LINE INTENSITIES OF CHROMOSPHERIC AND PHOTOSPHERIC SPECTRA OF A FLARE

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ABSTRACT

In this work we present the intensities of spectral lines determined from the time series of high resolution spectra obtained during the relaxing phase of subflare. The spectra were taken in the core of chromospheric Ca II K line and in two photospheric Fe I 522.5 nm and Fe I 557.6 nm lines. It is shown, that the energy of the flaring chromosphere slightly affects the underlying photospheric layers by heating a small area right under the core of the subflare.

Key words: solar spectral lines; photosphere; chromosphere; flare.

1. INTRODUCTION

The Ca II K line is widely used as a diagnostic tool for chromospheric observations, especially of solar flares ([1], [2], [3], [4]). This line provides many information about the physical conditions of the flaring chromosphere. During the impulsive phase of a flare the Ca II K line has strong red asymmetry [4], line core intensities exceed the continuum intensity and the line profile shows an unusual shape and behaviour.

In this work the core of Ca II K line, formed in a height of about 1500 km, was used to map the physical characteristics in a subflare. Strongly variable profile in active regions makes the restrictions for determining all the common intensities of K_1, K_2 and K_3 features. Thus the integrated intensity in 1 Å interval around the line center is often used.

The photospheric Fe I 557.6 nm and Fe I 522.5 nm lines are analyzed in this work together with Ca II K line. Both Fe I lines are formed in 370 km in upper photosphere. They differ in sensitivity to magnetic field, g_{eff}=2.25 and g_{eff}=0 are valid for Fe I 522.5 nm and Fe I 557.6 nm, respectively.

The energetic influence of a flare on the underlying atmospheric layers was investigated by comparing the Ca II K integrated intensity with the intensities of Fe I photospheric lines.

2. OBSERVATIONS AND DATA REDUCTION

The spectra were taken on June 1, 1993 with the Vacuum Tower Telescope (VTT) at the Observatório del Teide, Tenerife. The detail parameters of the observed spectral lines are given in [5]. The spectra of Ca II K line and Fe I lines were taken strictly simultaneously near the disc center in the flaring area. The width of the spectrograph slit was 150 μm. The resolution in spatial direction is 0.17" per pixel. The dispersion in wavelength direction for Fe I 522.5 nm, Fe I 557.6 nm and Ca II K 393.3 nm is 3.48, 3.67 and 2.58 mÅ /pixel, respectively.

For this work we have selected 12 sets of flare spectra (three spectral lines in each set) taken in the time interval of 08:12:30 UT - 08:14:46 UT. The H_α slit-jaw image of the observed region with three spectra from the first set (beginning of the observations) is shown in Fig.1. The reduction process we applied on the spectra included the dark current subtraction, precise flatfielding, elimination of the atmospheric refraction, continuum trend elimination and FFT profiles restoration (for details see [6]).

3. SPECTRAL CHARACTERISTICS AND CORRELATIONS

For both Fe I lines the line center intensities were determined. The integrated intensity K_{index} calculated on a 1 Å bandpass centered on the line core was adopted for the Ca II K line. The Ca II K line core position was determined from the flatfield spectrum.

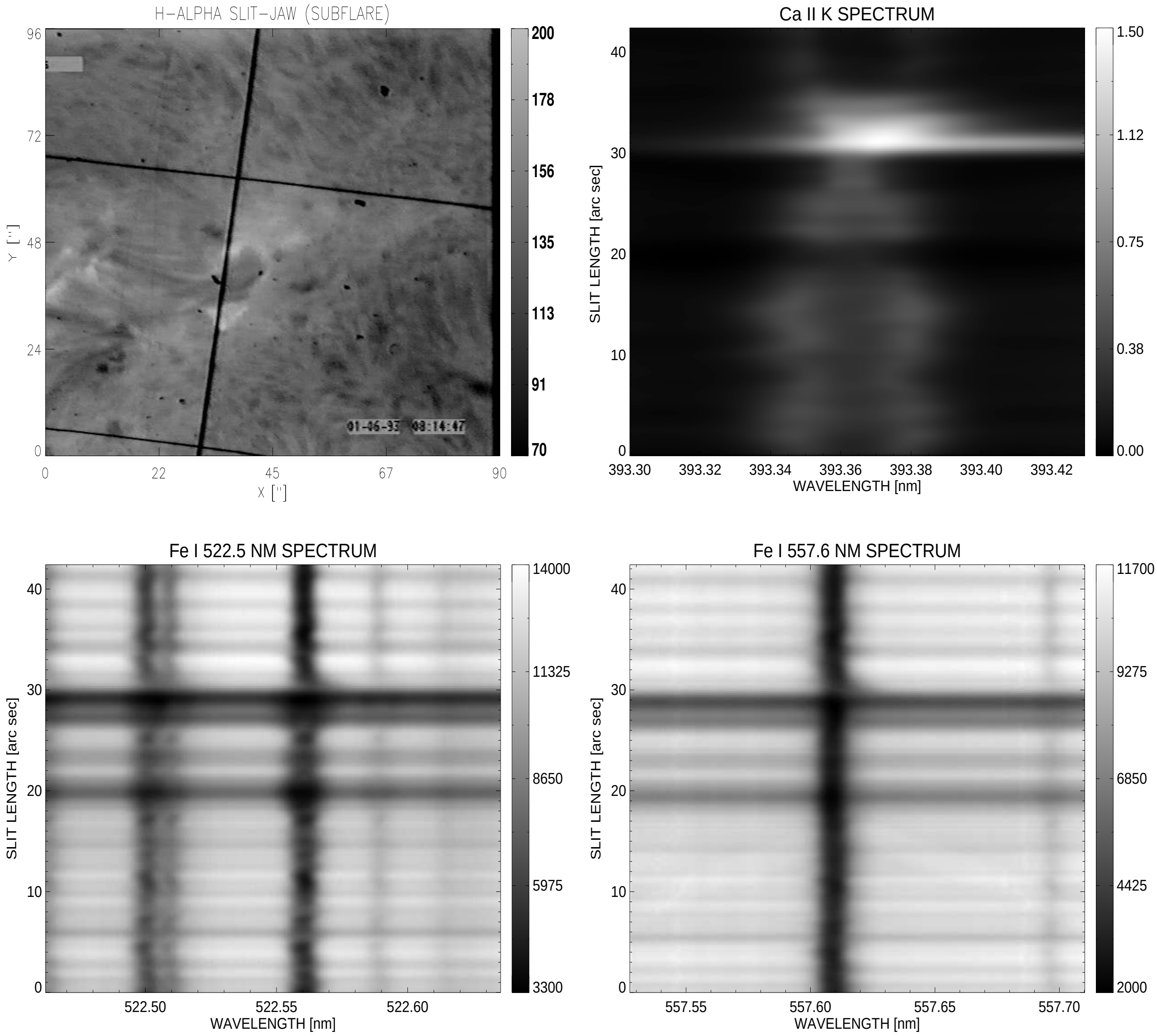

Figure 1. The H_α slit-jaw image of the investigated area with the spectra of all used line at the beginning of the observed series. Arbitrary units are used for intensities in all panels excluding Ca II K spectrum, where the intensity is in continuum intensity units. In H_α the whole observed area is shown, but only the lower part of the flare within 0"-40" in y-direction is investigated.

Each spectrum contains 250 spectral scans along the slit, for which the spectral characteristics were evaluated. The atmosphere of the flare is located within scans 170-210.

The correlation coefficients were calculated for couples of Ca II K integrated intensity - Fe I line core intensities for both Fe I lines for all 12 sets of spectra.

4. RESULTS AND DISCUSSION

The time evolution of the intensities during the observations is shown in Fig. 2 for the representative sample of three moments from the observed time series. From the plot of K_{index} along the slit (Fig. 2, upper row) it is evident, that the subflare was located within the scans 170-210. The flaring chromosphere is heated to high temperatures and the absorption Ca II K line profile turns to an emission profile, with the maximum line core intensity exceeding the continuum intensity. The integrated intensity is thus the highest, on the position of the flare. During the relaxing phase of the subflare it is rapidly decreasing (fall of 70% its initial value during 1 min 45 s) as the chromosphere cools. There are two spots visible in the K_{index} plot. One of them is on the slit position around the 120th pixel and the second one is on the place, where the subflare took place.

These two spots are clearly visible in the continuum

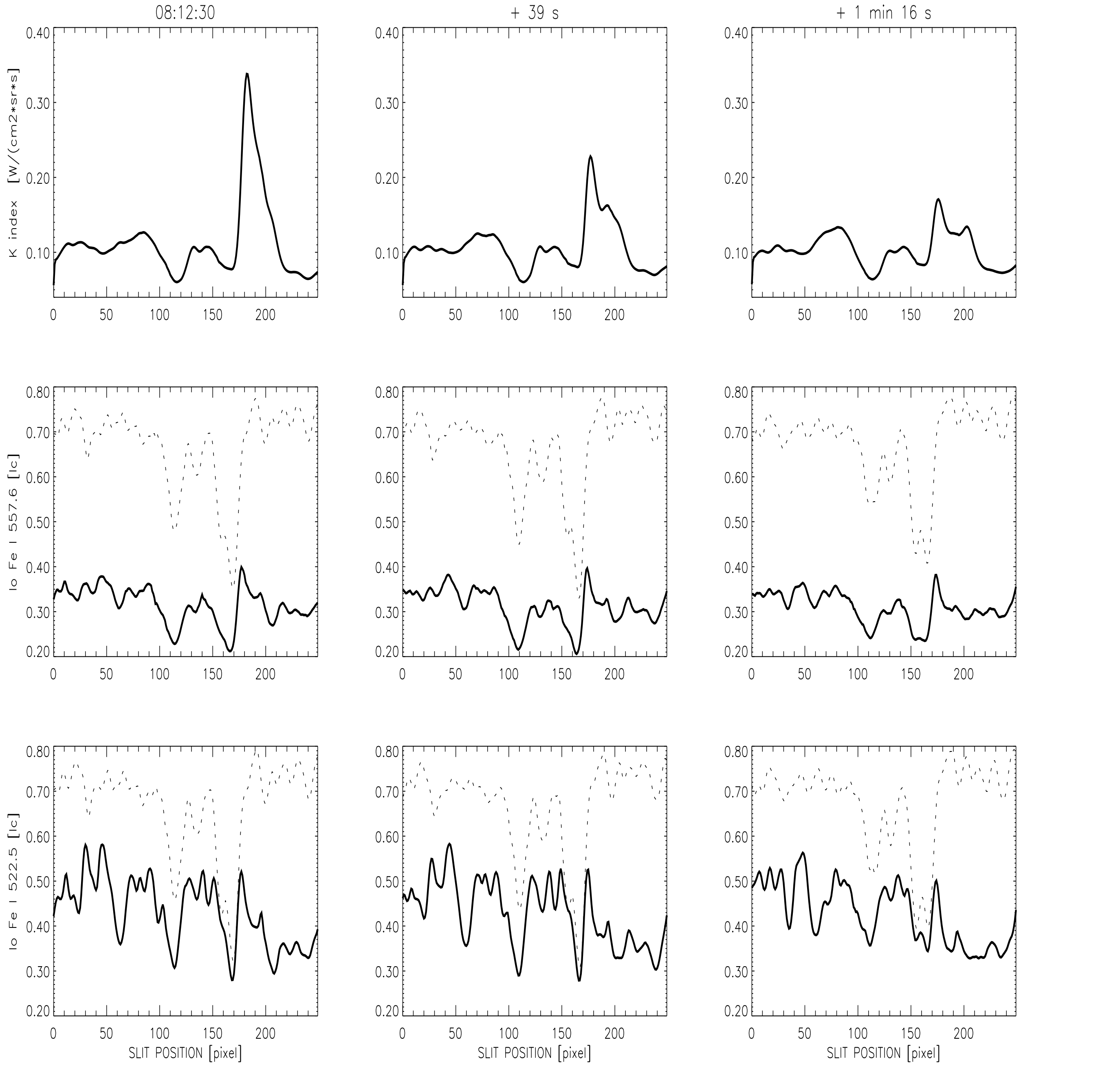

Figure 2. Temporal evolution of intensities along the slit. Upper row shows three samples of the time evolution of the integrated intensity of Ca II K line in units $Wcm^{-2}sr^{-1}s^{-1}$. Middle and lower rows show the line core intensities (solid lines) of Fe I 557.6 nm and of Fe I 522.5 nm lines, respectively. The continuum intensities for Fe I lines (dotted lines) are plotted for comparison only and y-axis values are not valid for them.

intensities of Fe I lines in Fig. 2 (dotted lines in the middle and lower rows) and in the line core intensity of Fe I 557.6 nm (middle row, solid line). In magnetic sensitive Fe I 522.5 nm spots are almost indistinguishable because of intensity changes due to present magnetic field.

The line core intensity of Fe I 557.6 nm (Fig. 2, middle row, solid line) shows enhancement around the position 180-190, where the flare in chromosphere occurred. This enhancement is not evident in the Fe I 522.5 nm line (Fig. 2, lower row, solid line) due to the strong intensity variations of this line due to the magnetic field.

The correlations of the Fe I line core intensities with the Ca II K integrated intensity are shown in Fig. 3. These are the maximal correlation coefficients for each pair of characteristics, which were obtained with the spatial lag of characteristics about 0-3 pixels in the slit direction. This shift is caused by the seeing. During the relaxing phase the correlation slightly ascend for both Fe I lines.

According to these facts we conclude, that the photosphere under the subflare was affected in the sense of enhanced line core intensity of magnetic non-

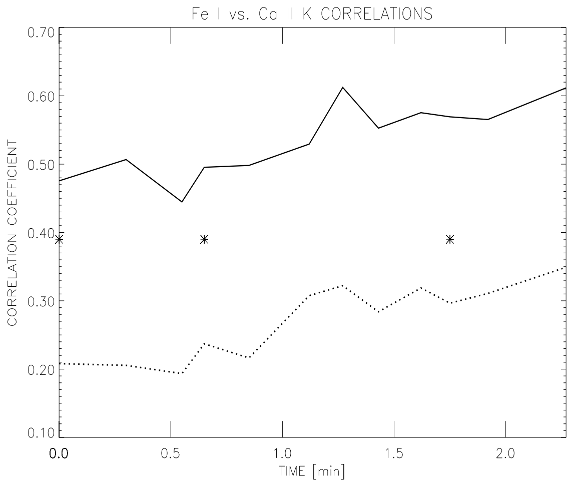

Figure 3. Correlation coefficients of the Ca II K integrated intensity with Fe I 557.6 nm line core intensity (solid line) and of the Ca II K integrated intensity with Fe I 522.5 nm line core intensity (dotted line) during the observed time series. The moments of the time series shown in Fig.2 are designated by asterisks.

sensitive Fe I 557.6 nm line. This enhancement is due to the higher temperature under the subflare when compared with the surrounding area. This means, that energy transport from the subflare towards the photosphere must have taken place. The direction of energy transport was perpendicular to the surface, because no spatial lag of characteristics from the chromosphere (integrated intensity) and photosphere (line core intensities of Fe I lines) was found for the correlations.
Different scenario was valid for the mass transport. The mass was transported in slightly in-curved direction as it was investigated in our previous work [7].

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