EQUIVALENT WIDTH OF MOLECULAR LINES IN STARS

II: *Lines of* (A − X) *Band of* CO *and* SiO *in the Solar Atmosphere*

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Abstract. The expected equivalent widths of the individual rotational lines of (A − X) band of CO and SiO has been calculated for the solar atmosphere. Some of these results are discussed.

1. Introduction

In an earlier paper (Krishna Swamy, 1975; called Paper I), we calculated the expected equivalent width of the lines of Lyman and Werner bands of the hydrogen molecule from the solar atmosphere. The other abundant molecule of interest in the solar atmosphere is the CO molecule. In fact, Goldberg *et al.* (1965) (see also Porter *et al.*, 1967) have identified some of the lines of CO molecule in the rocket spectra of Tousey (1964). In this paper, we would like to calculate the expected equivalent width of the individual rotational lines of the (A − X) band of the CO molecule. We will also calculate the equivalent width of the lines of (A − X) band of the SiO molecule (See Tarafdar and Vardya, 1972).

2. Calculation and Results

The method of calculation of the individual rotational lines of a molecule are discussed in detail in Paper I. Here we would like to mention only the essential points which are relevant to this paper. The calculation of the equivalent width involves an integration over the whole atmosphere. This requires a knowledge of the monochromatic optical depth and the opacity at the wavelength of interest. A knowledge of the opacity sources in the ultraviolet wavelength region is not complete, although we have a good idea of the major sources of opacity in these wavelength regions. In the present work, we have taken into account the absorption due to H, H⁻, He⁻, He I, Si I, Mg I, C I, Fe I, Al I and scattering of H, H_2 and e. Most of the molecular data for the CO molecule are taken from the compilation of Krupenie (1966). The measured oscillator strengths of most of the transitions of the CO molecule has been used (Hesser, 1968). For those transitions, for which the measured oscillator strengths are not available, we have used the calculated values. The molecular constants for the (A − X) band of the SiO molecule are taken from Lagerqvist and Ubler (1953). The oscillator strengths for different transitions of the SiO molecule have been calculated using the Frank-Condon factors of Liszt and Smith (1972) and the electronic oscillator strength of
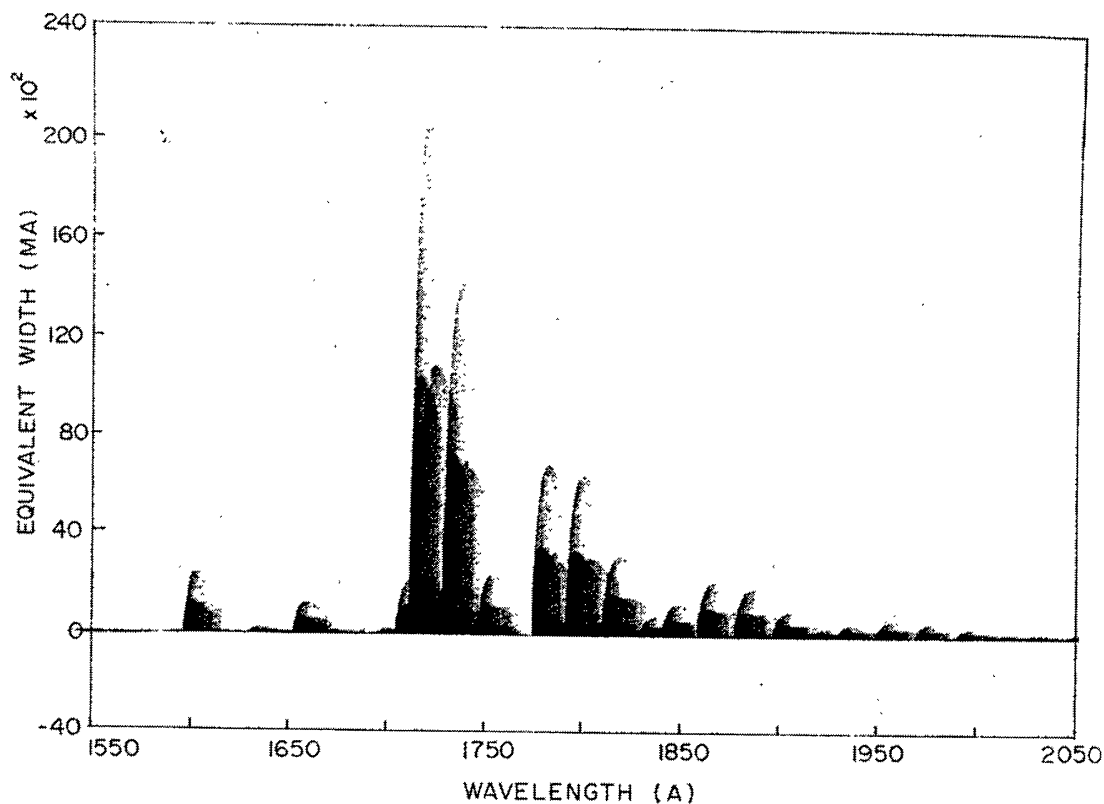
Fig. 1. Equivalent widths for the $(A-X)$ band of CO, are plotted as a function of wavelength for
$\mu = 1.0$.

0.133 (Smith and Liszt, 1972). The rotational strength factors for the two molecules of interest are given by Schadee (1964). We have considered various transitions arising from $v'' = 0$ to 14, $v' = 0$ to 13 and $J'' = 0$ to 50 for CO, while $J'' = 0$ to 30 for SiO. The results of calculations are shown in Figures 1 to 6. For CO molecule, the results for $\mu = 1.0$ and 0.5 are shown. For SiO molecule, we have shown the results only for $\mu = 1.0$. The positive and negative numbers in these figures indicate that the lines should be in absorption and emission respectively. One may note that the expected equivalent widths for the CO molecule are large, while for the SiO molecule they are small. Therefore it is harder to detect the lines of SiO molecule. Since at the present time, the resolution in the ultraviolet region is not very good, we have calculated the expected total equivalent width for a band pass of 0.2 Å. These results are shown in Figures 2, 4 and 6. Due to memory limitation on the computer, we could not include transitions beyond $J'' = 50$ for CO and $J'' = 30$ for SiO. The effect of this can be seen in the figures where the bands are not complete. Therefore the actual total equivalent widths for the band pass of 0.2 Å should be a little bit larger than shown in Figures 2, 4 and 6 for transitions of J'' greater than the limit used here.

3. Discussion

Unlike the case of H_2 molecule (Paper I), the lines of CO and SiO molecules should be mostly in absorption. This is what is expected as these lines are formed
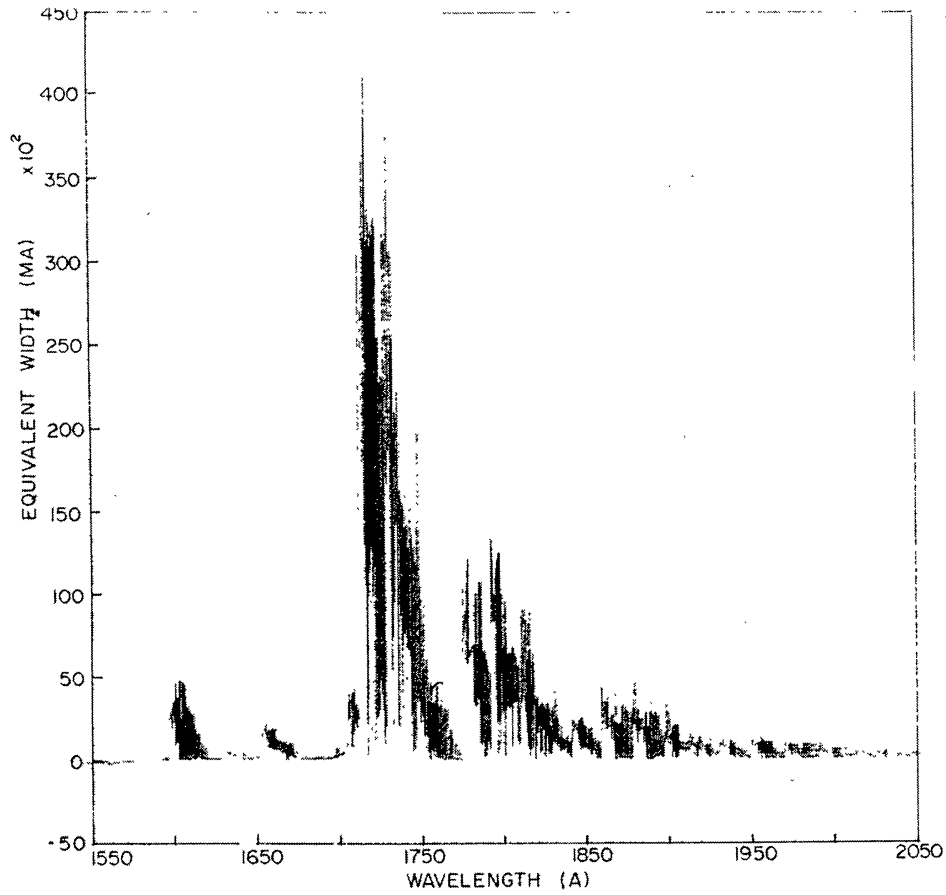
Fig. 2.   Total equivalent width within $\Delta\lambda = 0.2$ Å are plotted as a function of wavelength for $\mu = 1.0$.
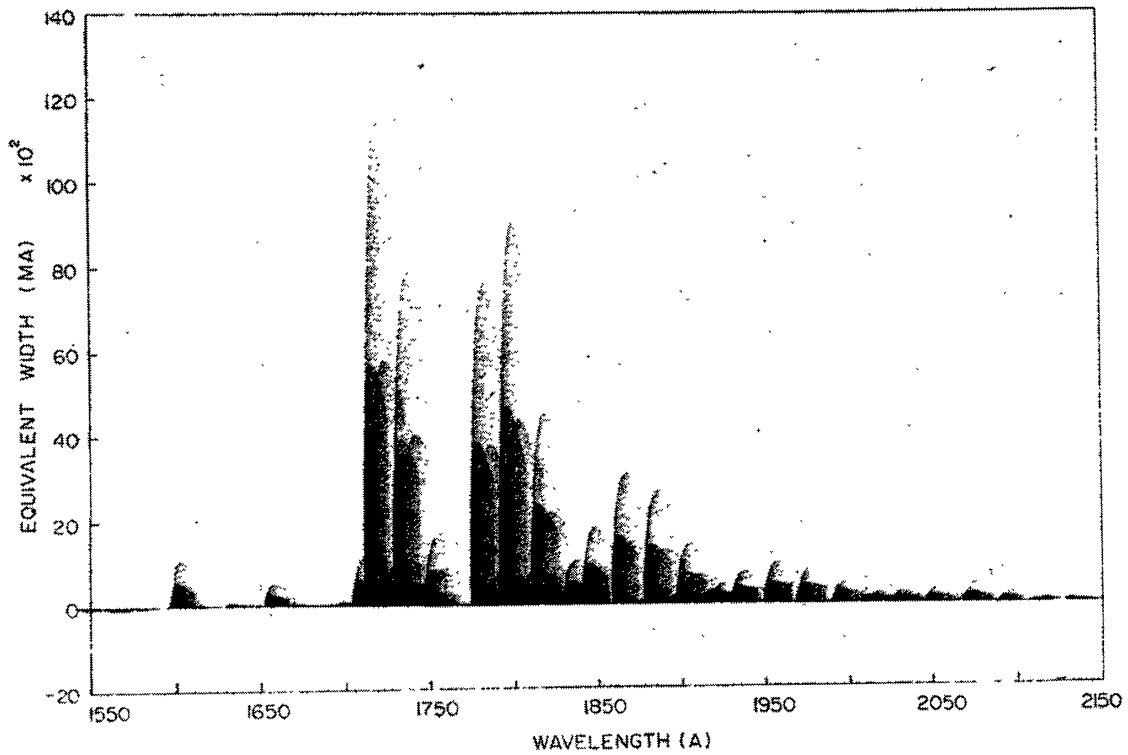

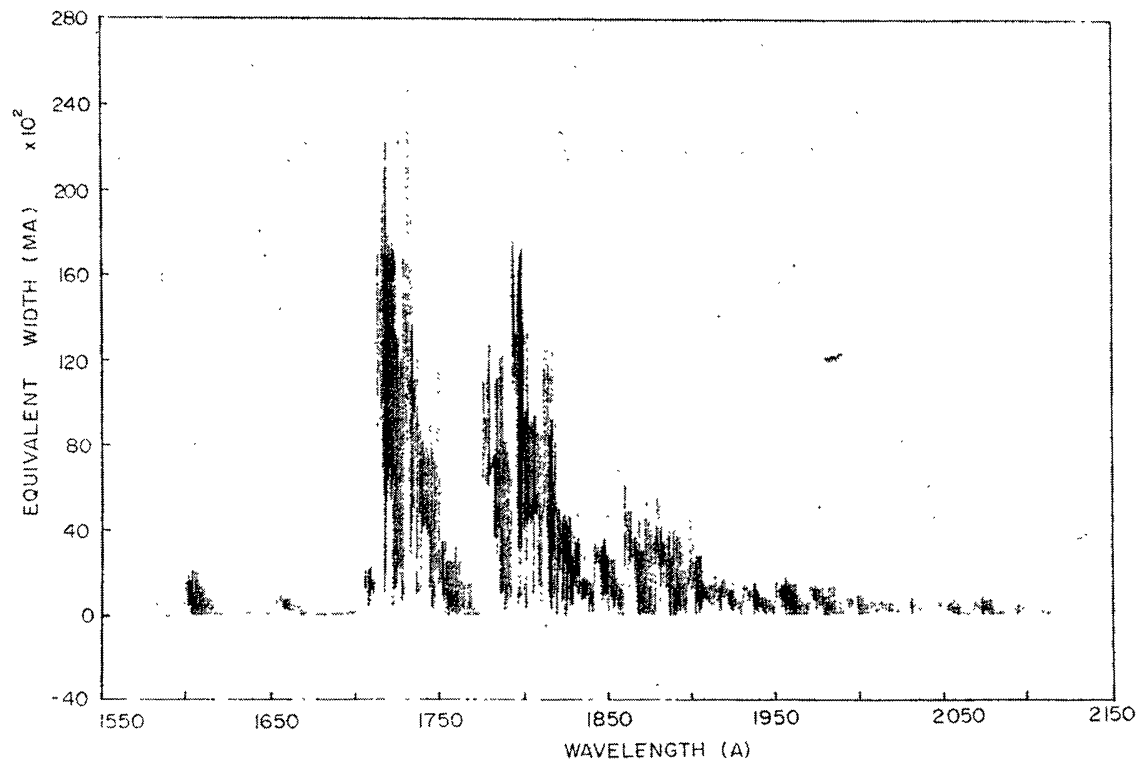Fig. 3.   Same as Figure 1, except $\mu = 0.5$.
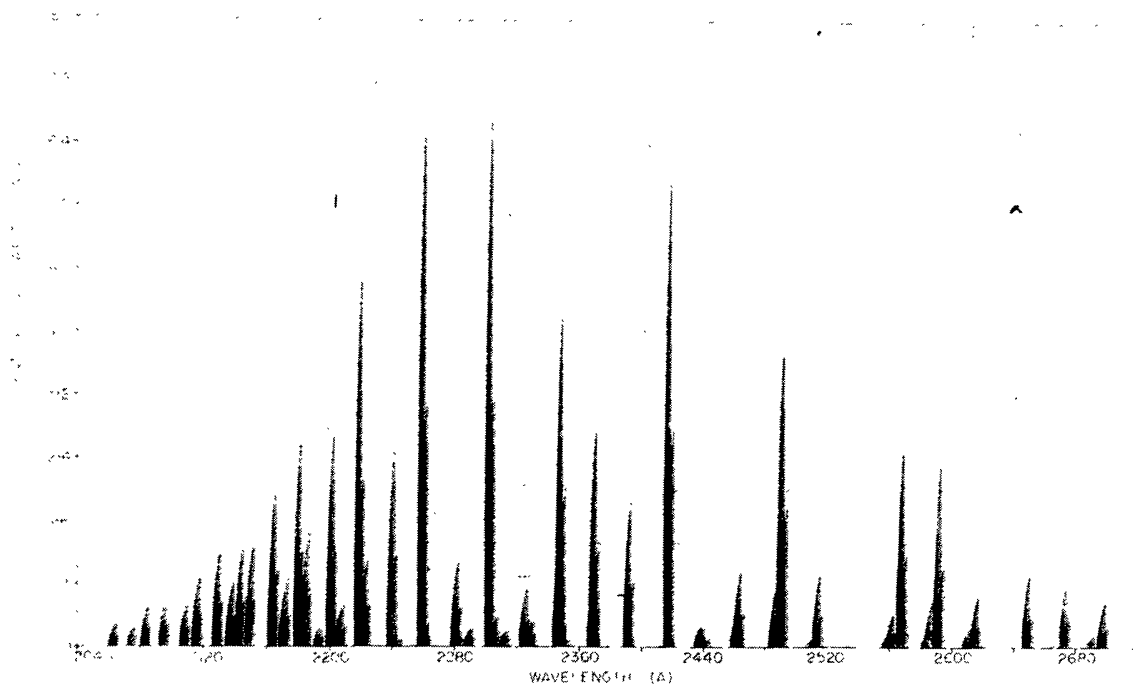
Fig. 4.   Same as Figure 2, except $\mu = 0.5$.

Fig. 5.   Equivalent widths for the $(A - X)$ band of SiO, are plotted as a function of wavelength for $\mu = 1.0$.
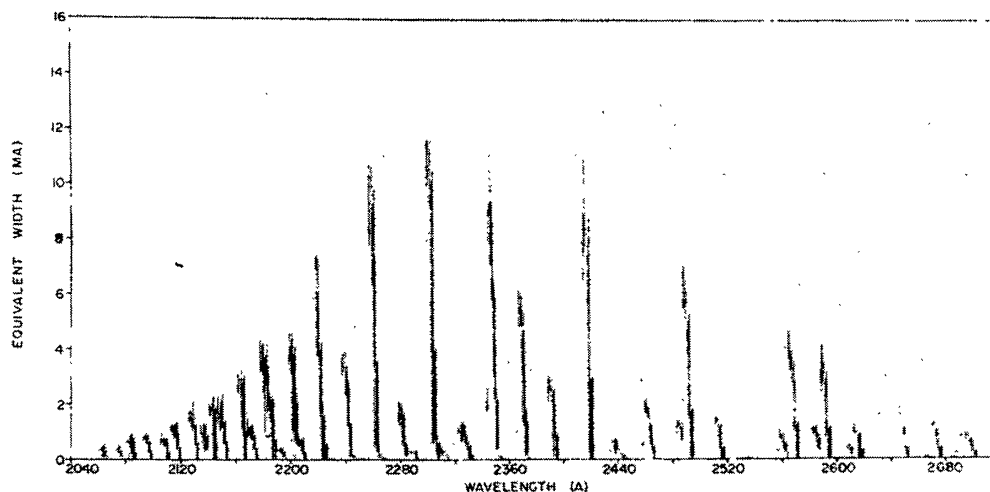
Fig. 6.   Total equivalent width within $\Delta\lambda = 0.2$ Å are plotted as a function of wavelength for $\mu = 1.0$.

in the deeper layers of the atmosphere compared to that of H_2 molecule. However, the cancelling effect due to the emission and absorption components are still present. One may also note that unlike the case of H_2 molecule, the lines of CO and SiO molecules are clamped together. The superposition of different bands in the same wavelength region can also be seen clearly. Therefore with the moderate dispersion, it is a bit hard to identify the individual lines of CO and SiO molecules. The observations of the solar continuum show that the flux around 1700 Å is smaller than in the adjoining region (Brueckner and Kjeldseth Moe, 1972; Parkinson and Reeves, 1969). This is consistent with the high absorption of CO in this wavelength region.

As pointed out in Paper I, although the line of H_2 molecule around 1700 Å are strong, they are still small compared to that of CO molecule. Therefore, it may not be possible to identify the lines of molecular hydrogen in this wavelength region.

At the present time, it is not possible to compare the calculated values of the equivalent width of the lines of CO molecule with observations. To the knowledge of the author, most of the observations available in the wavelength region where CO lines lie, do not provide the necessary data. Hopefully more quantitative results will be available in the near future. As pointed out before the expected lines of the SiO molecule are weak. Therefore it is hard to say whether these features could be observed (Broadfoot, 1972).

Acknowledgement

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