947)
R_1	R_2	Q_1	Q_2	P_1	P_2	Wave number in vacuum, cm^{-1}	Wavelength in air A	Wave-length A	Disk Int.		
	10					9147.960	10928.405	10928.43	0N	+ 0.025	⊙
	11					9146.603	10930.026	10930.06	−3N	+ 0.034	Cr. Atm?
	12					9144.920	10932.038	10932.06	−2	+ 0.022	Atm
			2			9139.370	10938.677	10938.68	2NN	+ 0.003	Atm
	17					9131.679	10947.890	10947.88	1	− 0.010	Atm
			5			9130.893	10948.832	10948.85	−3	+ 0.018	⊙
	20					9119.693	10962.279	10962.30	3ns	+ 0.021	Mg?
10, 11						9118.719	10963.449	10963.48	−1	+ 0.031	⊙
8						9117.394	10965.043	10965.03	−1	− 0.013	⊙
			9			9115.709	10967.069	10967.08	−3	+ 0.011	—
16						9112.611	10970.798	10970.80	−3	+ 0.002	—
	22					9109.982	10973.965	10973.97	−1NN*	+ 0.005	⊙
18						9107.321	10977.170	10977.18	5nl	+ 0.010	Atm
21						9106.424	10990.321	10990.34	−2	+ 0.019	Atm
		6				9089.477	10998.720	10998.74	−2	+ 0.020	—
		7				9087.893	11000.637	11000.63	−2	− 0.007	—
			15			9083.949	11005.414	11005.42	−1	+ 0.006	—
		9				9083.408	11006.069	11006.08	−2	+ 0.011	Atm?
25						9076.431	11014.529	11014.56	−3	+ 0.031	—
		15				9059.736	11034.827	11034.80	0N	− 0.027	⊙
			19			9056.343	11038.961	11038.95	12	− 0.011	Atm
		17	20			9048.569	11048.445	11048.44	1N	− 0.005	⊙
			22			9032.104	11068.586	11068.57	−2	− 0.016	⊙
		20				9028.808	11072.626	11072.64	−2	+ 0.014	Atm
		21				9021.440	11081.669	11081.65	−2N	− 0.016	⊙
					19	8992.074	11117.859	11117.86	4	+ 0.001	Atm
			28			8974.322	11139.853	11139.84	3	− 0.013	Atm
			29			8963.460	11153.351	11153.33	−3	− 0.021	⊙
					22	8957.590	11160.661	11160.65	(75)	− 0.011	Atm
				22		8938.321	11184.720	11184.69	−3	− 0.030	—
				25		8902.620	11229.573	11229.60	−2	+ 0.027	⊙
			35			8890.918	11244.353	11244.36	0	+ 0.007	Ti

*Sunspot line; absent from disk.

TABLE 2. $A^2\Pi$-$X^2\Sigma$ (1,0) BAND OF CN COMPARED TO THE SOLAR SPECTRUM

Rotational Quantum Numbers		Laboratory		Sun		Sun—lab. A	Identification by Babcock and Moore (1947)
Q_1	Q_2	Wave number in vacuum, cm^{-1}	Wavelength in air A	Wave-length A	Disk Int.		
	8	10906.437	9166.381	9166.39	−3	+0.009	Fe?
	9	10901.895	9170.200	9170.17	−3	−0.030	⊙?
	13	10880.399	9188.317	9188.346	−3	+0.029	⊙
10		10866.280	9200.256	9200.23	−3	−0.026	⊙
	22	10811.122	9247.195	9247.19	−3	−0.005	⊙

the right. The rotational quantum numbers of the lines as assigned in the laboratory analysis are entered under the headings for the various branches. It should be noted that the tables of Babcock and Moore are now under revision at the National Bureau of Standards but wavelengths longer than 6600 A will not be changed (Moore-Sitterly 1961).

The wavelengths of 569 lines were measured in the two CN bands: 322 in the (0,0) and 247 in the (1,0) band. Two criteria were used in identifying these lines with lines in the solar tables. First, lines were retained only if the differences in wavelength "sun-lab" were $|\Delta\lambda| \leq 0.03$ A, disregarding their previous identification by Babcock and Moore (1947). Second, lines were rejected if the relative intensities did not correspond to the rotational intensity distribution computed for a $A^2\Pi - X^2\Sigma$ band at the temperature of the photosphere, with due allowance made for the spectrographic resolution in the solar spectrum.

As shown in Tables 1 and 2, only 38 CN lines are attributed to the solar spectrum. This small number can be easily explained. First of all, weak solar lines (such as those due to CN) might escape detection altogether. Then, the combined errors in the laboratory and solar wavelengths might in some cases exceed the adopted limit of 0.03 A. The criterion of rejecting lines according to their relative intensities was strictly applied and eliminated many lines which fulfilled the condition $|\Delta\lambda| \leq 0.03$ A. However, some error might arise because the expected intensity distribution of the CN lines might be altered in the solar spectrum. For example, blends with other solar lines may cause intensity distortions. Finally, the region of the solar spectrum under examination is crowded with many atmospheric lines which are often intense; the CN lines, on the other hand, are very weak.

The identifications given in this paper can be regarded with confidence for the majority of them satisfy simultaneously both criteria described above. Some doubts can however be advanced for the CN lines coinciding with strong lines assigned by Babcock and Moore to atmospheric absorption. In these cases the lines satisfy the condition $|\Delta\lambda| \leq 0.03$ A only and it is assumed that those atmospheric lines mask the solar lines. This is quite possible and for this reason they are retained in the list.

Acknowledgments

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