ON THE O_2 SCHUMANN–RUNGE BAND SYSTEM IN SUNSPOTS

(Research Note)

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Abstract. The visibility in the umbral ultraviolet spectrum of the O_2 Schumann–Runge absorption band system has been explored. It is found that the band system may be visible in high dispersion sunspot spectrum.

1. Introduction

Among the abundant molecules found in sunspots, the homonuclear molecules H_2, N_2, and O_2 would not show vibration rotation lines since they possess zero permanent dipole moment. Also the resonance systems of these molecules fall in the region where the continuum opacity due to metals plays a dominant role and a search for these lines in the chromosphere above the spots, where the temperature increases outwards, would be more appropriate. Good models of spots that extend to chromosphere are lacking in the literature. Fortunately an inspection of the Franck–Condon factors for O_2 Schumann–Runge band system ($B^3\Sigma_u - X^3\Sigma_g$) suggests that the 6–3, 8–4, and 9–4 bands, which are well removed from the spectral region where the metal opacity dominates, should be almost as intense as the lines of the strongest bands like the 14-0 band in spite of a cut in the population for the higher vibrational levels. Here we report the calculated equivalent widths of the most intense lines of the P_1-branch of the 6–3, 8–4, and 9–4 bands of the O_2 Schumann-Runge system.

2. Equivalent Width Calculations

For variation of physical conditions in sunspots we adopted the Zwaan (1975) sunspot model and the method for calculating the equivalent width is the same as used by Krishna Swamy (1976). Partition functions and dissociation constants are taken from Glushko *et al.* (1962). The same dissociation energy has been given by Suchard (1975). Elemental abundances are from Engvöld (1977). The sources of continuous opacity considered by us are H, H^-, scattering due to H, H_2 and electrons (cf. Tsuji, 1964) and metal opacity due to Al, Mg, Si (cf. Travis and Matsushima, 1968). We used the RKR potentials for $q_{v'v''}$ with an electronic oscillator strength $f_{el} = 0.11$ (cf. Krupenie, 1972). The oscillator strengths used by us for equivalent

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width calculations are given in Table I. Hönl–London factors are adopted from Tatum (1966).

Wavenumbers for the most intense lines ($J''_{max} = 30$) of the 6–3, 8–4, and 9–4 bands of the P_1 branch were calculated according to the relation given by Herzberg (1950). The various spectroscopic constants used are from Suchard (1975) except for the values of λ and γ the spin coupling constants which are from Herzberg (1950). For the P_1 branch $J'' = N + 1$ and $J' = N$ (i.e., $J''_{max} = 30$ will correspond to $N = 29$). Equivalent widths were calculated for five disc positions (cf. Table I).

TABLE I

Centre-to-limb variation of the most intense lines of the P_1 branch of the (9–4), (8–4), and (6–3) bands of the O_2 Schumann–Runge System in Zwaan (1975) sunspot model

N_{max}	λ (nm)	band v'–v''	Oscillator strength $f_{el}f_{vib}$	Equivalent widths W (mÅ)				
				$\cos\theta = 1.0$	0.90	0.70	0.50	0.30
29	208.217	9–4	3.6802E−3	21.4	21.4	20.1	17.9	17.3
29	210.381	8–4	3.8016E−3	21.1	21.1	20.4	18.9	18.4
29	208.570	6–3	9.9786E−4	11.1	11.1	10.8	10.1	10.0

3. Discussions

The calculated equivalent widths of the chosen lines of the O_2 Schumann–Runge system given in Table I suggest that the molecule O_2 may show up in absorption in a high dispersion umbral spectrum. Also an inspection of the centre-to-limb variation of the calculated equivalent widths suggests that a search for this molecule should be made in regions near the centre of the disc. The decrease in equivalent widths near the limb has been examined by us. It is due to a decrease in the line to continuum opacity ratio in the region of line formation towards the limb.

Taking into consideration the various factors like the population of the vibrational levels, oscillator strengths and molecular opacity we expect that lines of the 9–4, 8–4, 7–4, 6–4, 6–3, 5–3, 5–4, and 4–4 bands should show up in umbral spectrum with expected equivalent widths ranging from 22 to 5 mÅ although the lines falling longward of 214 nm will be contaminated by the lines of SiO molecule and falling shortward of 214 nm by the lines of NO molecule (cf. Joshi *et al.*, 1978, 1979).

In the region 117 nm to 171 nm, Jordan *et al.* (1978) and Bartoe *et al.* (1978) have successfully photographed the umbral spectrum attaining a spectral resolution of 0.06 Å and a spatial resolution of 1.0 arc sec. However near 210 nm a good umbral spectrum is still not available. Since considerable progress has been attained in low flux detection techniques e.g., in the use of image intensifier tubes and reasonably fast emulsions, it seems possible to us that the spectrum of a well developed sunspot near 210 nm can be recorded within reasonable exposure times to facilitate a check of the predictions regarding the O_2 Schumann–Runge band.

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