3-D TOMOGRAPHY OF THE SOLAR PHOTOSPHERE

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ABSTRACT

We analyze the behaviour of solar photospheric granular motions using 2-D scans in different sepctral lines. The location of acoustic flux is investigated by a comparison of enhanced full width at half maximum variations with granular motions.

Key words: The Sun, convection.

1. INTRODUCTION

Dynamical motions in the solar photosphere and their propagation and time evolution are crucial for the understanding of various processes of solar activity and heating of upper layers. However, it is extremely difficult to obtain high quality data. We present an analysis from recent observations from the VTT (Observatorio del Teide) with the newly installed XEDAR cameras. In order to obtain a 2-d spectrogram, the Sun was scanned over an area of 20 arcsec by 50 scans. Thus a time series of 8 images separarted by a 130 s interval could be studied. Using lines of different line formation heights we obtain information about the vertical structure and motions of the evolving elements.

A comparison between previous observational results and theoretical 2-d simulations can be found in Gadun et al, 2000. The influence of oscillations on convective structures is discussed in detail in Rast (2000), where further references can be found.

2. DATA

The data were taken with the 70 cm VTT at the Observatorio del Teide in Izana, Tenerife. A more detailed description of this telescope can be found in Schröter et al. (1985) . We obtained during an observing campaign in 1999 time series of two dimensional spectral scans, where the spatial sampling interval was $\delta x = 0.4''$ and the total number of spectral exposures was 50. Thus an area of 20" was scanned. The time step between two successive images was $2.5\,s$. Thus one 2-d scan lasted for slightly more than 2 minutes. The spectrograms contained the two FeI lines:

- $Fe\,I$ at $630.1508\,nm$ and $W_\lambda = 127\,m\mathring{A}$, $EP = 816\,eV$ and $g_{eff} = 1.6$,estimated line core formation height 378 km (Gadun et al 2000).
- $Fe\,I$ at $630.2499\,nm$ and $W_\lambda = 83\,m\mathring{A}$, $EP = 816\,eV$ and $g_{eff} = 2.5$, estimated line core formation height 270 km (Gadun et al, 2000).

From these data the following spectral parameters were calculated after applying the usual image reduction procedures:

- continuum intensity
- central line residual intensity
- line center velocity
- full width at half maximum $fwhm$

In the next paragraph this time series of 8 images each separated by 130 s is analyzed in order to investigate the evolution of the solar photospheric fine structures.

3. RESULTS

We present the results for the evolution of the correlation of spectral parameters between a) two subsequent images in the time series (full line) and b) between the first image of the time series and the following ones.

The data calculated for the highest originating line I (h=378 km) are given by Fig. 1. In Fig. 2 the same kind of data is given for the deeper forming line II (h =270 km). It is clearly seen that the most pronounced difference is in the behaviour of the $fwhm$. For the deeper forming line the correlation between subsequent images remains constant at a moderate value of 0.50; however the correlation drops down very quickly between the first image and the other images in the time series. For the highest line the correlation for the $fwhm$ values is lower (correlation coefficient $\sim$ 0.40) and the decay between the first image and the other images is lower for the correlations. The correlations between residual intensities are higher for the lower forming line.

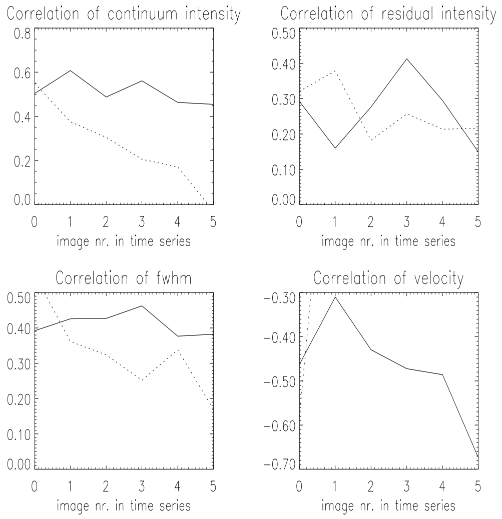

Figure 1. Correlation coefficients for line I, h=378 km; full line: between subsequent images of the time series, dotted line: between the first image of the time series and the subsequent images

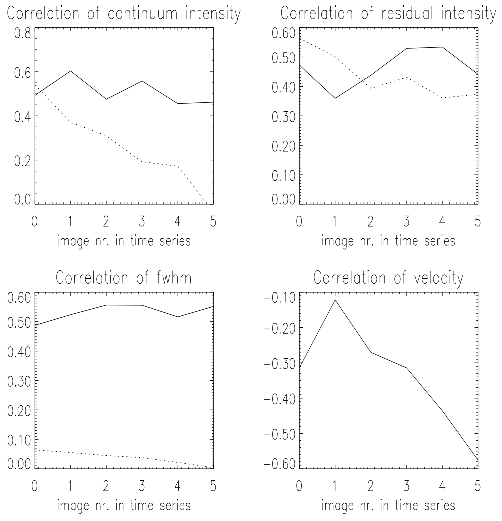

Figure 2. Correlation coefficients for line II, h=270 km; full line: between subsequent images of the time series, dotted line: between the first image of the time series and the subsequent images

In Fig. 3 examples of the evolution of the line parameters are given. The time intervall between the images is 130 s. We give two images for each line parameter separately for line I and line II. The continuum variations for both lines are add at the top of the figure for comparison.

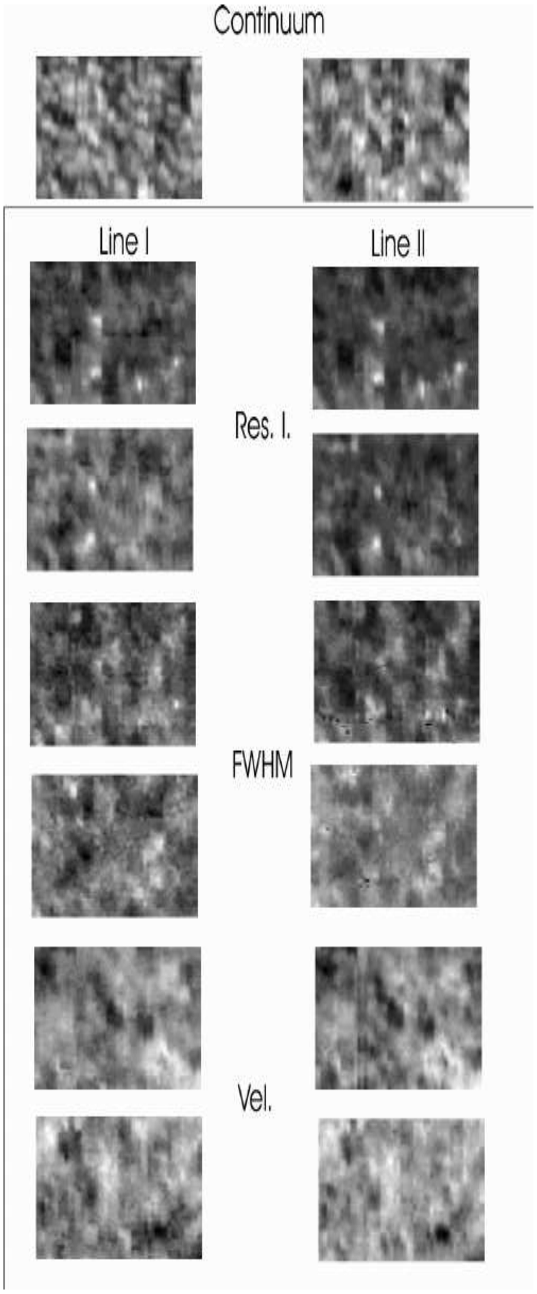

Figure 3. Examples of the variation of different line parameters; the time step between the two images is 130 s

In order to follow the variation of the full width at half maximum values we calculated for each image the corresponding mean value of that parameter. Then we denoted all values of this image that were above the mean value by a positive number and the other values by 0. The results are shown in Fig. 4

In Fig. 5 we show a kind of correlation between the continuum intensity and the $fwhm$. For each image the mean continuum intensity and the mean $fwhm$ was calculated. In the Fig. 5 bright denotes

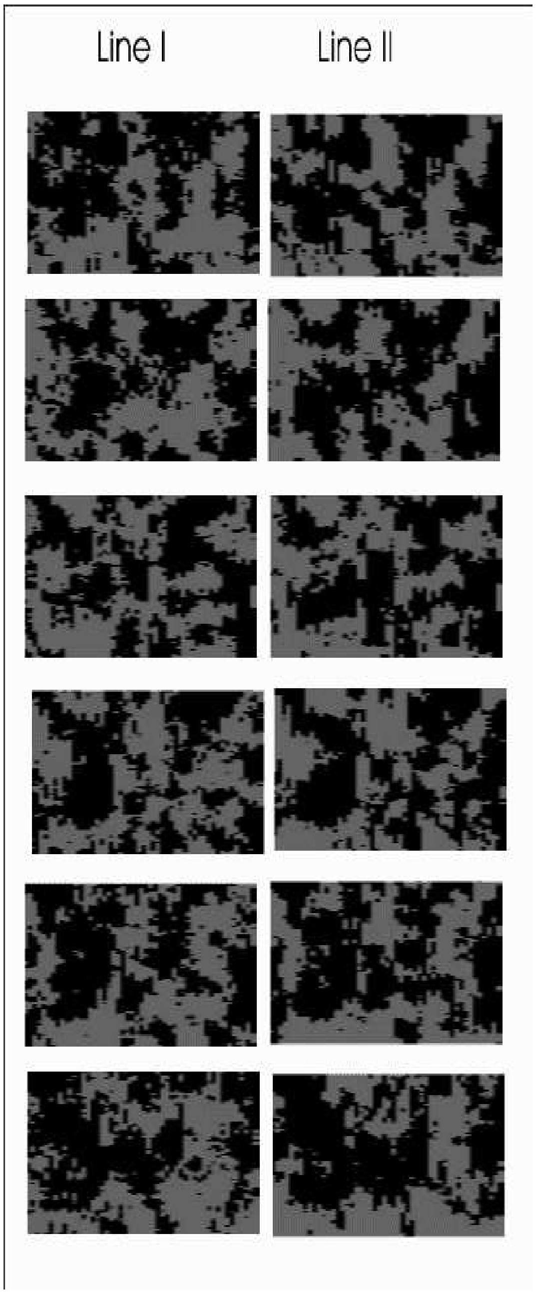

Figure 4. Variation of the $fwhm$; the values above the mean value are marked grey, the other values dark; the time step between the images is 130 s

areas where the continuum intensity is $< \bar{I}$ and the full width at half maximum is $< \bar{fwhm}$. Thus we can see if turbulent motions are associated with intergranular areas and follow their evolution.

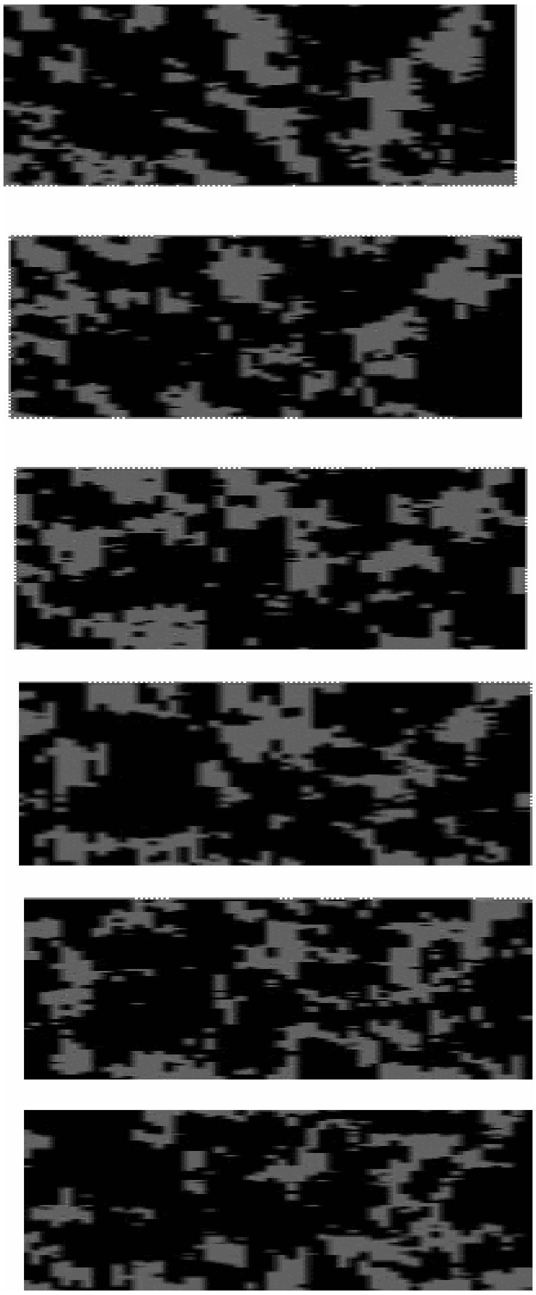

Figure 5. Correlation between continuum intensity and fwhm. Bright points denote areas where the continuum intensity is below the mean value of each image and the fwhm is above the mean value ; the time step between the images is 130 s

4. CONCLUSIONS

The evolution of granular/intergranular structures can be clearly seen when comparing the images of continuum intensity. This is illustrated by the top images in Fig. 3. The variation of the other line parameters is demonstrated by comparing two different images that are separated by the scanning intervall (130 s). By comparing the two lines (line I in the left column and line II in the right column) we can state that for velocity, full width at half maximum and residual intensity variations the images are very similar thus there does not exist a vertical gradient in the evolution of these parameters. However, for the full width at half maximum variations there seems to exist more features for the higher forming line II. This line paramater also behaves differently when regarding the correlationcoeffiecients. It decays more slowly between the first image and the other images in the case of the higher forming line I (compare Fig. 1 with Fig 2.).

An explanation for such a behaviour could be that in the higher photospheric layers regions of enhanced turbulence are more persistent than in the layer 100 km deeper (h=270 km for line II).

In the analysis here we give only two examples for the illustration. A similar behaviour was found for the other data.

Also the residual intensity correlation behaves similar. The correlation is higher for the deeper forming line as has to be expected. However, the correlation bewteen the first images and the subsequent images nearly remains constant. This indicates persistent temperature fields at these layers. Such a behaviour was not found for the velocity. The correlation rapidly decays between the first image and the subsequent ones.

This can be explained by the breakdwon of the correlation between temperature and velocity fields in the higher photosphere. The structure of the high photosphere was studied in Hanslmeier et al, 2000.

ACKNOWLEDGMENTS

A. H. thanks the 'Austrian Fonds zur Förderung der wissenschaftlichen Forschung' for supporting these investigations. A. K and J. R. acknowledge the grant VEGA 2/7229/20 and the Austrian and Slovak Academy of Sciences.

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