ON MUTUAL RELATION AMONG THE OUTER ATMOSPHERIC LAYERS IN NETWORK: SOHO/CDS STUDY

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ABSTRACT

SOHO/CDS measurements of emission in the network of the quiet solar atmosphere near disk center were used to derive mutual relations of emission and dynamics in different temperature regimes in/above supergranular network. Cross-correlation functions of the line intensities and the Doppler shifts of the chromospheric line He I 584.3 Å, the transition region line O V 629.7 Å and the coronal line Mg IX 396.1 Å were calculated in order to study relative variability of different atmospheric layers. Relatively high correlations were found between the intensities and the Doppler shifts of the He I and O V lines with two peaks of the intensity correlation function. The maximum value of the correlation of intensities (CC_{max} = 0.86) was reached for the zero time lag and the second maximum (CC = 0.78) was obtained for the time lag –190 s (O V precedes He I). Only one sharp peak (CC_{max} = 0.55) was detected in the Doppler shift correlation function of these lines for the zero time lag. For the correlation of O V and Mg IX intensities one peak (CC_{max} = 0.57) of the correlation function was also discovered for the time lag +150 s (Mg IX falls behind O V). In contrast, no correlation was obtained for the Doppler shifts of the O V and Mg IX lines. Summarizing we can assume clear relation in energy transfer and/or mass motion between chromosphere and transition region but no relation was found between corona and the lower parts of the solar atmosphere above the particular network under study.

1. INTRODUCTION

Previous measurements obtained especially by the HRTS instrument have revealed that the upper chromosphere, transition region and corona are not static, but in the contrary, that these areas are extremely dynamic mainly in/above the supergranular network [1]. After the launch of the *Solar and Heliospheric Observatory* (SOHO) in 1995, new opportunities have become available for study of temporal evolution of the upper solar atmosphere including its dynamics. But mechanisms of the energy and mass transfer from the photosphere to the corona are still not well understood. For identification of potential mechanisms it is necessary to detect variations of spectral characteristics (e.g. intensities, Doppler shifts) in emission lines from different heights above the solar surface in the same time. The *Coronal Diagnostic Spectrometer* (CDS) is suitable for a such kind of study, because of its capability to observe simultaneously spectral lines, which are formed in a wide temperature interval. Cross-correlation functions of the line intensities and the Doppler shifts of the chromospheric line He I, the transition region line O V and the coronal line Mg IX are presented in this contribution in order to study the relative variability of different atmospheric layers and their mutual connections.

2. DATA

The whole data set analyzed in this contribution, was obtained by the CDS/NIS (Normal Incidence Spectrometer) instrument [2] between 23:25 UT and 23:53 UT on May 14, 1998 as a part of the joint observing programme (JOP 78).[1] A quiet Sun supergranular network near disk center (see Fig. 1) was observed in He I 584.33 Å (2.0×10^4K), O V 629.73 Å (2.5×10^5K) and Mg IX 368.07 Å (9.3×10^5K) lines using the 'sit-and-stare' observation mode. It means that the slit position was fixed and the solar rotation was not compensated. 190 spectral images with the exposure time 5 s and with cadence of 9.1 s were obtained using the 2"×240" slit (N-S orientation). 1729 s long data set was created. Because of solar rotation, a ∼4" area of the solar surface was observed during the ∼25 min. The resulting area of this drift scan was 141" (NS) × 4.4" (EW).

3. DATA REDUCTION

The spectra were corrected for the most obvious instrumental features of the CDS/NIS instrument,[2] including the removal of the spectrum rotation and tilt, cosmic rays, micro-chanel plate burn-in and CCD flatfield. A

[1]JOP 078 proposal: www.astro.sk/∼choc/jop078_prop
[2]Details: http://solg2.bnsc.rl.ac.uk/software/uguide/uguide.shtml

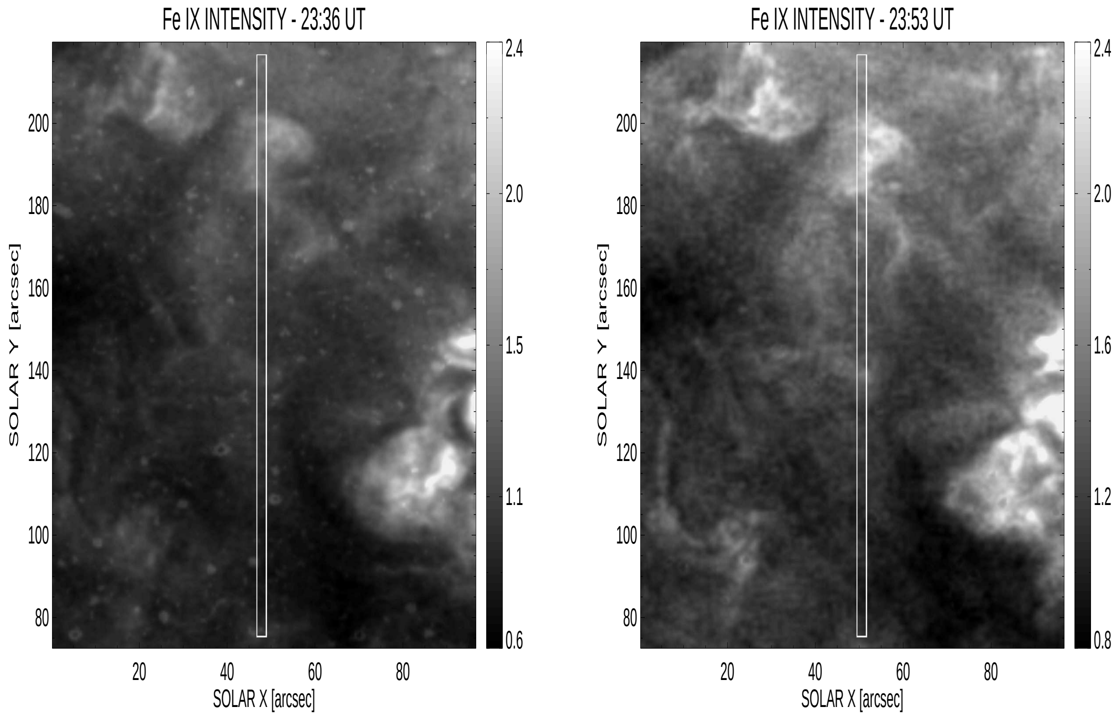

Figure 1. The TRACE Fe IX *171 Å filtergrams taken at moments which correspond to the middle (left image) and to the end (right image) of the CDS measurements. Locations of the CDS slit are indicated. The intensity values given in counts* s^{-1} *are displayed in logarithmic scale. The coordinate system is given relative to the disk center.*

single Gaussian profile with a linear background was then fitted to each spectral profile using relative weights of the data (Poisson statistics[3]). This was made using the standard routine CFIT[4] which is based on the Levenberg-Marquardt method of the minimalization of the least squares. The square root errors of the primary data were derived from the fitting of the spectral profiles for every primary data. Then the data were converted to the physical units: intensity to $\mathrm{erg\,cm^{-2}s^{-1}sr^{-1}Å^{-1}}$ and the Doppler shifts to $\mathrm{km\,s^{-1}}$. The scales of wavelength were adjusted using the overall redshift of the transition region lines [3] and their laboratory wavelengths [4]. Only data with the fit uncertainty χ^2 lower than 10 $\mathrm{erg^2cm^{-4}s^{-2}sr^{-2}Å^{-2}}$ were used for the analysis. The resulting 2D space-time maps of He I and O V line intensities and Doppler shifts are displayed in Fig. 2.

4. TARGET SELECTION

Only data between y = 111” and y = 116” (4 pixels along the slit) were selected for the correlation analysis. This is the brightest area of the supergranular network, visible in the He I line intensity (Fig. 2). It is characterized only by a slow increase of the He I and O V line intensities and by almost no changes in Mg IX line intensity. We will call this area *typical network*. The typical network is also visible in the TRACE images taken in the Fe IX line ($\sim 10^6$K) as the bright area at the upper part of the CDS slit position (Fig. 1).

The first results from the *’non-typical network’* were already published [5]. This area is characterized by repeated strong increases of the He I and O V line intensities and it is visible between y = 97” and y = 102” in Fig. 2.

5. RESULTS

The averaged values of the He I, O V and Mg IX line intensities and Doppler shifts were computed as spatial average over 7” using four primary data from the selected pixels along the slit in each exposure. The standard deviations of the primary data from the averaged values were also figured out. The temporal variations of the averaged values were then smoothed using the running mean of 5 data points, i.e. over 36 seconds. The temporal variations of the averaged data of the He I and O V line intensities and Doppler shifts were compared to temporal variations of spectral characteristics of the same lines published by Gallagher [6]. The comparison confirmed the simultaneous increases of the He I and O V line intensities. The temporal variations of the Doppler shifts showed different shapes but reached similar values of maxima and minima.

The cross-correlation functions of the averaged and smoothed temporal variations of the He I and O V as well as of the O V and Mg IX line intensities and Doppler shifts were calculated (Fig. 3). A relatively high maximum value (CC_{max} = 0.86) of the He I and O V line intensities cross-correlation function was found for the time lag

[3]CDS Software Note nr. 49: http://orpheus nascom.nasa.gov/cds/home/swnotes
[4]CDS Software Note nr. 47: http://orpheus nascom.nasa.gov/cds/home/swnotes

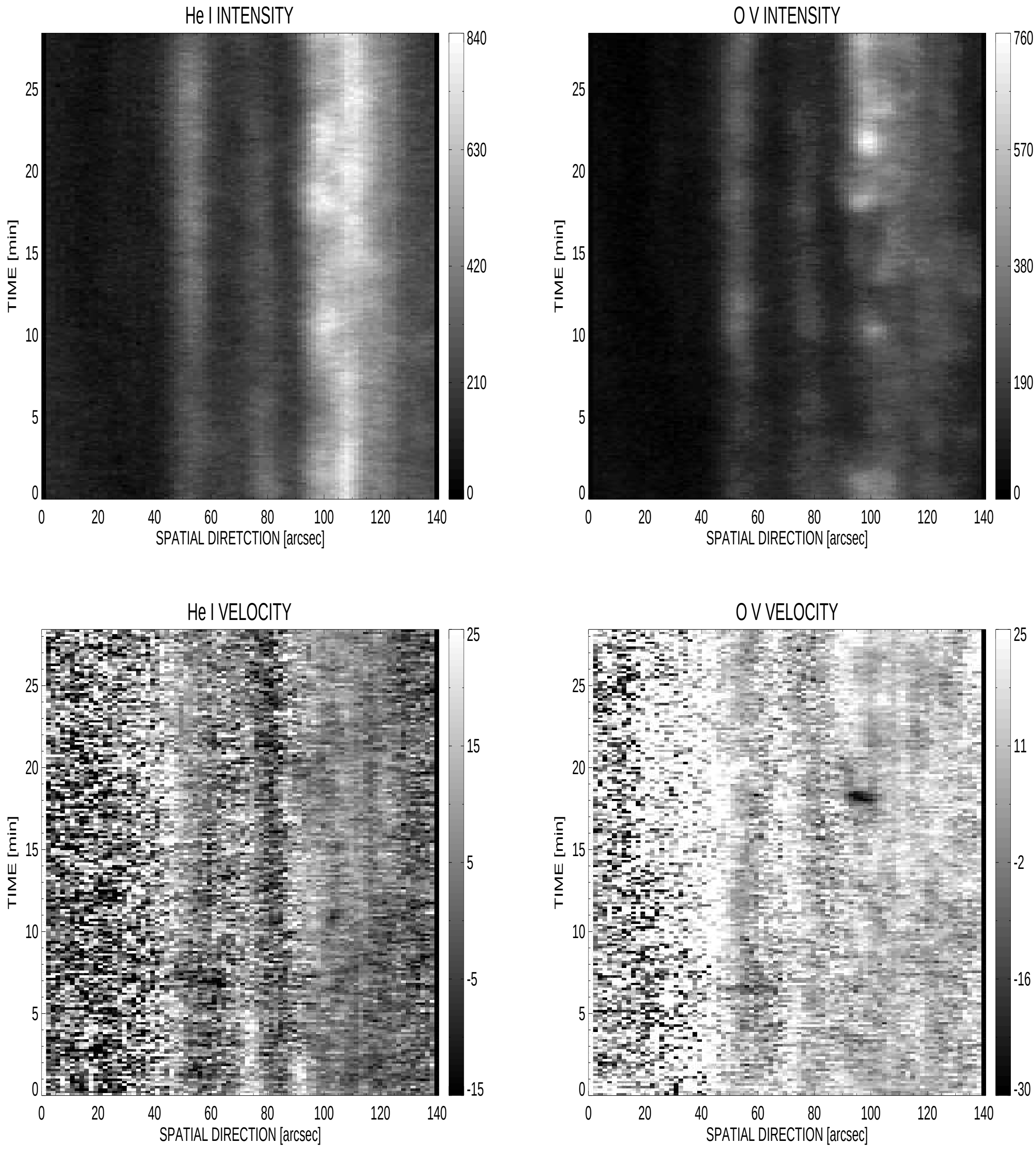

Figure 2. *2D space-time maps of He* I *and O* V *line intensities and the Doppler shifts. Typical network is shown in the area between 111" and 116". Non-typical network is visible in the area between 97" and 102". The intensity values are given in erg* $cm^{-2}s^{-1}sr^{-1}Å^{-1}$ *and the Doppler shifts in km* s^{-1}*. The horizontal axis describes spatial direction and the vertical axis describes time. The solar rotation was not compensated, so the vertical axis presents also the spatial extent of the observed solar features. Positive values of the Doppler shifts = redshift (toward the solar surface); negative values of the Doppler shifts = blueshift (toward the observer).*

0 s (Fig. 3; top left panel). The cross-correlation function reaches also a secondary maximum (CC = 0.78) for the time lag -190 s. It means that in some temporal subintervals changes of the O V line intensities precede changes of the He I line intensities. The cross-correlation function of the He I and O V Doppler shifts (Fig. 3; top right panel) reaches only one sharp maximum ($CC_{max} = 0.55$) for the time lag 0 s. This is an evidence of simultaneous mass motion in the chromospere and in the transition region. For the cross-correlation of the O V and Mg IX line intensities (Fig. 3; bottom left panel) only one peak ($CC_{max} = 0.57$) of the correlation function was discovered for the time lag +150 s. Based on this we can assume that some variances of the Mg IX line intensities follow the variances of the O V line intensities. In contrast, no correlation was found for the Doppler shifts of the O V and Mg IX lines (Fig. 3; bottom right panel).

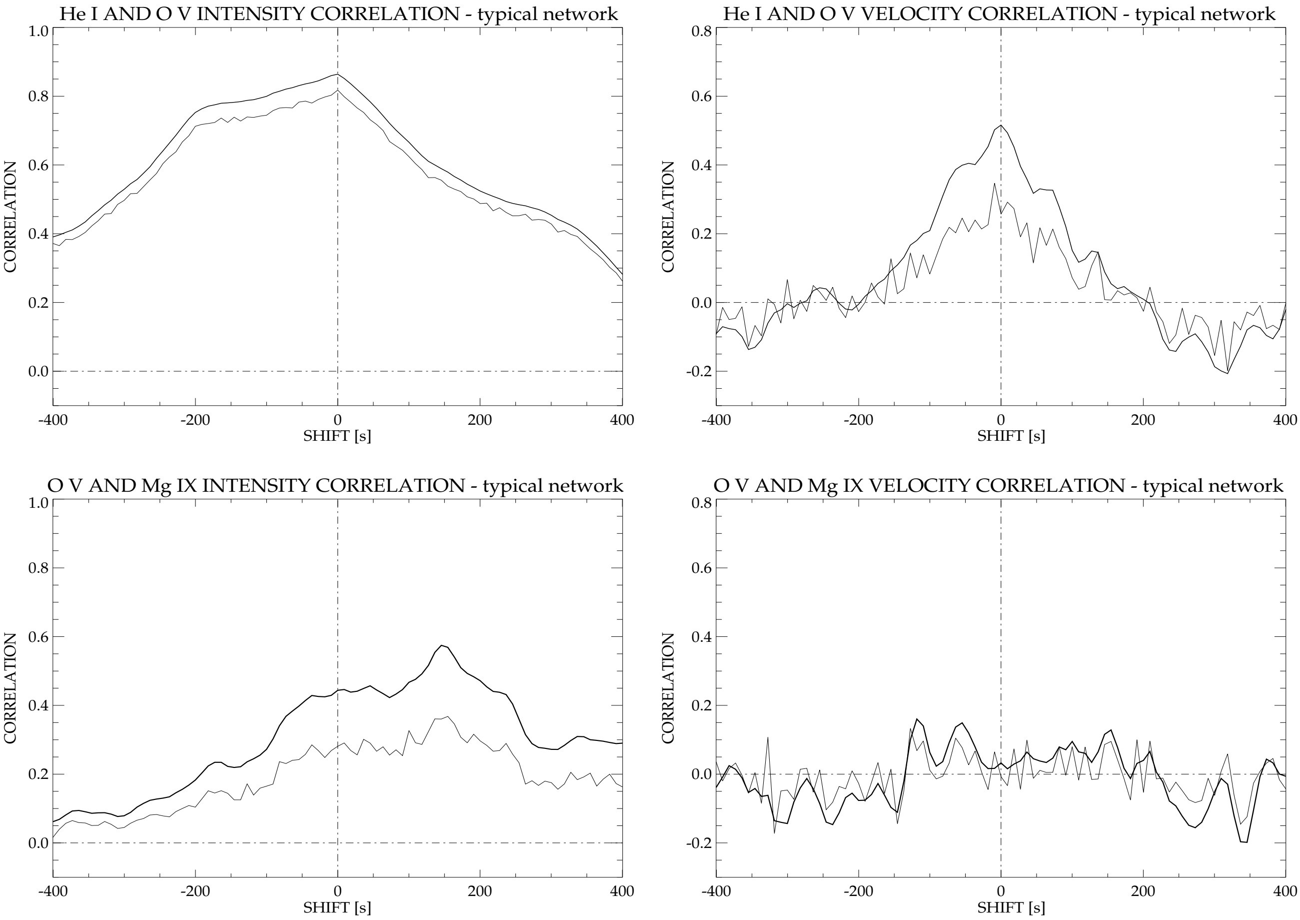

Figure 3. Cross-correlation functions of the He I*, O* V *and Mg* IX *line intensities (left panels) and Doppler shifts (right panels). The thin lines show the cross-correlation functions of the averaged temporal variations of the line intensities and the Doppler shifts and the thick lines display the correlation functions of the smoothed variations of the averaged data.*

An increase of the Fe IX 171 Å ($\sim 10^6$ K) line intensity was also detected by TRACE instrument between 23:36 UT and 23:53 UT contrary to almost no changes of the Mg IX 396.1 Å (9.3×10^5 K) line intensity observed by the CDS spectrometer.

6. CONCLUSIONS

Cross-correlation functions of the He I, O V and Mg IX line intensities and Doppler shifts were analyzed. Cross-correlations of the line intensities demonstrated relatively high mutual connection of all parts of the upper solar atmosphere in the particular network under study. Lower maximum value of the cross-correlation function of the He I and O V Doppler shifts implicated that mass motion in the chromosphere and in the transition region was independent at last in some temporal subintervals of measurement. No cross-correlation was found between O V and Mg IX Doppler shifts. The significant changes in the corona above the network considered here were detected in the Fe IX 171 Å line intensity using the TRACE instrument.

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