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THE PRESENCE OF C_2 LINES IN SUNSPOTS*

YUN, HONG SIK
Department of Astronomy, Seoul National University, Seoul, Korea
AND
H. A. BEEBE AND W. E. BAGGETT
Department of Astronomy, New Mexico State University
Las Cruces, New Mexico, U.S.A.

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ABSTRACT

High spatial and spectral resolution observations have been made over a sunspot (SPO 6403) with the Echelle Spectrograph at the Vacuum Tower Telescope, Sacramento Peak Observatory. Our observed spectra, scanned with SPO's fast microdensitometer, clearly show strengthening of C_2 lines in the penumbra relative to the photosphere and much weakening in the umbra in agreement with the predictions made by our molecular equilibrium calculations (Lee *et al.* 1981).

I. INTRODUCTION

Since the possible presence of C_2 lines in sunspots, especially in sunspot umbrae, was questioned by Branch (1969) and later Schadee (1970), considerable discussion has been generated by several workers as to whether or not the C_2 lines are indeed present in sunspots. Wöhl (1971, 1972) found the existence of the C_2 lines in his umbral spectra, but his claim was discredited by Lambert and Mallia (1973) on the ground that his analysis was based primarily on statistical procedures without any serious check with line identifications. Harvey (1972) also noted some positive evidence for the presence of C_2 lines in sunspots. However, he found sufficient cases which led him to conclude that the C_2 lines might very well be entirely absent. Finally, Lambert and Mallia (1973) summed up in their study by mentioning that C_2 lines are not detectable in umbral spectra.

These conflicting reports concerning the presence of the C_2 lines in sunspots suggest that it would be very instructive and desirable to make a careful analysis of high resolution spectra of sunspots with the Echelle Spectrograph at the Vacuum Tower Telescope, Sacramento Peak Observatory. We made such an attempt by placing a slit extending across umbral and penumbral regions of a sunspot (SPO 6403). In the present work we concentrated on a pair of C_2 lines at 5150.563Å and 5150.674Å.

The purpose of this paper is to show observational evidence for the presence of C_2 lines in sunspots. In the next sections we describe briefly the observations along with reduction procedures used to present the profiles of our observed C_2 lines. Finally, a brief discussion will be made of our results.

II. OBSERVATIONS AND REDUCTION PROCEDURES

Observations of high resolution spectra of C_2 lines have been made with the Echelle Spectrograph at Sacramento Peak Observatory in December 1981. High quality seeing prevailed on 9 December and we concentrated on a round single spot (SPO 6403). The spot was located near disk center and had an umbral diameter of approximately 15 arc sec.

We followed exactly the same observing procedures as in our earlier observing runs (Yun

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et al. 1980); namely, we observed disk center and the sunspot, including several frames in which the spot was blocked by an opaque wedge. The blocked spot frames were used to estimate scattered light in the spectrograph. Calibrations were made of the film rolls by employing a neutral density filter step wedge before and after each sequence.

Our spectra were taken in the 44th order, which yielded a dispersion of 9.5mm/Å on a 70mm film (Film type 2415). Throughout the observations the slit width was set at 200μm, and the exposures were made at 4 s, 8 s and 16 s. For the purpose of the present analysis the frames made at the 16 s exposure time were found to be properly exposed.

The observed spectra were scanned by the SPO fast microdensitometer and the collected data were stored on tapes for the subsequent data reductions at New Mexico State University. Before scanning the spectra, each frame in the spectral region near 5150Å was visually inspected to select the frame of the best image quality. Starting from the outer penumbral boundary and working toward the umbra, we made 136 scans for each frame with a separation of approximately 100 μm, which corresponds to about $\frac{1}{3}$ arc sec in spatial direction. These 136 scans completely covered the spot and went well into the surrounding photosphere. The same technique was repeated in scanning the blocked spot frame. Conversion of the density data to relative intensities was carried out by fitting average denisty level on the step wedge frame to a characteristic curve, which yielded relative intensity information. (See Yun *et al.* (1980) for further details.)

III. RESULTS AND DISCUSSIONS

Figure 1 shows the reduced profiles of our observed C_2 lines sampled over approximately $\frac{1}{3}'' \times \frac{1}{3}''$ spot (75 mm spot at the film plane) in the non-spot, the penumbral, the umbra-penum-

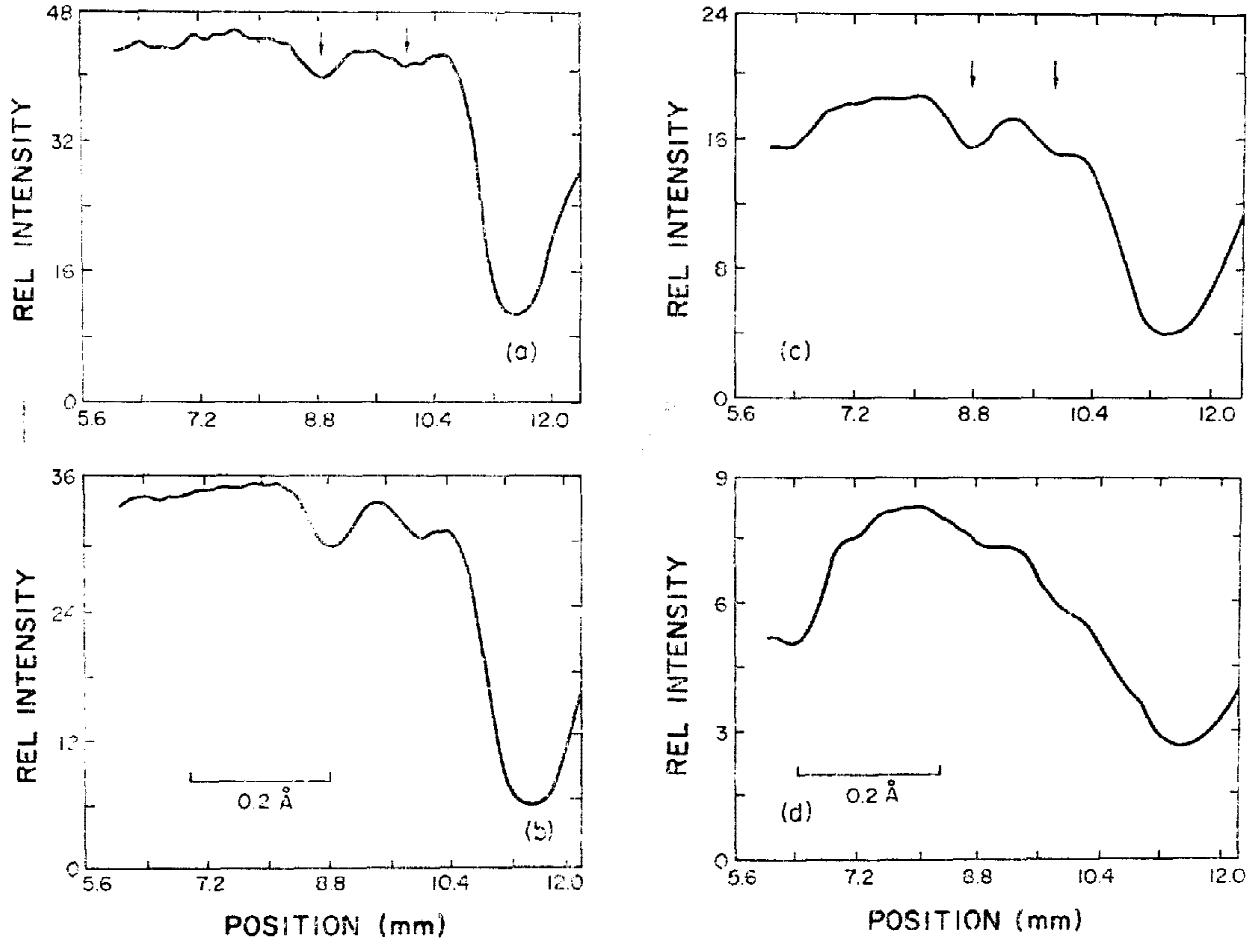

Fig. 1. - Reduced profiles of observed C_2 lines sampled over the non-spot (a), the penumbra (b), the umbra-penumbra boundary (c) and the umbra (d) of the sunspot (SPO 6403). The arrows indicate the locations of the observed C_2 lines.

bra boundary and the umbral regions, respectively. The raw data were smoothed by taking three point running means.

As can be seen from the figure, it is quite evident that the C_2 lines are present both in the umbra and the penumbra although the umbral lines are much weaken relative to the photosphere and severely blended by the neighboring Fe I λ5150.85 line. The strengthening of the C_2 lines in the penumbra is also noted, in agreement with the prediction made by our earlier molecular equilibrium calculations (Lee *et al.* 1981). In order to present a rough measure on the strength of the intensity of the C_2 λ5150.56 in the four different spatial regions, we normalized the observed profiles by the neighboring maximum intensity. The resulting rough estimates on the strength of the lines are listed in Table 1.

Table 1 ESTIMATES OF THE STRENGTHS OF THE LINE CENTER(C_2 λ5150.56) FOR FOUR REGIONS OF THE SUNSPOT SPO 6403*

Umbra	Umbra-Penumbra	Penumbra	Non-spot
~0.88	~0.84	~0.80	~0.83

* The central intensities are normalized to the neighboring maximum intensity, respectively.

IV. SUMMARY AND CONCLUSION

Observations of high resolution spectra of C_2 lines λ5150.53 and λ5150.67 have been made over a sunspot (SPO 6403) with the Echelle Spectrograph at the Vacuum Tower Telescope, Sacramento Peak Observatory on 9 December 1981.

The observed spectra were scanned by the SPO fast microdensitometer and the collected data have been converted into relative intensities. Some 130 profiles have been reduced, starting from the outer penumbral boundary and working toward the umbra with a separation of approximately $\frac{1}{3}$ arc sec in spatial direction, covering the spot and going well into the surrounding photosphere.

Sample profiles of the observed C_2 line representing the umbra, the umbra-penumbra boundary, the penumbra and the non-spot region are presented to illustrate the presence of the C_2 lines in sunspots. Our observed spectra clearly show strengthening in the penumbra and weakening in the umbra relative to the photosphere in accordance with the predictions made in our molecular equilibrium calculations (Lee *et al.* 1981), thus corroborating the presence of the C_2 lines in sunspots.

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