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Carbon monoxide and facula models

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Asbtract. Equivalent widths for a few lines of the first overtone band of carbon monoxide have been calculated in the solar infrared spectrum for five facular and two photospheric models. The calculations show a decrease in equivalent widths in the facular models of Stellmacher & Wiehr (1973), Stenflo (1975) and Chapman (1979) and an increase in the models of Schmahl (1967) and Shine & Linsky (1974). The models are also discussed in the light of Polonskij's (1966) and Tsuji's (1977) observations.

Key words : carbon monoxide—equivalent widths—facula models

1. Introduction

The molecular lines have not been so well studied in faculae as in the photosphere and the spots. The intensities of molecular lines are quite sensitive to such physical conditions as the run of temperature and gas pressure in the region of molecular line formation. To test the sensitivity of molecular lines for such changes, we have calculated the equivalent widths for different facular models.

This work discusses the results of calculations for a few lines of the (2–0) vibration-rotation band of carbon monoxide in different facular model atmospheres and in two representative photospheric models. The facular models are from Schmahl (1967), Stellmacher & Wiehr (1973), Shine & Linsky (1974), Stenflo (1975) and Chapman (1979). The photospheric models are from Holweger & Müller (1974) and Vernazza *et al.* (1976). Hereinafter these models are abbreviated as SF, SWF, StF, 7B14, HM and VAL respectively. The following considerations prompted us to take up the lines of first overtone band of CO in different facula models :

(a) the CO analysis might be more helpful in probing the atmospheric structure (Tsuji 1977);

(b) the vibration-rotation molecular data for CO are well established;

(c) the continuum in the infrared region where CO lines are observed is better defined, and blending is less severe. The effect of departures from local thermodynamic equilibrium (LTE) in the distribution of molecules in different

levels in respect of vibration-rotation transitions of CO would not be important in the case of the solar atmosphere (Pande 1968; Thomson 1973; Hinkle & Lambert 1975);

(d) quantitative analysis of CO lines in various facula models is still lacking in literature.

2. Equivalent width calculations

The procedure for calculating the equivalent widths of the first overtone band of CO lines is the same as given in Tripathi *et al.* (1981). The oscillator strength has been taken from Kirby-Docken & Liu (1978). The calculated equivalent widths are given in table 1 for the different models. The percentage change in equivalent widths for different facular models against the HM photospheric model is given in table 2. Comparison against the HM photospheric model is done because HM is a very hot photospheric model and the limb darkening observations in the interval $0.5 < \lambda < 2.5$ μm show a better fit in HM (Lambert 1978).

Table 1. Equivalent width (in mÅ) of first overtone lines of CO in different models

Line designation	Equivalent widths (mÅ)						
	SF	SWF	SLF	StF	7B14	HM	VAL
R(19)	38.2	14.6	22.0	8.7	8.0	19.7	—
R(20)	39.4	15.1	22.7	9.0	8.3	20.3	—
R(24)	38 5	14.8	22.3	9.1	7.8	19.7	36.0
R(27)	43.4	16 8	25.2	9.9	9.3	22.5	36.6
R(36)	44.2	17.9	25.8	10.6	9.9	22.9	37.0
R(37)	—	13.1	19.0	8.5	7.5	16.5	26.8
R(64)	—	8.1	11.5	6.3	5.3	10.4	15.0

Table 2. Percentage change in equivalent widths calculated in facula models against the HM photospheric model

Line designation	Models				
	SF	SWF	SLF	StF	7B14
R(19)	+93.9	−25.9	+11.7	−55.8	−59.4
R(20)	+94.1	−25.6	+11.8	−55.7	−59.1
R(24)	+95.4	−24.9	+13.2	−53.8	−60.4
R(27)	+92.9	−25.3	+12.0	−56.0	−58.7
R(36)	+93.0	−21.8	+12.7	−53.7	−56.8
R(37)	—	−20.6	+15 2	−48.5	−54.5
R(64)	—	−22.1	+10.6	−39.4	−49.0

3. Results and discussions

Tsuji (1977) measured the equivalent widths of some photospheric lines of carbon monoxide on Hall's (1974) atlas. A comparison shows that the photospheric model HM gives equivalent widths which are less than those measured by Tsuji (1977). This is in spite of the fact that we take a higher carbon abundance ($\log A_c = 8.66$) than does Tsuji (1977), who has $\log A_c = 8.28 \pm 0.15$. A higher carbon abundance is suggested by indicators like CH, CN, C_2 and C I (Lambert 1978).

The equivalent-width calculations for the above lines were carried out in VAL photospheric model also which gave higher equivalent widths than Tsuji (1977). Considering that a discussion of facula models against a hot photospheric model would be more appropriate we discuss our results against HM photospheric model only.

From the results of our equivalent width calculations we find (table 1) that the facula models SF and SLF show an increase in the equivalent widths whereas the models SWF, StF and 7B14 show decrease in equivalent widths. Polonskij (1966) has concluded from his observations of the first overtone lines of carbon monoxide that a reduction of around 10 per cent in equivalent widths is expected in facula as compared with the photosphere. In table 2 we give the percentage change in equivalent widths for different facular models against the HM model. The percentage change in equivalent widths has been calculated by using $100 \times (W_F - W_p)/W_p$, where W_F is the equivalent width for a model facula and W_p is the equivalent width obtained for the HM photosphere. As per table 2 the percentage reduction in equivalent widths, which has occurred only in SWF, StF and 7B14 models, varies around 22 in SWF, 50 in StF and 55 in 7B14. The models SF and SLF show strengthening of lines and therefore do not fit in light of Polonskij's (1966) observations. It should be noted that SF, SWF and SLF are homogeneous facula models whereas StF and 7B14 are spatially limited models.

4. Conclusions

The CO analysis puts a stringent constraint on the solar model atmosphere due to the fact that the CO line formation layer is higher than that of the other molecules. The equivalent width calculations of some of the CO lines in different facular models reveal that the homogeneous facula models SF and SLF show increase in equivalent widths over the photosphere, which contradict observations of Polonskij (1966). Model SWF, however, shows a 22 per cent reduction in intensity of the lines which is somewhat higher than expected. The models StF and 7B14 should not be compared with Polonskij's (1966) observations since they are not average facula models but spatially limited models.

It is seen that the Polonskij's (1966) observational results which are for average facula do not correspond to the theoretical results obtained with facular models which horizontally limit the extent of facula while the average facular models are also inconsistent with these observations. It is, therefore, felt that low noise high quality spectra are needed for an average facula as well as for spatially limited faculae to explain the model-based equivalent widths of carbon monoxide.

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