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SPECTRAL STATISTICS OF FE I AND CA II K LINES IN QUIET AND ACTIVE SOLAR ATMOSPHERE

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Abstract. Based on two Fe I and Ca II K lines spectra obtained with high spatial and spectral resolution we investigated some spectral characteristics of these lines in quiet and active regions. In this paper we present behaviour of the central line intensities in different types of solar activity. We discuss the obtained results and compare them with results reported by another authors.

1. Introduction

The solar spectra with high spatial and spectral resolution enable us to diagnose the differences of the physical conditions in regions on different stage of activity. To determine dynamic and magnetic characteristics of some region, it is important to choose suitable spectral lines which are formed at appropriate heights of the solar atmosphere. The analysis of the spectral characteristics of these lines is a base for the theoretical calculation of the solar atmosphere model. This paper is a part of a project whose aim is to determine the physical parameters of solar atmosphere based on calculations of the synthetic spectra.

Table 1: Spectral lines characteristics

line	wavelength [nm]	eqv. width [mÅ]	multiplet	excit. pot. [eV]	Lande factor [g_{eff}]
Fe I	557.6	113	686	3.43	0.0
Fe I	522.5	68	1	0.11	2.5
Ca II K	393.3	20253	1	3.2	1.17

In the first phase of the analysis it is necessary to find out behaviour of the spectral lines and to determine the qualitative characteristics of these lines in regions with different levels of activity. Determination of these characteristics and their comparison for different active regions is a topic of this paper.

2. Observations

The data were taken on Vacuum Tower Telescope (VTT) at Observatório del Teide, Tenerife on June 1, 1993. The data include more than 1000 solar spectra taken in three different spectral regions. The parameters of the observed spectral lines are given in Table 1. Two Fe I spectral lines were chosen to obtain an information about dynamic and magnetic characteristics at identical height of the solar atmosphere. Both Fe I lines are formed at the same height of the photosphere ($\sim$300 km), but Fe I 557.6 nm line is purely dynamic and Fe I 522.5 nm is magnetically sensitive line. Specific parts in the wings of the third line, Ca II K 393.3 nm, are formed at the same height, but the center of Ca II K is formed in the chromosphere ($\sim$1500 km). Thus we can get also an information about the overlaying atmosphere.

From all of 1000 spectra we selected 14 best sets of spectra for preliminary analysis and finally for detail analysis we used only 4 sets of spectra, which represent different levels of solar activity (Table 2). Each set of three spectra (Fe I 557.6 nm, Fe I 522.5 nm, Ca II K 393.3 nm) was taken simultaneously, i.e. exposition was started at the same

Table 2: Finally used sets of spectra

n:	time [UT]	disk location	activity level
1	08:01:01	$\mu = 1$	quiet region
2	08:40:50	$0.77 > \mu > 0.5$	filament
3	08:28:31	$0.97 > \mu > 0.77$	plage
4	08:12:48	$1 > \mu > 0.97$	subflare

time. Exposure time was 0.2 s for Fe I lines spectra and 2.0 s for Ca II K line. The spectra were taken with 1024 $\times$ 1024 pixel CCD cameras with binning 2. Thus the final spectra are 512 $\times$ 512 pixels with the spatial resolution 0.17" (along the slit) and the dispersion in wavelength direction is 3.5×10^{-4} nm for Fe I lines and 2.5×10^{-4} nm for Ca II K line. The spectrograph slit was 150 μm wide.

3. Data reduction

The spectra were reduced using IDL software including the IDL KIS LIB (library of IDL programs developed at Kiepenheuer-Institut für Sonnenphysik, Freiburg) and our own IDL programs. The standard dark current subtraction and FFT profiles restoration were applied. Special procedure was used to remove the flat-field. After basic reduction of all spectra we obtained the final profiles from which we determined the spectral characteristics.

4. Spectral characteristics

The following spectral characteristics were determined for our analysis: I_c – continuum intensity and I_o – line center intensity (residual intensity).

Resulting two-dimensional spectra for each line (see Fig.1) contain 419 spectral profiles, so we determined 419 values of I_c and I_o for each spectrum. In advance, it was necessary to eliminate the continuum trend, to calibrate spectra to the real "atlas" continuum, to smooth

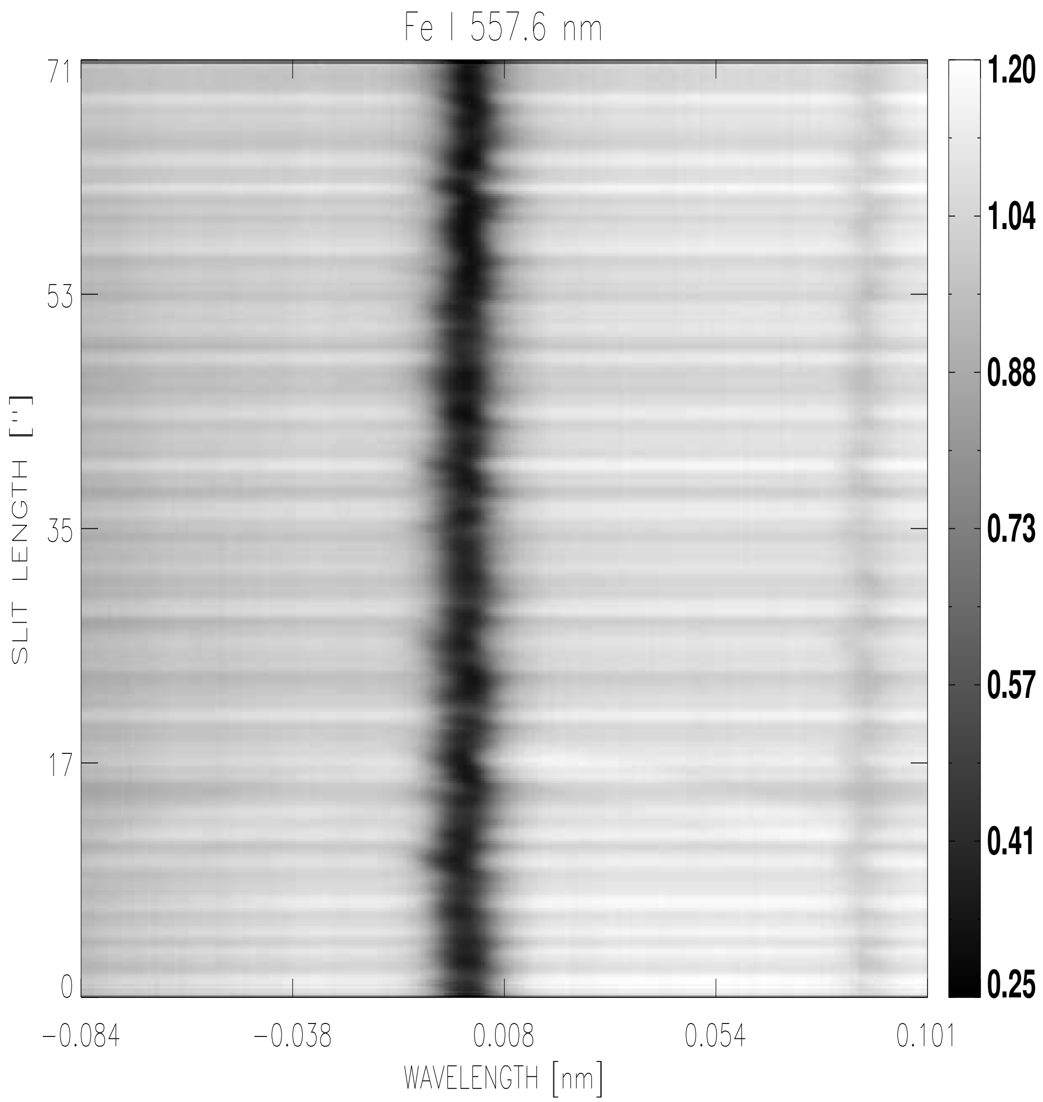

Figure 1: An example of Fe I 557.6 nm spectrum after basic reduction

the profiles using FFT and to eliminate an influence of the atmospheric refraction.

Elimination of the continuum trend and spectrum calibration to the real continuum.

The resulting spectra have their own continuum trend in direction of dispersion. Therefore, it was necessary to correct this trend and reach harmony with the atlas values. Correction was done using the values of the line surrounding quasicontinua taken from Liege atlas (Delbouille et al. 1990) To obtain the real values of continuum we multiplied the intensity of quasicontinua by the correction factors which were estimated using the Liege atlas again.

Elimination of the atmospheric refraction influence.

Observed spectral lines Fe I and Ca II K represent two very distant parts of spectrum (the difference is 130 nm) so it was necessary to eliminate the influence of atmospheric refraction. Therefore, we rotated the VTT spectrograph tank before observations to an appropriate position to have the slit parallel to the meridian to keep the effect along the slit only. Using the correlation between the intensity fluctuations in Fe I cores (I_o) and in Ca II K wings the shift of spectra along the slit was determined. The best correlation was found for 11 pixels shift between Fe I 557.6 nm and Ca II K and for 9 pixels shift between Fe I 522.5 nm and Ca II K. Also 2 pixels shift between Fe I lines was found. So we found that the Fe I line spectra were shifted comparing to Ca II K spectrum of about 2".

5. Results and discussion

Figure 2 represents the ratios of the central line intensities (I_o) for all 3 lines in all 4 different regions. We keep identical scales in all panels of the Figure 3, to display clearly the differences between the quiet region and different active regions.

The ratios of the central line intensities I_o reflect the temperature and density stratification in the photosphere. For the quiet region the I_o changes in one Fe I line are reflected in another one too. This result is expected because both Fe I lines are formed at the same height in the photosphere. The estimated intervals of Fe I I_o intensities are in good agreement with values obtained by Berrilli et al. (1999). Intensities in the center of Ca II K do not react to the changes in the photosphere.

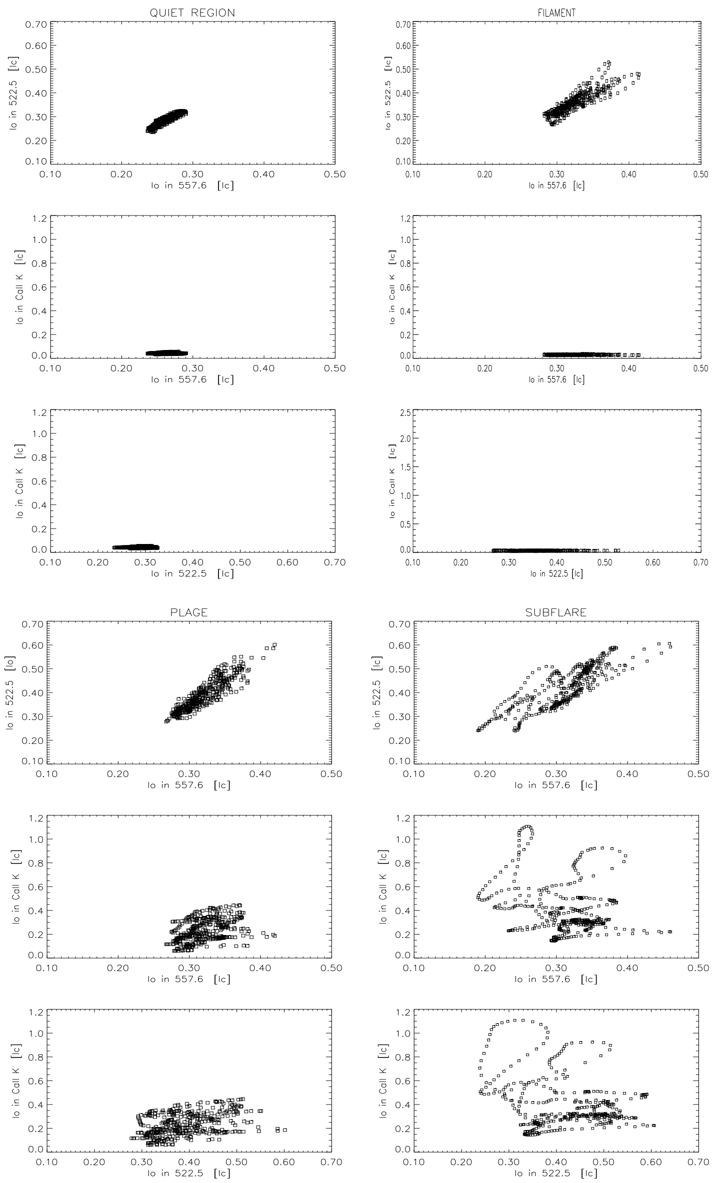

Figure 2: Line intensity ratios in all investigated regions.

This correspond to the results found by Carlsson and Stein (1992) who simulated behaviour of the Ca II K line in chromosphere and they shown that there is reflection of the photospheric dynamics mainly in the Ca II K_{2v} intensities but no reflection appears in the Ca II K_3 intensities.

In region of a cool filament we can see even a drop in Ca II K intensities because the filament is a strong absorber of Ca II K line center radiation.

In the case of plage all layers of photosphere and chromosphere are heated so one can recognize a correlation of the Ca II K line center intensities and Fe I line center intensities. All intensities are also shifted to higher values due to higher temperature.

There is different situation for the subflare. We can find here a high rise of Ca II K line center intensity without reaction in Fe I lines and also high rise of Fe I line center intensities without reaction in Ca II K. This situation could be explained by a hypothesis of the structured active region, where flaring plasma spreads in a narrow curved bunches (loops) downwards to the photosphere. Thus, the hot plasma loop observed in chromosphere at a particullar point ends in the photosphere at different position concerning the line of sight. Therefore at the same position on the slit we can observe enhanced intensities in photosphere and no activity in chromosphere and vice versa.

It is necessary to model a synthetic spectra and compared them with observed ones for quantitative determination of physical parameters in the appropriate levels of the photosphere. This work will be done in the near future.

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