

The value of the optical thickness in its turn influences the degree of the levels excitation as it is seen in Figs. 1 and 2.

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ABSENCE OF THE PHILLIPS BANDS IN THE SOLAR PHOTOSPHERIC SPECTRUM

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The absence of Phillips bands in the solar photospheric spectrum and the presence of Swan bands seems to point to a non-LTE path for the formation and disappearance of C_2 molecules in the solar photosphere.

Отсутствие полос Phillips-а в спектре солнечной фотосферы

Отсутствие этих полос при одновременном существовании полос Swan-а приводит к мысли о неравновесном (non-LTE) пути образования молекул C_2 для объяснения их ненаблюдаемости в солнечной фотосфере.

1. Introduction

In the case of C_2 molecule the Swan bands are easily observable in the photospheric spectrum. So it is natural to enquire whether other bands with the lower electronic states, close to the ground level of the Swan system, are observable in the photospheric spectrum or not. In the present paper we discuss the absence of the Phillips ($a^1\Pi_u - x^1\Sigma_g^+$) system and conclude that no molecules form in the $X^1\Sigma_g^+$ electronic state (the ground state) of the C_2 molecule.

2. Search For the Phillips Bands in the Photospheric Spectrum

The wavelengths of the lines belonging to the various bands of the Phillips system (2-0, 3-0, 4-1, 3-1 and 5-2) were taken from Phillips (1948). These were corrected for vacuum-to-air conversion and the gravitational red shift.

These wavelengths were then matched with the infrared solar spectrum wavelengths of Swenssen et al. (1970). Because of only a few chance coincidences, the absence of the absorption lines belonging to the above bands in the photospheric spectrum is concluded. Unfortunately, the solar tables of wavelengths and identifications of species other than C_2 in the region occupied by the 0-0 band of the Phillips system are not available to us. So we cannot confidently state that this band is absent in the photospheric spectrum. But a cursory inspection of the laboratory wavelengths (Ballik and Ramsay, 1963) and the atlas by Mohler et al. (1950) suggests that this band is absent.

3. Oscillator Strengths of the Phillips System Bands

Penner (1959) quotes an oscillator strength of $f_{e1}f_{0-0} = 2 \times 10^{-2}$ for the Phillips system and Schadee (1964) gives $f_{e1}f_{0-0} = 10^{-2} - 10^{-3}$ for the

Swan system. Adopting the method given by Hutschison (1930) and $f_{e1}f_{0-0}$ for the Swan system = 2.4×10^{-2} we calculated the oscillator strength for the (0-0) band of the Phillips system using the expression:

$$(3.1) \quad \frac{f_1}{\omega_1 |R_1|^2} = \frac{f_2}{\omega_2 |R_2|^2},$$

where the f 's denote oscillator strengths, the ω 's the wave numbers in the centres of the bands and the $|R|^2$'s the squares of the electric dipole moments of the two mentioned systems. Thus, we find $f_{e1}f_{0-0} = 7.359 \times 10^{-2}$ for the Phillips system which checks up with the value given by Penner (1959). The ratio $f_{e1}f_{0-0}/f_{e1}f_{2-0}$ for the Phillips system is found to be 10.72 on the basis of (3.1).

4. Equivalent Width Calculations

The equivalent widths W of the λ 12458.65 Å line of 0-0 band and λ 8984.04 Å line of 2-0 band of Phillips system are evaluated for the BCA photosphere (Gingerich and de Jager, 1968) adopting the weak line approach followed by Gaur et al. (1971).

The equivalent width can be written as

$$(4.1) \quad W = f_{e1}f_{vib} \times I,$$

where I is an integral which accounts for all the factors, such as the weighting factor, continuous and selective opacities, etc., determining the equivalent width of a given line.

The molecular constants are from Glushko et al. (1962), continuous opacity is calculated from Tsuji's (1956) tables and the selective absorption coefficient in the same manner as given in Gaur et al. (1971). The concentration - optical depth curve for C_2 in BCA is borrowed from Pande and Gaur (1972). The integral in equation (4.1) turns out to be 9.270×10^{-8} and 5.066×10^{-8} for λ 12458.65 Å line of 0-0 and λ 8984.04 Å line of 2-0 bands of the Phillips system respectively. Accepting the $f_{e2}f_{vib}$ equal to 2×10^{-2} and 2.6×10^{-3} respectively for the mentioned bands the equivalent widths are $W(0-0) = 185$ mÅ and $W(2-0) = 13$ mÅ. Thus, under LTE the 0-0 and 2-0 bands of the Phillips system should be observable.

5. Results and Discussion

It is concluded that the investigated Phillips bands are absent from the solar photospheric spectrum. This absence is not compatible with the LTE hypothesis for the formation of C_2 Swan band lines which

are definitely present in the solar photospheric spectrum. The proximity of the lower electronic states of the Phillips and Swan systems and the comparable oscillator strength for the two systems suggest that the lines belonging to the various bands of the two systems should be comparable in equivalent widths if LTE is taken to prevail. In fact, our calculations of the equivalent widths of two selected lines of the (0-0) and (2-0) bands of the Phillips system yield too large equivalent widths under LTE. Further, the centre-to-limb variations of the Swan band lines (Laborde, 1964; Raghavan, 1968) suggest that under LTE the equivalent widths of the selected lines of the Phillips band may increase towards the limb by a factor of about 2 as compared with their values at the center of the disk. However, the very observational absence of Phillips bands at the center of the disk indicates that this minor gain in equivalent widths towards the limb will not make these bands observable over the whole solar disk for reasons given below.

One can perhaps explain the absence of Phillips bands by imagining temperature inhomogeneities in the region of formation of C_2 Swan band lines. Then it is not possible to account for the presence of the Swan band lines because the lower electronic state of the Swan system lies above the ground state from where the Phillips band lines would arise. Moreover, as C_2 has a dissociation energy of 6.2 eV it becomes difficult to understand how a relatively unstable molecule MgH, with dissociation energy of only 2.3 eV can then survive. In brief, homogeneous and inhomogeneous photospheric models cannot explain the absence of the Phillips system bands together with the presence of the Swan system bands under LTE. So, it appears that no C_2 molecules form in the ground electronic state $X^1\Sigma_g^+$ while they can appear in the $^3\Pi_u$ state i. e. the processes which populate the various electronic states of C_2 molecules are of a non-LTE nature.

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MOLECULAR ABUNDANCES IN SUNSPOTS

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The results of the dissociation equilibrium calculations for Zwaan's sunspot model are given. It appears that many di- and tri-atomic molecules form in sufficient abundances in the spots. It is suggested that for assessing the differences between the physical conditions of various sunspot models the locations of various molecules on the average geometrical depth of formation versus temperature (at that depth) curve can serve as a theoretical criterion.

Содержание молекул в солнечных пятнах

Даются результаты вычисления диссоциативного равновесия для модели солнечного пятна, которую предложил Зваан. Оказывается, что многие двух- и трехатомные молекулы образуются в пятнах в достаточном количестве. Предлагается в качестве теоретического критерия для оценки разностей физических условий в разных моделях солнечных пятен использовать появление различных молекул на кривой геометрическая глубина образования — температура на этой глубине.

1. Introduction

Following earlier work on molecular abundances in the solar photosphere and in faculae (Pande et al., 1969a, b), the present investigation reports on the molecular abundances in sunspots based on Zwaan's (1965) sunspot model (hereinafter abbreviated as ZSM).

The possibility of triatomic molecular formation in sunspots is also investigated here. The presence of H₂O in sunspot spectrum has recently been reported (Wöhl, 1969; Mallia and Blackwell, 1970; Mallia et al., 1970) so a search for other triatomic molecules in sunspot spectrum may be desirable. We think that the dissociation equilibrium calculations may also help in picking up more abundant triatomic molecular species for identification. For these reasons, a number of triatomic molecular species were also included in our calculations of molecular abundances in ZSM.

2. The Calculations of Molecular Abundances in ZSM

In all about one hundred atomic, molecular and other species were included in the present calculations. Besides the species listed by Pande et al. (1969a), the following additional species were also considered:

Ti, Ti⁺, TiO, TiO₂, Sr, Sr⁺, SrH, SrO, Y, Y⁺, YO, V, V⁺, VO, CaH, BN, H₂O, HO₂, H₂S, HCO, HCN, HNO, C₃, CO₂, C₂H, CH₂, CH₃, CH₄, O₃, N₃, N₂O, NO₂, NH₃, SiC₂, Al₂O, AlCl₂ and ZrO₂.

The sources from which the dissociation and other constants were borrowed are: H₂⁺ (Vardya, 1961), CaH, TiO₂, SrO and SrH (Tsuji, 1964) and for other species Glushko et al. (1962) and Tatum's (1966) tables.

The references from which the solar elemental abundances were borrowed are: Cl (Lambert and Mallia, 1968), V (Warner, 1968), Sr (Lambert and