PROFILES OF H\textsc{i} (L\alpha), Mg\textsc{ii} (h and k), Ca\textsc{ii} (H and K) LINES OF AN ACTIVE FILAMENT AT THE LIMB, WITH THE LPSP INSTRUMENT ABOARD THE OSO-8 SATELLITE

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Abstract. We scanned the H\textsc{i} L\alpha, Mg\textsc{ii} h and k, Ca\textsc{ii} K and H lines simultaneously with the LPSP instrument on OSO-8, to investigate the low and moderate temperature regions of an 'active region filament'. The L\alpha line is not reversed except for the innermost position in the prominence. Intensity (k/h), (K/H) ratios are respectively 2 and 1.1, indicating that the Mg\textsc{ii} lines are optically thin, and that Ca\textsc{ii} K is saturated, although not clearly reversed. The results obtained during the second sequence of observations (K saturated before L\alpha for example) indicate that within the size of the slit (1''×10'') we are not observing the same emitting features in the different lines.

We also observe an important line-of-sight velocity at the outer edge of the feature, increasing outwards from a few km s\(^{-1}\) to 20 km s\(^{-1}\) within 2''. Less than half an hour later, this velocity is reduced to 15 km s\(^{-1}\) while the intensities increase. Full width at half maximum intensities for this component indicate turbulence variations from 22 to 30 km s\(^{-1}\). The observed high velocities at the top of the prominence can be compared with radial velocities that Mein (1977) observed in H\alpha at the edges of an active filament and interpreted as velocity loops slightly inclined on the axis of the filament.

1. Introduction

With space-borne experiments, the UV spectral range is now available for prominence observations. Previous OSO and Skylab results refer to the prominence-corona interface as observed in the EUV lines formed at temperatures ranging from a few times 10 000 K to 10\(^{6}\) K. Noyes et al. (1972) noticed that prominences appear as faint objects for temperatures above 3 × 10\(^{5}\) K; Schmahl et al. (1974) showed that prominence material is optically thick in the L\alpha line and Lyman continuum of H\textsc{i}. Rocket slitless spectra obtained during the 1970 eclipse (Gabriel et al., 1971; Orrall and Speer, 1974) led to the same conclusions. The comparison between prominence and disk brightnesses for the whole set of lines recorded on Skylab makes an 'emission measure' analysis possible (Orrall and Schmahl, 1976) for the prominence-corona interface.

As far as the cool part of a prominence is concerned, photometric measurements have been made, from the ground, in visible hydrogen, helium and calcium lines: recent results are found in Landman and Illing (1977), Landman et al. (1978), Engvold (1976). Brightnesses or line ratios may be compared to the results of theoretical models; for example, those of Ishizawa (1971), Heasley and Milkey (1976), Poland et al. (1971), which assume departures from LTE.

On the other hand, line profiles can provide data on the opacity, temperature, and turbulent motions in prominences. Analysis of visible hydrogen and helium lines has
established a low temperature \((T \approx 6000 \text{ K})\) and a turbulence of about \(6 \text{ km s}^{-1}\) for quiescent prominences and higher values for active prominences (see Tandberg-Hanssen's Solar Prominences, p. 16). Ca II profiles have been measured by Engvold and Livingston (1971), Morozhenko (1974), and more recently by Mouradian and Leroy (1977) together with Hα, Landman et al. (1977) with Hβ and D3 and Engvold (1978) with Hα and D3. Inferred temperature and turbulence values are in the ranges 8000–10 000 K and 5 to 8 \text{ km s}^{-1}; moreover, Landman et al. (1977) called attention to a two component structure of the profiles that would have been missed had only brightness measurements been available.

A few measurements have been made in the h and k lines of Mg II. Bonnet et al. (1967) first detected Mg II emission on a medium resolution (0.4 Å) spectrum cutting across a prominence on January 13, 1967, Fredga (1969) obtained an image, and Feldman and Doschek (1977b) measured both profiles above an active region with a 0.12 Å resolution and derived nonthermal velocities ranging from 15 to 25 \text{ km s}^{-1} for distances 4" to 8" above the limb. Hydrogen Balmer series profiles give velocities between 0 to 15 \text{ km s}^{-1} at 2" above the limb (Feldman and Doschek, 1977c), but these authors found low velocities in the transition zone between quiescent prominences and the corona.

The Lα line of H I which is formed at higher temperatures has been extensively studied by Hirayama (1964), Yakovkin and Zeldina (1968), Burns (1970), and Poland et al. (1971). Kawaguchi (1964) suggested that, although detailed balance may hold in the interior of the prominence, the Lα radiation may be transferred to Lyman continuous quanta as a result of absorption of the Balmer continuous radiation and subsequent recombination to the ground level at the surface. This is a way to take into account the need for a strong penetration of the UV radiation field in the prominence, established by the non LTE computations of Heasley and Mihalas (1976), and Heasley and Milkey (1976). Until now no emergent Lα profile has been computed or measured.

We present below simultaneous profiles of H I (Lα), Mg II (k and h), and Ca II (H and K) lines, obtained with the LPSP instrument on OSO-8, on an 'active region filament' (following Tandberg-Hanssen's definition) as it crossed the west limb. Profiles of these 5 lines have also been obtained for quiescent prominences and will be published later.

The Lα and Mg II profiles on a prominence with a 20 mÅ resolution are the first to be reported in the literature.

2. Observations

The feature studied in this paper is a long filament, one foot of which was located above the spot of active region MacMath No. 13738. We observed it on 7 July 1975 at 10 UT when it was at the west limb, while the spot was already beyond it. Internal images were generated during the passage of the spacecraft through the South Atlantic Anomaly and could not be used for localization purposes. This was done
instead using the scarce material available, namely the Boulder Hα spectro-
heliogram of the day and a Hα coronographic picture taken at 18:54 UT at Meas Solar Observatory. Hα spectroheliograms, daily maps of the Sun and Hα synoptic charts enabled us to locate precisely 4 prominences which are visible on the coronographic plate. On the other hand, the spacecraft pointing quality was checked and corrected for non-linearity effects. From this data we computed the actual position of the slit above the limb and were able to locate it on the Hα coronographic plate. Figure 1 shows an enlargement of the Hα image: the pointed structure is about 12" high above the occulting disk; the size and the orientation of the slit are also shown.

![Image](image)

Fig. 1. Part of the Hα coronographic image obtained at 18:54 UT, 7 July 1975 (Courtesy Meas Solar Observatory, Hawaii). The structure and the slit are indicated with an arrow.
2.1. Observing Procedure

Information on the instrument and the observing techniques is given by Artzner et al. (1977) and Bonnet et al. (1978).

Using the instrument's own rastering capability, we observed the prominence in eight radial steps of one arc sec, using a $1'' \times 10''$ slit. We then returned to the first position, and repeated the sequence. At each position we made a spectral scan with 256 consecutive grating positions from $-1.1$ to $+1.0$ Å in $\lambda_\alpha$, $-2.3$ to $2.1$ Å in Ca II, and $-2.8$ to $2.6$ Å in Mg II lines. The equivalent gate time was 0.52 s for each of the 256 steps and the spectral resolution was 20 mÅ.

2.2. Raw Data

Hereafter, we refer to the 8 positions as 27, 28, ..., 34, in order of increasing distance from the limb. These numbers are the actual azimuthal values of the position of the secondary mirror in an internal $64'' \times 64''$ raster. The scanning direction was nearly perpendicular to the solar limb. The number of counts per 0.13 s is lower than predicted, based on the size of the slit and the transmission of the instrument. We compared the observed Ca K and H wings with the wings computed from the measured instrumental scattered light at the same distance from the solar limb. The rapid increase of the scattered light in proportion with the aging of the instrument, made the comparison difficult. We concluded that the slit could not be properly opened by a maximum area factor of 2. Most of our results will therefore be given as count numbers but absolute intensities are also computed, roughly.

2.3. The Reduction Procedure

Each detector's dark current (measured every 3 mn) was subtracted from the signal. The scattered light was removed with the following method: profiles obtained at the outermost part of the spatial scan (position 34) were found to result from the instrumental diffusion of disk light; for each line, they were averaged and the resulting profile was subtracted with the appropriate factor, from the other profiles (Lemaire, 1978).

For the $\lambda_\alpha$ line, since the position and width of the geocoronal reversal are well known (and are used as a wavelength reference, see Section 3.1.b), we removed the geocoronal feature from the $\lambda_\alpha$ line by a parabolic least-square fit.

The profiles were then deconvolved from the spectrometer profile (including grating ghosts) and smoothed with a Fourier technique, following Brault and White (1971).

3. Analysis of Data

Each profile required about 164 s observing time, and the full sequence of observations covering positions 27 to 34 was completed in almost 21 min. We have two sequences, for positions 27, 28, 29, 30 (first sequence, Figure 2), and positions 27, 28,
Fig. 2a–c.
Deconvolved $\lambda$, k, h, K, H profiles superimposed for positions 27, 28, 29, 30 (first sequence). (Abscissae: velocity (km s$^{-1}$) except for $\lambda \alpha$ where the distance to the center of the line is in Å; ordinates: total number of counts for the counting gate, 0.52 s). (a): $\lambda \alpha$; (b): k; (c): h; (d): K; (e): H. For all lines: $\bigcirc$ (circles) – position 27; $\triangle$ (triangles) – position 28; $+$ (plus) – position 29; $\times$ (crosses) – position 30. $\lambda \alpha$ geocoronal reversal has been removed.

29 (second sequence, Figure 3), scanned 21 min later. In Figure 2, we include spectra obtained at position 30 to show that the prominence emission decreases rapidly as we move the slit outwards.

3.1. Spatial analysis

Figures 2 and 3 show the $\lambda \alpha$, h, k, K, and H profiles, superimposed for different consecutive positions. The wavelength scale is in ångstroms for $\lambda \alpha$, and in velocity units for the other lines. The determination of the ‘zero’ velocity is discussed at the end of this paragraph and positive velocities correspond to movements detected
Fig. 3a-c.  \( \text{L} \alpha, \text{Mg} \, \text{II} \, \text{k} \) and \( \text{Ca} \, \text{II} \, \text{K} \) profiles superimposed for positions 27, 28, 29 (second sequence). Same units and symbols as for Figure 2. (a) refers to \( \text{L} \alpha \), (b) to k, (c) to K lines.
towards the observer. We concentrate our attention on the cores of the lines, and limit the profiles to ±0.5 Å for Lα and ±80 km s⁻¹ for the metallic lines.

3.1.a. First Sequence (Figure 2)

Lα profile: Figure 2a shows the change from a slightly reversed profile (position 27) to non-reversed profiles with a statistical accuracy of 3%. Full widths at half maximum (FWHM) range from 0.58 to 0.41 Å (Table 1a).

<table>
<thead>
<tr>
<th>Line</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27</td>
</tr>
<tr>
<td>Lα</td>
<td>0.58</td>
</tr>
<tr>
<td>k (Mg II)</td>
<td>36</td>
</tr>
<tr>
<td>h (Mg II)</td>
<td>37</td>
</tr>
<tr>
<td>K (Ca II)</td>
<td>38</td>
</tr>
<tr>
<td>H (Ca II)</td>
<td>45</td>
</tr>
</tbody>
</table>

Mg k profile: In Figure 2b, we recognize two components: the main component has a positive velocity which increases outwards from position 27 to 29.

Mg h profile: Inspection of Figure 2c shows the same behaviour as for Mg k. The positions of the main components given in Table IIa do not differ for Mg k and h by more than 2 km s⁻¹, corresponding to 1 grating step. The FWHM of this component, given in Table 1a, also do not differ by more than 2 km s⁻¹ for k and h. The negative (red-shifted) component is centered around ~33 km s⁻¹ but fades out in the outer parts of the prominence (position 29).
### TABLE IIa

Velocity of the main component for metallic lines as a function of the spatial position (unit: km s\(^{-1}\)) for sequence 1

<table>
<thead>
<tr>
<th>Position</th>
<th>27</th>
<th>28</th>
<th>29</th>
<th>30</th>
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<tr>
<td>k</td>
<td>4</td>
<td>10.5</td>
<td>21.5</td>
<td>5</td>
</tr>
<tr>
<td>h</td>
<td>3</td>
<td>8.5</td>
<td>19.5</td>
<td>8</td>
</tr>
<tr>
<td>K</td>
<td>4</td>
<td>11</td>
<td>23.5</td>
<td>11</td>
</tr>
<tr>
<td>H</td>
<td>4</td>
<td>6</td>
<td>23</td>
<td>6</td>
</tr>
</tbody>
</table>

### TABLE IIb

Velocity of the main component (unit: km s\(^{-1}\)) for sequence 2

<table>
<thead>
<tr>
<th>Position</th>
<th>27</th>
<th>28</th>
<th>29</th>
</tr>
</thead>
<tbody>
<tr>
<td>k</td>
<td>3</td>
<td>7.5</td>
<td>15</td>
</tr>
<tr>
<td>h</td>
<td>9</td>
<td>7.5</td>
<td>16</td>
</tr>
<tr>
<td>K</td>
<td>7.5</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>H</td>
<td>3</td>
<td>9</td>
<td>16</td>
</tr>
</tbody>
</table>

Ca II H and K profiles: (Figures 2d, e). They display a complex velocity structure, but contain a main component which shifts increasingly to the blue (positive velocities) as we go from position 27 to 29 and a secondary component centered at about \(-21.5\ \text{km s}\(^{-1}\). Despite these similarities, H and K show differences. These differences, already present in the h and k profiles, are more important here and include differences in the ratio of intensities and the widths of the blue and the red components (see discussion in Section 3.1.b).

This is illustrated, for instance, by the broad width at line center of the H profile at position 28, compared to a two-component K profile. This made the determination of the FWHM and the position of the blue component sometimes impossible (Tables Ia and IIa).

#### 3.1.b. Second Sequence

Figures 3a, b, c, show spectra obtained 21 min after the first sequence for Lα, Mg k and Ca K. Mg h and Ca H are similar to Mg k and Ca K, respectively. Tables Ib and IIb summarize the blue peak FWHM and positions for all 5 lines.

Lα: From Figure 3a, position 27 is the only one which gives a reversal; position 29 is very bright but unreversed.

Mg k (and h): From Figure 3b and Table Ib, the FWHM are constant except for Mg h at position 29 where the FWHM is smaller. The blue component, as measured
in k and h, is consistent for positions 28 and 29 (+7.5 and 15.5 km s\(^{-1}\)) but not for position 27 (see below).

Ca K (and H): The Ca K line, in Figure 3c, shows an important red component between \(-12\) and \(-18\) km s\(^{-1}\). As a result, the FWHM of the blue component could not be evaluated for positions 27 and 28. The peak position of this last component varies from +7.5 to 18 km s\(^{-1}\).

A careful inspection of Tables Ia, b, IIa, b, raises questions concerning the differences between k and h, K and H. As far as velocities are concerned, the sources of error are due to the determination of the 'zero velocity' position, the dispersion and the statistics. In the Mg II and Ca II channels, no reliable photospheric line is present in the spectra and we relied upon spectra performed a few orbits later at Sun center. The precision of this determination is \(\pm 1\) step, and it has been shown by Lemaire (1978) that the thermal drift within one orbit is the same for all lines and is less than one grating step.

The dispersion law is very well established and gives a relative position determined better than 0.1 step at small distances from the central position. For most profiles, the statistics are high enough to allow for a \(\pm 0.5\) step precision in the computation. This means that the overall precision for the position of the blue component is better than \(\pm 2\) grating steps, corresponding to \(\pm 4.8\) km s\(^{-1}\) for the lines of Mg II, and \(\pm 2.4\) km s\(^{-1}\) for the lines of Ca II. Our precision is twice as good for the FWHM since in this case no absolute velocities are needed, i.e. \(\pm 2\) km s\(^{-1}\) for L\(\alpha\), \(\pm 2.4\) for Mg II and \(\pm 1.2\) km s\(^{-1}\) for Ca II. However, due to poor statistics and larger difficulties in correcting for stray light, the Ca II H line shows a somewhat different profile from the Ca II K one.

The discrepancies between the Mg and Ca lines may be explained as due to the presence of numerous emitting structures which vary differently with time and position in the two sets of lines.

Contrary to Landman et al. (1977), we did not attempt to split the profiles into two (or more) gaussian functions and evaluate the contribution of each one to the observed intensity. Nevertheless, we can clearly identify two components, an important 'blue' component with velocity varying between 4 to 20 km s\(^{-1}\) (sequence 1) and 6 to 16 km s\(^{-1}\) (sequence 2) for positions differing only by 2" above the limb, and a weaker 'red' component.

3.2. Temporal variations

The profiles obtained during the first and second sequence are superimposed in Figures 4a, b, c (position 27), Figures 5a, b, c (28), and Figures 6a, b, c (29). Most lines show a lower intensity in sequence 2 for positions 27 and 28 and the main component remains at +4 km s\(^{-1}\) (27) and 8 km s\(^{-1}\) (28). At position 28\(_2\) (second sequence) Ca K exhibits a somewhat different behaviour with equally bright blue and red components at velocities of \(\pm 14\) km s\(^{-1}\). However, at position 29, the L\(\alpha\) and Mg k profiles are notably brighter during the second sequence whereas the Ca II K lines are equally bright. The blue shift is about 4 km s\(^{-1}\) smaller during sequence 2.
Fig. 4a–c. Superimposed Lα, Mg k, Ca K profiles for positions 27₁ and 27₂ (first and second sequence). Not different from Mg k and Ca K, h and H lines have been omitted in Figures 4, 5, and 6. (a) refers to Lα, (b) to k, (c) to K. ○ (circles) – sequence 1; △ (triangles) – sequence 2.
Fig. 5a–c. Same as Figure 4 for positions $28_1$, $28_2$. 

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Fig. 6a–c. Same as Figure 4 for positions $29_1, 29_2$. 
3.3. Integrated Intensities and Positions in the Prominence

We added all the counts within the ranges (−0.5, +0.5 Å) for Lα and (−80 km s\(^{-1}\), +80 km s\(^{-1}\)) for all other lines and present in Figure 7 the variation of this total number of counts versus the radial position for sequences 1 and 2. The first sequence shows the edge of the observed structure. The second one indicates that this edge has moved outwards during 21 min in the Mg \(\text{II}\) and Ca \(\text{II}\) lines and the relative intensities of the five lines are somewhat different (28 is the peak position for k and H, the lowest for K, and intermediate for h). In particular, the Lα line shows a strong enhancement at position 29 where the error bar corresponds to the statistical accuracy. The examination of the Ca \(\text{II}\) H and K wings showed that no pointing variation between sequence 1 and sequence 2 could account for these differences.

3.4. Line Intensity Correlations

We now compare integrated intensities as has been done previously for the hydrogen

![Image of Figure 7](image-url)

Fig. 7. Integrated intensities (total number of counts within the range (−0.5, +0.5 Å) for Lα and (−80, +80) km s\(^{-1}\) for other lines plotted against the horizontal position: ---: Lα, ------: Mg k, -- -- --: Ca K, --- ---: Mg h, --- ---: Ca H. Left-hand side refers to sequence 1; right-hand side to sequence 2. The total number of counts should be multiplied by 10 for Ca K and Ca H.
lines (Stellmacher, 1969) and the Ca$^+$ and He lines (Illing et al., 1975; Landman and Illing, 1976, 1977; Landman et al., 1978). We compute integrated intensities as the sum of recorded counts, corrected for the different exit slit widths, grating step sizes and instrument sensitivities. We compared profiles obtained on a quiet region a few orbits later with calibrated spectra (Kitt Peak Atlas; White and Suemoto, 1968; Kohl and Parkinson, 1976) to determine the relative sensitivities for k, h, K and H. Transmission ratios are 1.2 ± 0.4 for k/h and 2.0 ± 0.3 for K/H.

Figure 8a shows the results for Ca K and H. A large scatter exists around a least squares linear correlation which we attribute to poorer statistics in the Ca H channel. When respective sensitivities are taken into account, the intensity ratio averaged on position 27, 28, 29 turns to be 1.05 ± 0.3. This is a particularly low value, as compared to Engvold (1978) and would imply a high saturation of the K line.

The Mg k and h data in Figure 8b contain only a few points which depart from a straight line. These points are for the second sequence of observations and are shown as 27, 28, 29. When statistical accuracy is taken into account (see error bars), they are very close to the line. From the slope of this line, we derive an intensity ratio of 2 ± 0.6, the value given by the oscillator strengths.

On Figure 8c, which correlates k to Lα, one straight line can not fit the observations and we have drawn two possible lines corresponding to low and high intensity regions. This lack of correlation is not surprising since these lines are probably formed at different temperatures. The observed correlation for low k and Lα intensities can be explained if resonance scattering of chromospheric k and Lα lines is the source of emission: intensities are then proportional to line-of-sight populations.

The correlation is better between Ca K and Lα (Figure 8d). The last two correlation plots indicate some Mg$^+$ k and Ca$^+$ K saturation when the intensities are large for the second sequence of observations (points 27, 28, 29). The (Mg k, Ca K) correlation (Figure 8e) indicates that these points lie on a straight line but with a negative slope (line 2). We wish to stress that all the lines are recorded simultaneously through the same entrance slit. Moreover, we checked carefully that the pointing system worked properly. Thus the negative correlation (Figure 8e) must be solar. Jefferies and Orrall (1958) suggested that H and He lines are formed in different regions. Is this also true for Ca$^+$, Mg$^+$, and H? The lack of simple linear correlations among the lines may also be simply the result of the different ways Lα, k, h, and K, H lines are formed. Lα is formed by photoionization and subsequent cascade (a radiation effect) and hence is sensitive to the Lyman continuum incident radiation, while the Mg$^+$ k intensity decreases when Mg$^+$ is ionized (perhaps a thermal effect).

3.5. Absolute intensities

Despite the slit problem mentioned above, we estimated the emergent intensities (Table III) using the maximum slit area factor of 2. When we take into account the uncertainty of the positioning of the slit (measured from the scattered light), the
Fig. 8a–c.
Fig. 8d–e. Correlations between integrated intensities of lines. (a): (Ca K, Ca H); (b): (Mg k, Mg h); (c): (Mg k, Lα); (d) (Ca K, Lα); (e): (Mg k, Ca K). Ca K, Ca H number of counts should be multiplied by 10.
### TABLE III

Line intensities for both sequences of observations (units: ergs s$^{-1}$ cm$^{-2}$ sr$^{-1}$)

<table>
<thead>
<tr>
<th>Line Position</th>
<th>$\lambda_{\alpha}$ (10$^4$)</th>
<th>Mg $k$ (10$^4$)</th>
<th>Mg $h$ (10$^4$)</th>
<th>Ca $K$ (10$^4$)</th>
<th>Ca $H$ (10$^4$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27$_1$</td>
<td>2.2</td>
<td>3.1</td>
<td>1.6</td>
<td>7.4</td>
<td>5.7</td>
</tr>
<tr>
<td>28$_1$</td>
<td>1.4</td>
<td>2.6</td>
<td>1.3</td>
<td>4.9</td>
<td>4.15</td>
</tr>
<tr>
<td>29$_1$</td>
<td>1.1</td>
<td>1.6</td>
<td>0.8</td>
<td>3.7</td>
<td>3.25</td>
</tr>
<tr>
<td>27$_2$</td>
<td>1.1</td>
<td>2.1</td>
<td>1.1</td>
<td>4.5</td>
<td>4.7</td>
</tr>
<tr>
<td>28$_2$</td>
<td>1.0</td>
<td>2.4</td>
<td>1.1</td>
<td>4.1</td>
<td>6.4</td>
</tr>
<tr>
<td>29$_2$</td>
<td>1.8</td>
<td>2.3</td>
<td>1.2</td>
<td>4.2</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Precision of the relative sensitivity determination, and the precision of the absolute intensities (see Lemaire, 1978), we estimate the following accuracies in the absolute intensity measurements: $-56$, $+6\%$ for $K$, $-55$, $+5\%$ for $H$, $-74$, $+16\%$ for $h$ and $k$, $-85$, $+35\%$ for $\lambda_{\alpha}$.

Ca II H and K intensities exceed the values of Landman and Illing (1977), but are consistent with the measurements reported by Heasley et al. (1977), Engvold and Livingston (1971) and Engvold (1978) on quiescent prominences.

Mg II intensities show that the brightest point is one half as intense as $k_{1,0}$ on the disk ($1/3$ for $h_{1,0}$). All values are comparable with those reported by Feldman and Doschek (1977-a) for an active region 12" above the limb (1.8 and $1.1 \times 10^4$ ergs cm$^{-2}$ s$^{-1}$ sr$^{-1}$ for $k$ and $h$).

$\lambda_{\alpha}$ is as bright in the prominence at position 27 as on the disk. Vernazza and Reeves (1978) found fainter off-limb active regions, but our values are in the low range of intensities computed by Heasley and Mihalas (1976) for different quiescent prominences models. Their computations (see their Table 2) show that the $H\alpha$ intensity is not very different from the $\lambda_{\alpha}$ intensity. $H\alpha$, then, should be as high as $5 \times 10^{-2} B_0$, and be easily visible on spectroheliograms. It is necessary to point out, however, that active filaments are variable objects with complex structures compared to quiescent prominences. Since our measured $\lambda_{\alpha}$ intensity is quite uncertain we directly compared our values with measurements performed at Sun center a few orbits before and after. With an accuracy of ($-53$, $+3\%$), we find that the ratio of measured $\lambda_{\alpha}$ intensity in the prominence to the intensity in a quiet region at Sun center ranges from 1.35 to 0.6 (positions 27$_1$ and 28$_2$, respectively).

### 4. Interpretation of the Data

Most of our observed profiles of metallic lines indicate two systematic flows, relatively faint material with a receding velocity of the order of 20 km s$^{-1}$ and bright material with an approaching velocity as high as 20 km s$^{-1}$. We have established that this line of sight velocity increases outwards. We compare here these features with
other observations on different filaments. On the July 15, Hα synoptic chart, the filament is 37° inclined on the Equator. We can first consider the observed line-of-sight velocities as the projections of velocities parallel to the filament (and 1.25 times higher). Smith (1968) noticed and absorption or emission flow along the axis of the filament directed towards a sunspot seen on the disk. In our data the flow appears to come from the spot, which is located behind the limb. Our filament can be compared with the arch filament system described by Bruzek (1967) in that our filament has a mass flow along the filament as high as 20 km s\(^{-1}\) and some expansion with a velocity of \(\sim 1\) km s\(^{-1}\) (as measured, here, by the difference between sequences 1 and 2). Moreover, we noticed an increasing flow towards the edge over a distance scale of only 2". This result and the existence of two components (at least) may indicate that within an area of 3" \(\times\) 10" we are looking at two shallow arches with flows originating from a common footpoint located at the very limb.

Hα observations of an activated filament by Mein (1977) showed an increasing radial velocity towards the edges of the filament with opposite signs on both sides. Velocity loops inclined at small angles on the axis of the filament were suggested by Mein. Such a picture may be valid here, if we consider that, at the limb, we are observing the top of such loops, where velocities are horizontal.

Engvold et al. (1978) recently report that one third of quiescent prominences show moving edge features, with average line shifts of 30–40 km s\(^{-1}\) and dimensions perpendicular to the edge, of 1–2 arc sec; their emission line profiles also consist of several components. The authors suggest that these moving edge features are the result of magnetic reconnection between the prominence and the surrounding cavity fields.

None of the above pictures can be ruled out in the case of our observations.

Most of our observed profiles are not reversed. Lα is reversed only for position 27, for which the peak separation \(\Delta \lambda_p\) is 0.35 Å and 0.25 Å for sequences 1 and 2 respectively. If we assume that the source function decreases monotonically along the line of sight from the position where the peaks are formed to the position where the reversed part is formed, we can derive the line center optical depth \(\tau_0\) by

\[
\tau(\Delta \lambda_p/2) = \tau_0 \exp \left[ -\left( \frac{\Delta \lambda_p}{2 \Delta \lambda_D} \right)^2 \right] = 1,
\]

where we assume a Doppler absorption profile, incoherence within 3 Doppler widths (±0.18 Å), and the Barbier–Eddington approximation.

The Doppler width, taken as constant, is computed with the local mean temperature and velocity \((T \sim 10 000\) K, \(v \sim 8\) km s\(^{-1}\)), leading to \(\tau_0\) of the order of \(10^5\) and \(10^3\) for position 27\(_1\) and 27\(_2\).

In spite of high uncertainties in the determination of lines ratios, K/H and k/h ratios of 1.05 and 2 (respectively) indicate that Ca \(\Pi\) lines are saturated while Mg \(\Pi\) lines are not. This fact contradicts the higher abundance of Mg, compared to Ca. Previous observations show that K/H ratio may be as low as 1 for bright prominences.
(Engvold, 1978) and k/h ratio as high as 1.95, 20" above an active region at the limb (Feldman and Doschek, 1977a). But these observations refer to different structures. We suggest that the temperature in the region of the prominence we observed is low enough (≈6000 K) to prevent full Mg ionization and still allows for Ca ionization.

The FWHM for metallic lines, measured on the main blue component, are about 37 km s\(^{-1}\) and 50 km s\(^{-1}\) for sequences 1 and 2. Neglecting the small thermal contribution, we find turbulent velocities of 22 and 30 km s\(^{-1}\), respectively. These values are compatible with active filament velocities (described by Liszka, 1970), but we cannot separate microturbulence from macroturbulent 'clouds'.

We notice also that the FWHM do not change appreciably with height above the limb. Hirayama (1971) noticed a rise of the kinetic temperature from the central to the outer part of a quiescent prominence (6000 to 12 000 K) and of the turbulent velocity (7.9 to 20 km s\(^{-1}\)). Such a result is not found for the main (blue-shifted) component of the active region prominence we observed.

5. Conclusion

With the first simultaneous profiles of H I \(\lambda\alpha\), Mg II k and h, Ca II K and H lines obtained for an active region prominence above the limb, we find the following features:

1. A complex velocity structure with an approaching line-of-sight velocity that increases towards the periphery of the prominence and reaches 20 km s\(^{-1}\). This structure is persistent for 21 min despite intensity changes. These changes are not the same for \(\lambda\alpha\) as for other lines, perhaps due to the different mechanisms of line formation.

2. The turbulence of the approaching component remains in the range 22 to 30 km s\(^{-1}\) for 21 min.

3. We do not notice an increase of the excitation at the outer edge of the prominence.

4. Our \(\lambda\alpha\), Mg II k and h, Ca II H and K brightnesses are comparable with previously measured or computed ones. While most of our \(\lambda\alpha\) profiles are not reversed and the intensity ratio k/h = 2, the Ca II lines seem to be saturated (K/H = 1.1).

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References


