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On the oscillator strengths of the Phillips bands

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Abstract. The recently published values of oscillator strengths for the Phillips bands were checked with those obtainable from the solar spectrum. The results of (1982) Erman *et al.* based on the assumption of a varying electronic transition moment appear to be in good agreement with the solar value.

Key words : oscillator strength—solar spectrum—Phillips bands—C_2 molecules

1. Introduction

Consequent upon the detection of transitions from the singlet states of the C_2 molecules in a variety of celestial objects (Souza & Lutz 1977; A'Hearn & Feldman 1980; Brault *et al.* 1982) new windows for the detection of this molecule have opened. The Phillips system of bands is being used to determine column densities of the C_2 molecules in interstellar clouds (Danks & Lambert 1983). Also, they are important features in the spectra of carbon stars. Obviously one would need a reliable estimate of oscillator strengths in order to correctly interpret the line intensities and to obtain correct column densities. From the laboratory investigations by Erman *et al.* (1982) it is not clear whether the transition moment $R_e(\bar{r})$ is a function of internuclear distance $\bar{r}$ or not. We decided to resolve this issue with the help of the solar spectrum.

2. Formulations and calculations

We first used the (0—0) band of the Swan system to fix the carbon abundance, dissociation energy and the model atmosphere, with the help of the KPNO atlas (Brault & Testerman 1972). These values were then used to calculate the line intensities (W_{cal}) of the Phillips bands. The calculated and the observed equivalent widths (W_{obs}) were matched utilizing different values of the oscillator strengths (cf. Sinha 1981, 1982).

Two photospheric models, one (HM) due to Holweger & Müller (1974) and the other (VAL) due to Vernazza *et al.* (1977), were utilized. The other important

parameters are as follows :

Carbon abundance	: 8.67 (Lambert 1978).
Dissociation energy	: 6.11 eV (Lambert 1978).
Microturbulence velocity	: 0.85 km s^{-1} (Brault *et al.* 1982).
Molecular constants for the $^3\pi_u$ state	: Huber & Herzberg (1979).
Molecular constants for the $^1\Sigma_g$ state	: Chauvielle *et al.* (1977).
Opacity sources	: Tsuji (1966).
Oscillator strengths for the Phillips bands	: Erman *et al.* (1982)
Oscillator strength for the Swan band	: f_{0-0} = 0.0239 (Lambert 1978)
Rotational line strength	: Schadee (1964).

3. Results and Discussions

The Swan band equivalent widths for the centre of the solar disc ($\mu = 1.0$) and for a near-limb position ($\mu = 0.2$) were measured from the KPNO atlas (Brault & Testerman 1972). A total of about fifty good quality lines were selected from this atlas with the help of the table of wavelengths (Phillips & Davis 1968). A detailed list of line identifications and equivalent widths will be published elsewhere (Sinha 1984). In figures 1 and 2 we present a comparison between the observed and the calculated equivalent widths for $\mu = 1.0$ and $\mu = 0.2$. It can easily be inferred from an inspection of these figures that the HM model gives a better fit between observations and calculations for both the positions on the solar disc. The broken lines represent 20% scatter (arbitray) in observations. For the HM model the scatter never exceeds 30%. The calculated results for the VAL model are higher because this being a cooler model leads to more of molecule formation. Keeping also in view the arguments due to Lamdert (1978) in favour of the HM model and the need for increasing the temperature structure of the VAL model (Blackwell *et al.* 1982), we can conclude that a dissociation energy $D_0^0(C_2) = 6.11$ eV, the carbon abundauce N(C) = 8.67 and the HM model can explain the Swan band intensities of the molecules C_2.

We now proceed to calculate the equivalent widths of the Phillips bands with the help of the parameters fixed above for all the lines of the (0—0) and the (1—0) bands included in the investigation due to Brault *et al.* (1982). However, for the sake of comparison we shall retain the VAL model with a preference for the HM model.

In figures 3(a) and 4(a) the results utilizing such values of oscillator strengths which are calculated on the assumption of a constant $R_e(\bar{r})$ are presented. Similarly in figures 3(b) and 4(b) we present the results when $R_e(\bar{r})$ depends upon $\bar{r}$. A comparison of the oscillator strengths given in these figures shows that the $\bar{r}$-independent values are about 50% lower. Consequently, in both the figures 3(a) and 4(a) we obtain smaller than observed values of equivalent widths. So in order to get a fit between observations and calculations the higher values of oscillator strengths obtained with the help of a $\bar{r}$-dependent $R_e(\bar{r})$ is to be used. Figures 3(b) and 4(b) clearly illustrate this point. The average values of (W_{obs}/W_{cal}) for the (0—0)

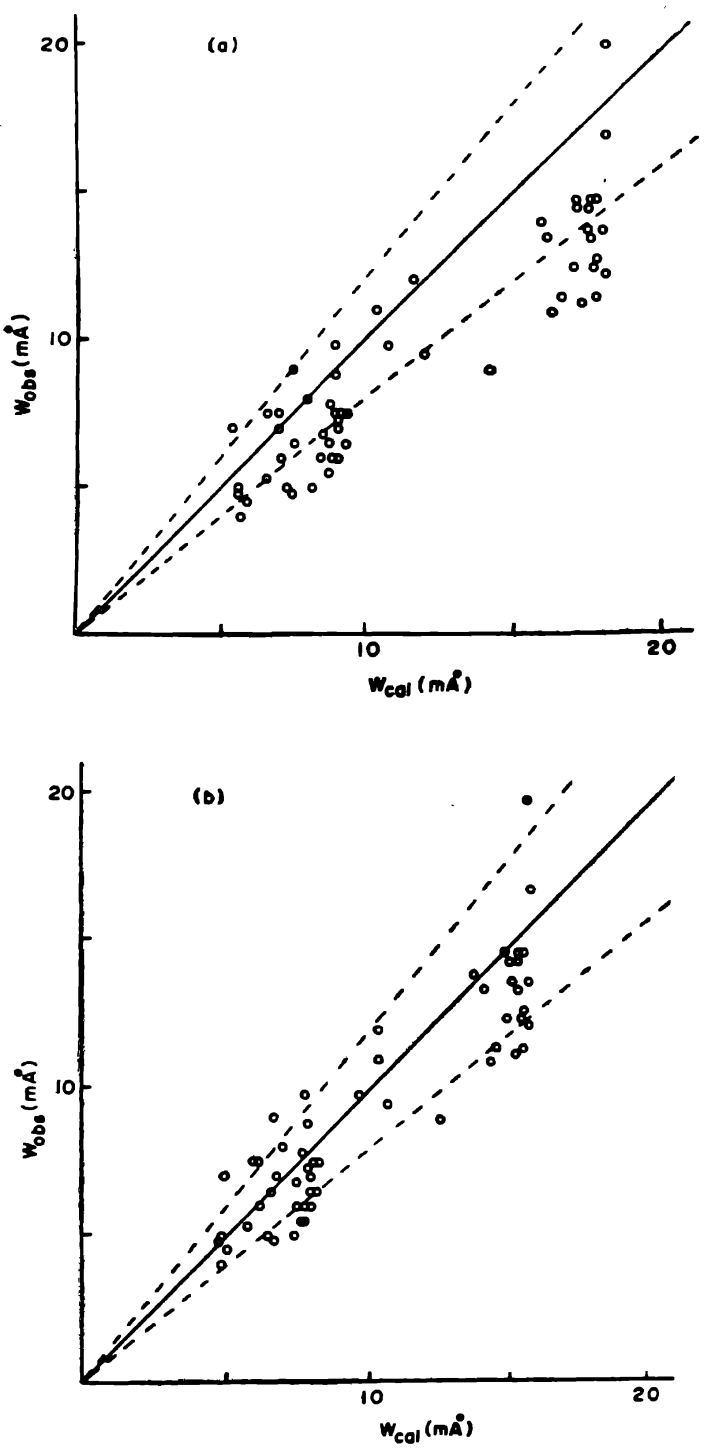

Figure 1. Comparison of the calculated (W_{cal}) and the observed equivalent widths (W_{obs}) of the (0—0) band of the Swan system of the C_2 molecules for $\mu = 1.0$. (a) refers to VAL based results and (b) to HM based results.

and the (1—0) band is 1.05 ± 0.15 and 1.10 ± 0.20 respectively in the HM model. In figure 5 we plot the W_{obs} values against the W_{cal} values for the model HM after scaling the oscillator strengths of the (0—0) and the (1—0) bands by 5% and 10%

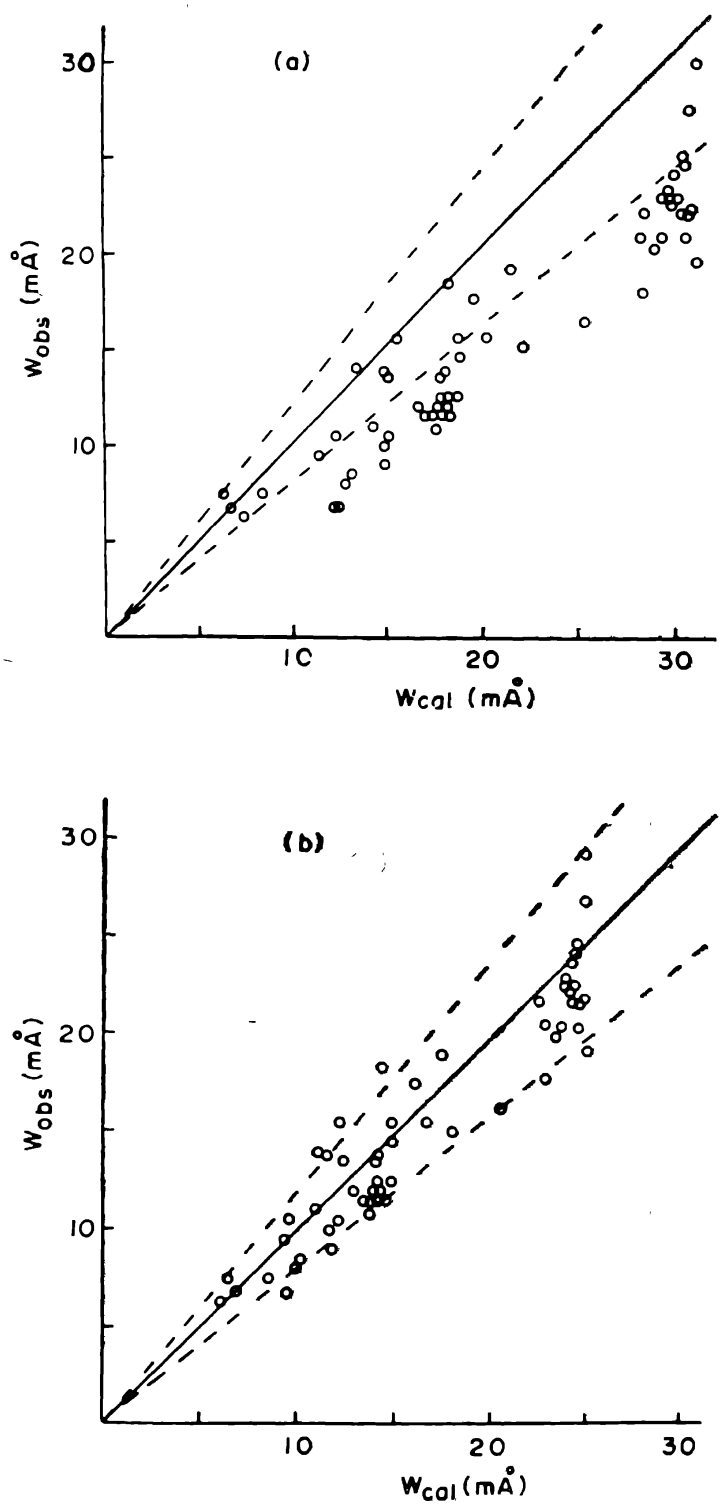

Figure 2. Same as in figure 1 but for $\mu = 0.2$.

respectively. However, this small correction needed in the values of the oscillator strengths lies well within the uncertainity of life-time measurements. In all the above calculations the J-dependent Franck-Condon factors due to Dwivedi *et al.* (1978) were properly used.

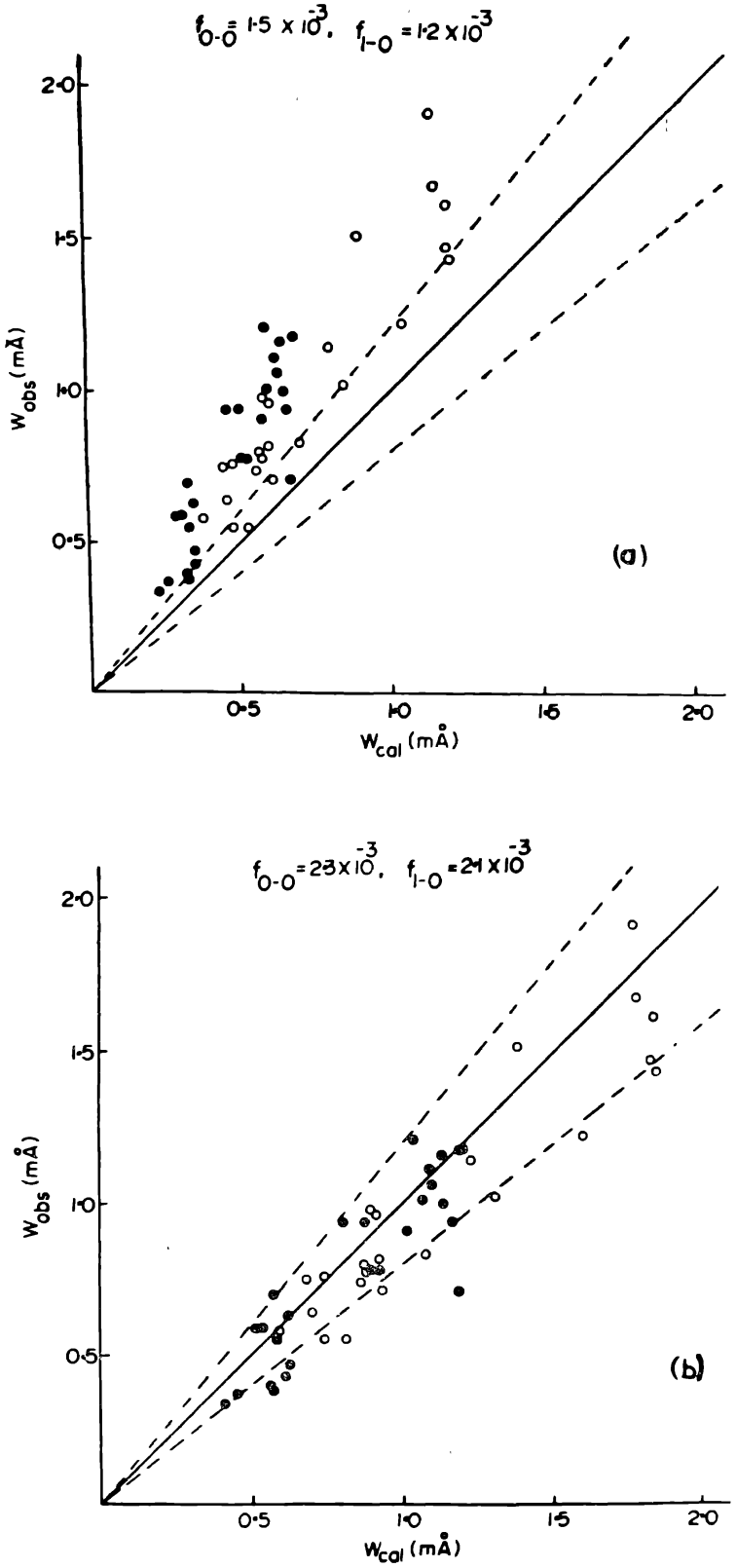

Figure 3. Comparison of the calculated (W_{cal}) and the observed equivalent widths (W_{obs}) of the lines of the Phillips bands for the model VAL utilizing different sets of f values. Open circles refer to the (0−0) band and filled circles to the (1−0) band.

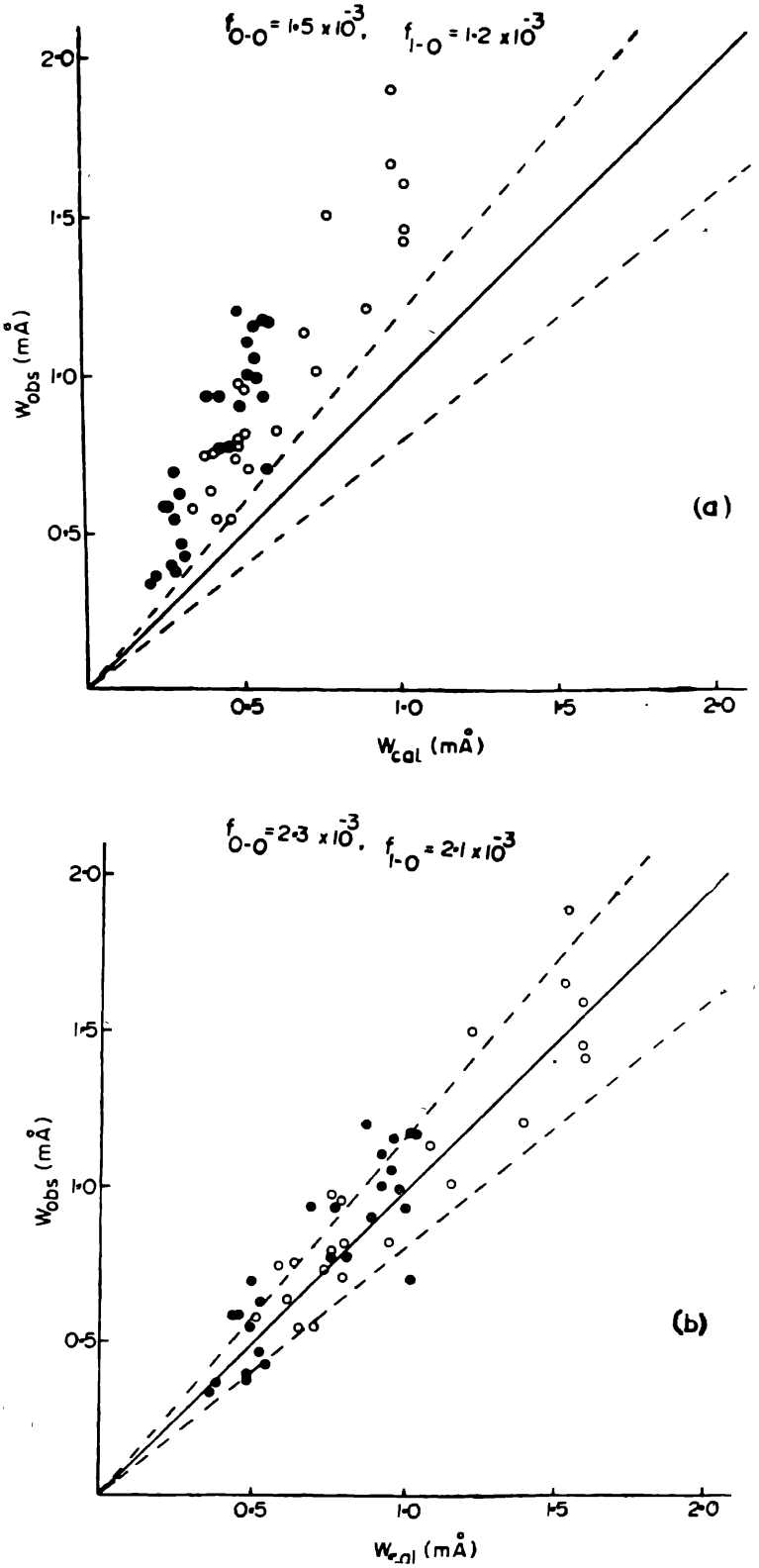

Figure 4. Same as in figure 3 but for the HM model.

Thus in brief we conclude that the f_{0-0} and the f_{1-0} values as reported by Erman *et al.* (1982) on the basis of the assumption of a $\bar{r}$-dependent R_e ($\bar{r}$) are in good

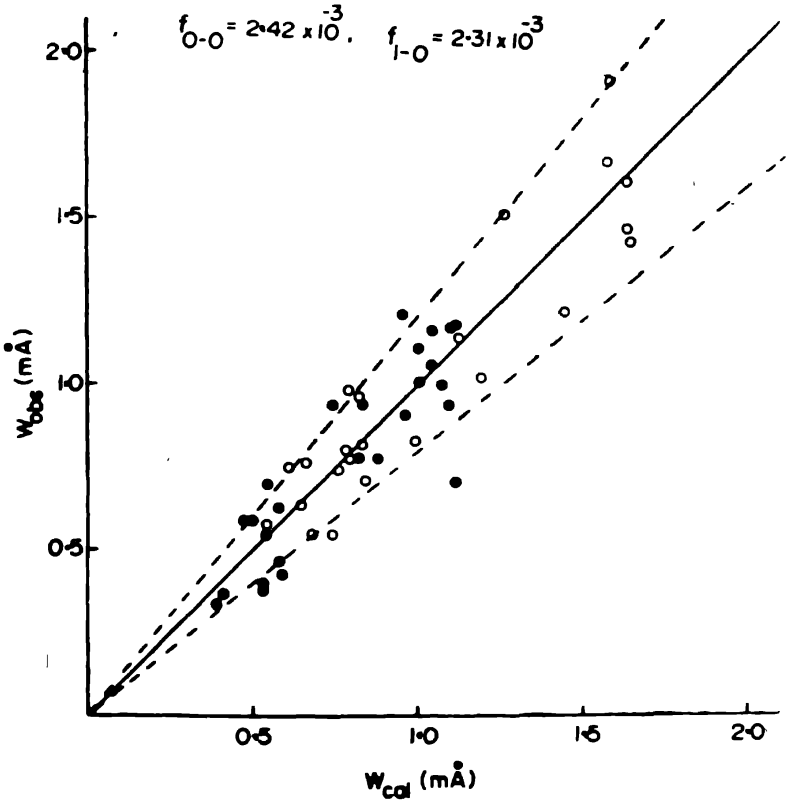

Figure 5. Same as in figure 3 but after a scaling of the oscillator strengths (see text) for the HM model.

agreement with the observations of the solar spectrum. It may be added that though Cooper & Nicholls (1975) found a high value of oscillator strength ($f_{0-0} = 3.7 \times 10^{-3}$), they too report a weak dependence of $R_e(\bar{r})$ upon $\bar{r}$ in a laboratory investigation.

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