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Preprint

THE RELATIVE INTENSITIES OF CI LINES IN THE SOLAR EUV SPECTRUM

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1967

UNCLASSIFIED
(Approved for Publication)

CLM - P146

THE RELATIVE INTENSITIES OF CI LINES IN THE SOLAR EUV SPECTRUM

by

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ABSTRACT

The relative intensity of two CI Lines at 1993·5 Å and 1657·4 Å, observed in the limb spectrum of the sun, is a factor $2{\cdot}6 \times 10^3$ larger than that expected if both lines were optically thin. It is shown that the observed intensity ratio may be explained in terms of the transfer of photons from λ1657·4 Å to λ1993·6 Å due to a large optical depth in the line at 1657·4 Å. The observed upper limit on the relative intensity of two further lines at 1992·0 Å and 1657·0 Å has been used to show that the line at 1993·6 Å is optically thin. Hence it is shown that τ(1657·4 Å) = 1300, and τ(1993·6 Å) = 0·44. These values provide an independent evaluation of optical depth against which chromospheric models may be checked. Assuming a mean temperature of $\overline{T_e} = 8000^0$K, and a mean scale height of 350 km, the optical depths lead to a mean hydrogen particle density of $\underline{N}(H) = 5{\cdot}8 \times 10^{12} cm^{-3}$.

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July, 1967

1. INTRODUCTION

BURTON et al. (1967) have drawn attention to the anomalous relative intensity of two CI lines in the solar EUV spectrum, observed at the limb. The two transitions involved are $2p^2\ ^1D_2 - 2p3s\ ^3P^o_1$, at 1993·6 Å, and $2p^2\ ^3P_1 - 2p3s\ ^3P^o_1$, at 1657·4 Å (see Fig.1). Since these two lines have a common upper level, their relative intensity, in optically thin conditions, is given by:-

$$\frac{E(1993\cdot6\ \text{Å})}{E(1657\cdot4\ \text{Å})} = \frac{A(^3P^o_1 - {}^1D_2)}{\lambda(^3P^o_1 - {}^1D_2)}\ \frac{\lambda(^3P^o_1 - {}^3P_1)}{A(^3P^o_1 - {}^3P_1)} \qquad \ldots (1)$$

where A is the spontaneous transition probability. Using transition probabilities calculated for this purpose by TATUM (1967), the intensity ratio from equation (1) is $1\cdot9 \times 10^{-3}$, which is a factor of $2\cdot6 \times 10^{3}$ smaller than the value of 5·0 from the observations of Burton et al.

However, the intensity ratio given by equation (1) relies on both the lines being optically thin, i.e. it relies on the assumption that all the photons created in a line eventually escape from the atmosphere in that line. In Section 2 of the present paper it is shown that if the lines have optical depths greater than unity then the intensity ratio depends also on the optical depths in the two lines. As λ1993·6Å can be shown to be optically thin, the intensity ratio depends only on the optical depth in λ1657·4 Å (in addition to the atomic parameters given in equation (1), so that the τ(1657·4 Å) necessary to explain the observations may be determined. This value may then be used to calculate $N(H)$, the mean hydrogen particle density in the region of the chromosphere observed.

The intensity ratios of other pairs of lines from levels in the 2p3s configuration have also been calculated for the cases of optically thin and thick lines, but the value of these further results is at present limited by insufficient observational data.

2. DATA

Fig. 1 shows the levels included in the calculations. Table I gives the transition probabilities and oscillator strengths as calculated by Tatum, (using the method of BATES and DAMGAARD (1949) as modified by BURGESS and SEATON (1960), to calculate the values of σ^2, and intermediate coupling theory, from CONDON and SHORTLEY (1959), to give the line strengths). The solar intensities, also given in Table I, are taken from BURTON et al. (1967), and refer to the energy incident at the top of the earth's atmosphere, in units of 10^{-8} erg cm^{-2} sec^{-1}. For lines which are not observed an upper limit has been placed on their intensity, depending on the scattered light background at the appropriate wavelength. The lines of the multiplet at 1657 Å are blended, and their intensities are reliable only to within a factor of two. The reliability of the relative intensities will depend on the wavelength separation of the two lines concerned. In the case of E(2582·9 Å)/E(1657·4 Å) and E(2478·6 Å)/E(1930·9 Å) errors of up to a factor of 3 are possible.

3. THEORY

Consider an excited level from which n emission lines are possible. Let b_1 be the probability that a photon will be emitted in line '1', where:

$$b_1 = \frac{A_1}{\sum_n (A_n + C_n N_e) + \sum_m (u_\nu B_m + C_m N_e)} \qquad \ldots (2)$$

where $\underline{n}$ refers to processes to levels below the excited level and $\underline{m}$ to processes to levels above the excited level. $\underline{CN_e}$ is the collisional excitation, or de-excitation rate, $\underline{u_\nu}B$ is the photo-excitation rate. As the problem is concerned with the relative intensity of lines from a common upper level, the size of the terms competing with $\underline{A}$, the spontaneous transition probability, is not important. The problem of the transfer of resonance radiation has been discussed by ZANSTRA (1949), OSTERBROCK (1962) and others. Zanstra suggested that the eventual emission in a line may be found by considering the probability of a photon being re-emitted after each absorption, at a frequency ν in the wings where $\tau_\nu < 1$. For a Doppler broadened line

$$\tau_\nu = \tau_o \, e^{-(\nu-\nu_o)^2/\Delta_D^2} \qquad \ldots (3)$$

where $\Delta\nu_D$ is the e^{-1} width, and τ_o is the optical depth from the centre to the edge of the plasma. Or, taking $\underline{x} = \left(\frac{\nu-\nu_o}{\Delta\nu_D}\right)$

$$\tau_\nu = \tau_o \, e^{-\underline{x}^2} . \qquad \ldots (4)$$

Following Zanstra, let $\underline{q}$ be the probability that a photon is emitted at a frequency greater than $\underline{x}_1$. The line profile is given by

$$\underline{P}(\underline{x}) = \frac{1}{\sqrt{\pi}} e^{-\underline{x}^2}$$

so that

$$\underline{q} = 2 \int_{\underline{x}_1}^{\infty} \frac{1}{\sqrt{\pi}} e^{-\underline{x}^2} d\underline{x}$$

$$\underline{q} = 1 - \mathrm{erf}\,\underline{x}_1 \qquad \ldots (5)$$

Now take $\underline{x}_1$ to be the frequency at which $\tau_{\underline{x}} = 1$, and assume that all photons reaching this frequency immediately escape from the atmosphere. Then from equations (4) and (5)

$$\underline{q} = 1 - \mathrm{erf}\, (\ell n \tau_o)^{1/2} \qquad \ldots (6)$$

for $\tau_0 > 1$; q can be taken as the probability per emission of a photon escaping, and $(1-q)$ as the probability of re-absorption to the excited level. With τ_0 large, $(1-q)$ is large and a large number of re-absorptions take place before all the photons escape. At each re-absorption the photons are redistributed amongst the n levels possible from the excited level, according to their value of b_n, from equation (2). Thus the intensity of a line with small τ_0 is increased at the expense of a line with large τ_0.

The total fraction of photons created, escaping in line '1' may now be found. Of the photons emitted from the excited level there is a probability b_1 that these will be in line '1'. A fraction $q_1 b_1$ will immediately escape, and a fraction $(1-q_1)b_1$ will be absorbed to re-populate the excited level. The excited level may also be populated by absorption in the remaining $(n-1)$ lines, so of the photons emitted in all the lines, a fraction $\sum_n b_n(1-q_n)$ is absorbed. Of these photons a fraction b_1 will be emitted in line '1', and a fraction $b_1 q_1$ will escape. Thus the total fraction of photons created, escaping in line '1' is:

$$W_1 = b_1 q_1 + b_1 q_1 \sum_n b_n(1-q_n) + b_1 q_1 \left[\sum_n b_n(1-q_n)\right]^2$$

$$= \frac{b_1 q_1}{1-\sum_n b_n(1-q_n)} \qquad \ldots (7)$$

This may be compared with the fraction escaping in line '1', in optically thin conditions, which is

$$W_1' \text{ (thin)} = b_1$$

as $q = 1$ for each line.

For two lines from a common upper level, if both lines are optically thin the relative intensities are given by

$$\frac{E'_1 \text{ (thin)}}{E'_2 \text{ (thin)}} = \frac{b_1}{\lambda_1} \cdot \frac{\lambda_2}{b_2} \qquad \ldots (8)$$

as in equation (1). In optically thick conditions,

$$\frac{E_1}{E_2} = \frac{b_1 q_1}{\lambda_1} \cdot \frac{\lambda_2}{b_2 q_2} \qquad \ldots (9)$$

To apply the above theory for a point deep in a uniform atmosphere to a line formed in the solar chromosphere is of course a considerable over-simplification of the situation, but nevertheless, it should give an indication of the effects to be expected.

The goemetry of the solar atmospheric layer producing the emission is shown in Fig.2. A spherically symmetric layer of height H will have a mean tangential path length L, where

$$L = (2R_{\odot} H)^{\frac{1}{2}} \qquad \ldots (10)$$

for $H < 10^4$ km, and the base of the layer at a height $h_0 < 7 \times 10^3$ km above the photosphere. The work of HOLSTEIN (1947) shows that the imprisonment of resonance radiation is controlled by the optical depth in the direction of the shortest dimension of the atmosphere. Thus in the radial direction, the fraction of photons created, escaping in line '1' is given by equation (7), where the values of q_n are determined by τ_n in the radial direction. The probability of escape in the tangential direction will be determined by τ_n in that direction, but the re-absorption will still be determined by τ_n in the radial direction, so the fraction escaping in line '1' in the tangential direction is

$$W_1(L) = \frac{b_1 q_1(L)}{1 - \sum_n b_n(1-q_n(H))} \qquad \ldots (11)$$

However, as the term $1 - \sum_n b_n(1-q_n(H))$ in equation (11) cancels out when considering the relative intensity of two lines from a common upper level, equation (9) is still valid. Thus the relative intensity of two lines from a common upper level, depends not only on the spontaneous transition probabilities, but also, through q, on the relative optical depth in the lines.

4. DERIVATION OF OPTICAL DEPTHS FROM THE RELATIVE INTENSITIES

As shown above, the observed relative intensity of each pair of lines from a common upper level may be used to calculate the relative values of q for the lines. If both lines are optically thick, i.e. $\tau_1, \tau_2 \gg 1$, then from equation (8), $q_1/q_2 = \tau_2/\tau_1$. In this case only the ratio of the optical depths may be found. However, if one line is optically thin, $\tau_1 < 1$, then $q_1 = 1 \cdot 0$. Hence q_2 and τ_2 for the thick line can be found from equations (9) and (6). The optical depth in any of the CI lines listed in Table I may then be found, for, as will be shown below, the relative optical depths of two lines depends only on their wavelengths, oscillator strengths and the populations of their lower levels.

By definition

$$\tau = 2\tau_o = \int_o^s k_o \, ds$$

where k_o is the absorption coefficient at the line centre, s is the path length in the atmosphere. The absorption coefficient for a Doppler broadened line is given by

$$k_o = \frac{2}{\Delta\nu_D} \sqrt{\frac{\ell n 2}{\pi}} \left(\frac{\pi e^2}{mc}\right) N_1 \, f_{12} \qquad \ldots (12)$$

where $\Delta\nu_D$ is the ½-width of the line, and is given by

$$\Delta\nu_D = \frac{\nu_o}{c}\left[\frac{2RT_i \; \ell n 2}{M}\right]^{\frac{1}{2}} \qquad \ldots (13)$$

Where $\underline{T_i}$ is the ion temperature, and $\underline{M}$ is the atomic weight of the atom (in terms of that of hydrogen). $\underline{N}_1$ is the population of the lower level. Substituting for the atomic constants in eqs.(12) and (13), gives

$$\tau_0 = 5 \cdot 8 \times 10^{-15} \; \lambda(\text{Å}) \; \underline{f}_{12} \; \underline{M}^{\frac{1}{2}} \; \frac{\underline{N}_1}{\underline{N}(i)} \; \frac{\underline{N}(E)}{\underline{N}(H)} \int_0^{s} \frac{\underline{N}(\underline{i})}{\underline{N}(E)} \; \underline{N}(H) \; \underline{T}_{\underline{e}}^{-\frac{1}{2}} \; d\underline{s} \qquad \ldots (14)$$

where $\underline{N}_1/\underline{N}(\underline{i})$ is the population density of the lower level relative to that of the ion, $\underline{N}(\underline{i})/\underline{N}(E)$ is the ion abundance, $\underline{N}(E)/\underline{N}(H)$ is the abundance of the element with respect to hydrogen. $\underline{T}_{\underline{e}}$ is taken equal to $\underline{T_i}$.

From equation (14), the ratio of the optical depths of two lines from the same ion, formed in the same region of the atmosphere is

$$\frac{\tau_1}{\tau_2} = \frac{\underline{f}_1}{\underline{f}_2} \; \frac{\lambda_1}{\lambda_2} \; \frac{\underline{N}_1}{\underline{N}_2} \quad . \qquad \ldots (15)$$

Now from equation (6) it can be seen that in the case of one line being optically thin, the value of τ_2/τ_1 from equation (15), should be larger than the value of $\underline{q}_1/\underline{q}_2$ found from the observed relative intensities. This argument may now be used to show that both λ1992·0 Å and λ1993·6 Å are optically thin. From the observed upper limit of $\underline{E}$(1992·0 Å)/$\underline{E}$(1657 Å) < 0.25, it is found that $\underline{q}$(1992·0 Å)/$\underline{q}$(1657·0 Å) < $7 \cdot 20 \times 10^4$. But from equation (15) τ_0(1657·0 Å)/τ_0(1992·0 Å) > $1 \cdot 4 \times 10^5$. (Taking $N(^1D_2) \leqslant N(^3P_2)$.) Therefore τ_0(1992·0 Å) < 1, and $\underline{q}$(1992·0 Å) = 1·0. Thence it is possible by using equations (6) and (15), to calculate an upper limit of 0·75 for τ_0(1993·6 Å), so that λ1993·6 Å is optically thin. From the observed relative intensity of λ1993·6 Å and λ1656·4 Å, and $\underline{q}$(1993·6 Å) = 1·0, $\underline{q}$ and τ_0 for 1657·4 Å have been calculated. From τ_0(1657·4 Å) and equation (15), the optical depth in the remaining lines may be found if the relative populations of levels in the ground term configuration are known, and hence the value of q for each line may be calculated. It has been assumed that the levels of the ground term ^3P are populated according to their statistical weights, and $N(^1D_2)/N(^3P_1)$ and $\underline{N}(^1S_0)/\underline{N}(^3P_0)$ have been calculated from a Boltzmann distribution with $\underline{T}_r = 6000^0$K. The results are given in Table II. Only the relative intensities of lines from the $^1P_1^0$ level depend on the latter assumption, which may be checked when improved observational data are available. The relative intensities of lines from common upper levels expected on the basis of the above values of q are given in Table III, together with the observed relative intensities, and those expected if each line were optically thin.

5. CALCULATION OF N(H) FROM τ_0(1657·4 Å)

The value of τ_0(1657·4 Å) found by the method in the preceding section is τ_0(1657·4 Å) = 650, this being the value from observations at the solar limb. Substituting the atomic parameters for λ1657·4 Å in equation (15), and taking $\underline{N}(C)/\underline{N}(H) = 4{\cdot}08 \times 10^{-4}$ (from MÜLLER (1964)), it is found that

$$\int_0^L \underline{N}(H)(\underline{N}(\underline{i})/\underline{N}(E))\ \underline{T}_e^{-1/2}\ d\ell = 1{\cdot}44 \times 10^{20} \qquad \ldots (16)$$

From the ionization equilibrium of CI and CII, it is reasonable to assume that the CI lines are formed where $4500^0K < \underline{T}_e < 10{,}000^0K$. For $\underline{T}_e < 10^4\ ^0K$, $\underline{N}(\underline{i})/\underline{N}(E) = 1{\cdot}0$. Taking a mean temperature of $\underline{T}_e = 8000^0$K will not introduce a large error into the results. Then

$$\int_0^L \underline{N}(H)\ d\ell = 1{\cdot}29 \times 10^{22} \qquad \ldots (17)$$

ALLEN (1963) tabulates the scale height of $\underline{N}$(H) in the solar chromosphere as a function of temperature. For $4{,}500^0K < \underline{T}_e < 10{,}000^0K$, he gives 140 km < $\underline{H}$ < 800 km. Making use of equation (10) this gives

$1{\cdot}4 \times 10^4$ km $< \underline{L} < 3{\cdot}4 \times 10^4$ km. Taking a mean value of $\underline{L} = 2{\cdot}2 \times 10^4$km and substituting in equation (17), it is found that $\underline{N}(H) = 5{\cdot}8 \times 10^{12}cm^{-3}$. On the chromospheric model of THOMAS and ATHAY (1961), this corresponds to the value expected at $\simeq 7{,}000^{\circ}K$. Thus the optical depth found from the observed relative intensities is compatible with the values expected in the solar chromosphere.

Making use of equation (10), and assuming $\tau_{\underline{H}} = \frac{\underline{H}}{\underline{L}} \tau_{\underline{L}}$, it is possible to predict the ratio $\frac{\underline{E}(1993.6 \text{ Å})}{\underline{E}(1657{\cdot}4 \text{ Å})}$ in the spectrum observed on the disk. Using the same mean value of $\underline{H} = 3{\cdot}5 \times 10^2$ km, it is found that $\tau_0(1657{\cdot}4 \text{ Å}) = 10$, or, in terms of relative intensities $\frac{\underline{E}(1993{\cdot}6 \text{ Å})}{\underline{E}(1657{\cdot}4 \text{ Å})} = 0{\cdot}06$.

If the limb spectrum is excluding some of the radiation from the low chromosphere, then the observed disk ratio may be higher than 0·06.

6. DISCUSSION OF OBSERVED AND CALCULATED RATIOS

The pairs of lines whose intensity ratios are most sensitive to the optical depth are those for which one line is thin and the other has a large optical depth. Ratios involving a permitted line and an intercombination line are most likely to satisfy the above condition, as their oscillator strengths usually differ by several orders of magnitude. The intensity ratios given in Table III show that until the line at λ2582·9 Å can be observed there is no other ratio which can be used to distinguish between the case where all lines are optically thin, and that where certain lines (as given in Table II) are optically thick. The line at 1614·5 Å is blended with a line of SiI, and unless the rest of the $^1D_2 - {}^3P^o_{0,1,2}$ multiplet can be observed, the agreement between the observed ratio of $\underline{E}(1614{\cdot}5 \text{ Å})/\underline{E}(1930{\cdot}9 \text{ Å})$

and the calculated ratio, with the $^1D_2 - {^1P^o_1}$ transition optically thick cannot be considered significant.

7. SUMMARY OF RESULTS

The observed relative intensity of the CI lines at λ1993·6 Å and λ1657·4 Å is a factor of $2{\cdot}6 \times 10^3$ greater than that expected if both lines were optically thin. It has been shown that the observed intensity ratio may be explained in terms of the transfer of photons from λ1657·4 Å into λ1993·6 Å, due to the large optical depth in the line λ1657·4 Å. The total optical depths found for the two lines are $\tau(1993{\cdot}6 \text{ Å}) = 0{\cdot}44$, and $\tau(1657{\cdot}4 \text{ Å}) = 1300$. It is predicted that the disk ratio of the two lines should be $\underline{E}(1993{\cdot}6 \text{ Å})/\underline{E}(1657{\cdot}4 \text{ Å}) \geqslant 0.06$. The above values of τ lead to a mean hydrogen particle density of $\underline{N}(H) = 5{\cdot}8 \times 10^{12}$ cm^{-3}, for the region of the chromosphere observed. This independent evaluation of the optical depth provides a useful parameter against which models of the chromosphere may be checked.

8. ACKNOWLEDGEMENTS

The author is grateful for a considerable amount of advice from Dr A.G. Hearn, and to Dr J.B. Tatum for providing the oscillator strengths for the CI lines. She wishes to thank W.M. Burton for suggesting suitable upper limits on the intensity lines not observed, and Professor C.W. Allen and Dr R.W.P. McWhirter for their useful criticisms of the manuscript.

The author is at present attached to the Culham Laboratory from University College, London.

Note added in proof

In the present paper it has been predicted that in the disk spectrum, the relative intensity of $\lambda 1993{\cdot}6$ Å and $\lambda 1657{\cdot}4$ Å should be within the limits

$$5{\cdot}0 > \frac{E(1993{\cdot}6\ \text{Å})}{E(1657{\cdot}4\ \text{Å})} > 0{\cdot}06$$

the value depending on how much low chromospheric emission is included in the limb spectrum. In a private communication Widing has given a rough estimate of the observed ratio as $\simeq 0{\cdot}6$. This gives $\tau(1657{\cdot}4\ \text{Å})_{disk} = 200$, and with $T_e = 8000^{o}K$, $H = 750$ km, leads to $N(H) = 2{\cdot}6 \cdot 10^{13} cm^{-3}$.

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TABLE I

Observed Intensities and Atomic Data for CI Transitions

Transition	ΔJ	λ Å	E 10^{-8} erg.cm^{-2}sec^{-1}	f_{12} / 10^{-2}	A_{21} / 10^{7} sec
$2p^2\ ^3P$ - $2p3s\ ^3P^o$	2-2	1657·0	200	1·58	3·84
	2-1	1658·1	150	0·526	2·13
	1-2	1656·3	150	0·878	1·28
	1-1	1657·4	200	0·526	1·28
	1-0	1657·9	200	0·702	5·11
	0-1	1656·9	< 150	2·11	1·71
- $2p3s\ ^1P^o$	2-1	1614·5	50	$1·81.10^{-4}$	$7·70.10^{-4}$
	1-1	1613·8	< 20	$1·19.10^{-4}$	$3·04.10^{-4}$
	0-1	1613·4	< 20	$5·85.10^{-3}$	$4·99.10^{-3}$
$2p^2\ ^1D$ - $2p3s\ ^3P^o$	2-2	1992·0	< 50	$9·58.10^{-6}$	$1·61.10^{-5}$
	2-1	1993·6	1000	$1·06.10^{-3}$	$2·97.10^{-3}$
- $2p3s\ ^1P^o$	2-1	1930·9	120	2·45	7·29
$2p^2\ ^1S$ - $2p3s\ ^3P^o$	0-1	2582·9	<1000	$1·84.10^{-2}$	$6·12.10^{-3}$
- $2p3s\ ^1P^o$	0-1	2478·6	<1000	4·11	1·49

TABLE II

Values of τ_o, $\underline{q}$ for the CI Lines

Transition	ΔJ	Å	τ_o	$\underline{q}$
$2\underline{p}^2\ ^3P - 2\underline{p}3\underline{s}\ ^3P^o$	2-2	1657·0	3260	$5{\cdot}20 \times 10^{-5}$
	2-1	1658·1	1080	$1{\cdot}66 \times 10^{-4}$
	1-2	1656·3	1080	$1{\cdot}66 \times 10^{-4}$
	1-1	1657·4	650	$3{\cdot}86 \times 10^{-4}$
	1-0	1657·9	not needed	
	0-1	1656·9	868	$2{\cdot}16 \times 10^{-4}$
$- 2\underline{p}3\underline{s}\ ^1P^o$	2-1	1614·5	0·363	1·0
	1-1	1613·8	0·144	1·0
	0-1	1613·4	2·35	0·20
$2\underline{p}^2\ ^1D - 2\underline{p}3\underline{s}\ ^3P^o$	2-2	1992·0	0·0020	1·0
	2-1	1993·6	0·221	1·0
$- 2\underline{p}3\underline{s}\ ^1P^o$	2-1	1930·9	495	$4{\cdot}25 \times 10^{-4}$
$2\underline{p}^2\ ^1S - 2\underline{p}3\underline{s}\ ^3P^o$	0-1	2582·9	0·022	1·0
$- 2\underline{p}3\underline{s}\ ^1P^o$	0-1	2478·6	4·64	$8{\cdot}0 \times 10^{-2}$

TABLE III

Observed and Calculated Relative Intensities

Standard Transition	Relative Transition	λ Å	Intensities relative to that of standard transition		
			Observed	$\tau_o < 1$	Calculated τ_o from Table 2
$^3P_2 - {}^3P^o_2$		1657·0	1·00	1·00	1·00
	$^3P_1 - {}^3P^o_2$	1656·3	0·75	0·33	1·05
	$^1D_2 - {}^3P^o_2$	1992·0	0·25	$3{\cdot}48 . 10^{-6}$	$6{\cdot}70 . 10^{-2}$
$^3P_1 - {}^3P^o_1$		1657·4	1·00	1·00	1·00
	$^3P_o - {}^3P^o_1$	1656·9	0·75	1·34	0·75
	$^3P_2 - {}^3P^o_1$	1658·1	0·75	1·67	0.72
	$^1D_2 - {}^3P^o_1$	1993·6	5·0	$1{\cdot}93 . 10^{-3}$	5·0
	$^1S_o - {}^3P^o_1$	2582·9	5·0	$3{\cdot}06 . 10^{-3}$	7·98
$^1D_2 - {}^1P^o_1$		1930·9	1·00	1·00	1·00
	$^3P_o - {}^1P^o_1$	1613·4	0·17	$8{\cdot}20 . 10^{-4}$	0·39
	$^3P_1 - {}^1P^o_1$	1613·8	0·17	$4{\cdot}90 . 10^{-5}$	0·12
	$^3P_2 - {}^1P^o_1$	1614·5	0·42	$1{\cdot}26 . 10^{-4}$	0·30
	$^1S_o - {}^1P^o_1$	2478·6	8·3	0·16	3·0 . 10
$^3P_2 - {}^3P^o_2$		1657·0	1·00	1·00	1·00
	$^3P_1 - {}^3P^o_1$	1657·4	1·0	0·20	1·48

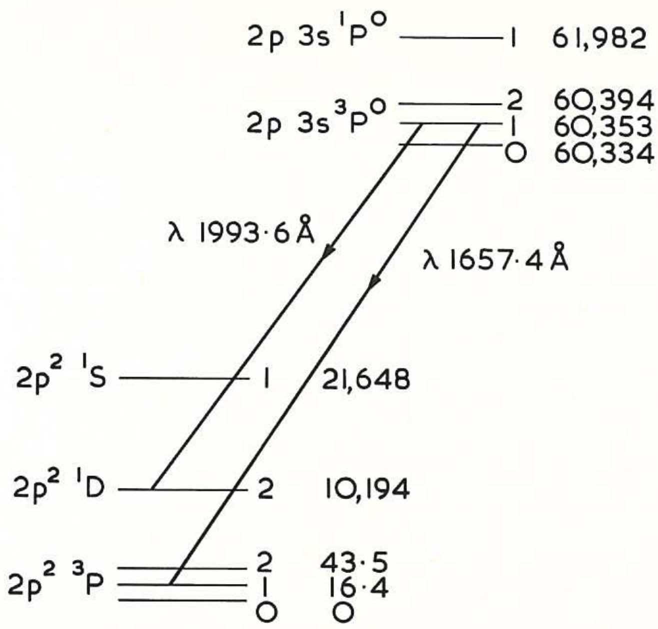

Fig. 1 (CLM-P 146)
Energy levels in CI, with energies in cm^{-1}

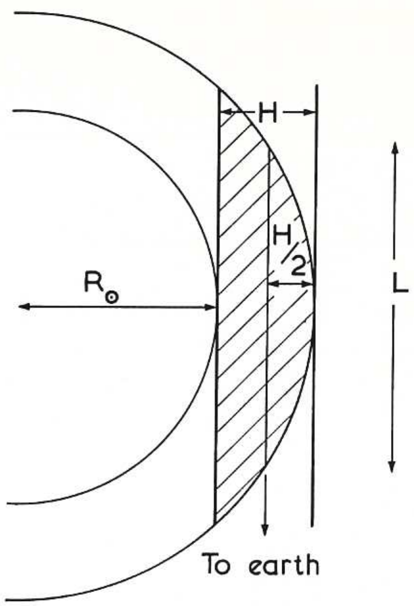

Fig. 2 (CLM-P 146)
Plan of a layer of the chromosphere observed at the limb