SOLAR GRANULATION SPECTROSCOPY: DYNAMICS OF THE INTERGRANULAR SPACE

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ABSTRACT  Using spectrograms of high spatial resolution, we investigated the functional interdependence between the convective intensity fluctuations at \( \tau_{5000} = 1 \) and the line broadening of magnetically insensitive weak absorption lines in nonactive regions. We found an extra broadening of the absorption lines in the intergranular regions. We attribute this increase to enhanced nonthermal velocities due to the decay process of the granulation associated with the dark regions. The variation of this broadening with height in the photosphere can be attributed to the variation of the nonthermal velocities of convective origin in the photosphere. Moreover, our findings could be relevant to the diagnostics of the recently proposed shock phenomena at the borders of solar granules.

Keywords: Sun: photosphere – Sun: granulation – line profiles.

INTRODUCTION

By means of high spatial resolution spectrograms we are now able to investigate in substantial detail the granulation, especially the transition from the granules to the intergranular space. What changes does a line profile undergo in the intergranular space?

This investigation is based on spectrograms taken with the vacuum tower telescope (VTT) in Izana (Tenerife), in July 1990. The spectrograms are taken at the center of the solar disk and include the wavelength range \( \lambda \lambda \) 4910 — 4914 Å. In this study we investigate the lines \( \lambda \) 4911.54 and 4912.03 Å with the equivalent widths 24 and 47 respectively. The line \( \lambda \) 4912.03 Å is magnetically nonsensitive and it is formed about 140 km above \( \tau_{5000} = 1 \). We digitized the spectrograms and processed the data in order to get four sets of data points: (FWHM$_i$, I$_i$), (Equivalent-Width$_i$, I$_i$), (Center-Line-Depth$_i$, I$_i$) and (Wing-Line-Depth$_i$, I$_i$), along the slit of the spectrograph for each absorption line.
Fig. 1 shows the results of fitting the two sets \((\text{FWHM}_i, I_i)\) and \((\text{Equivalent Width}_i, I_i)\), to a straight-line model \(y = a + b \times x\) (regression line) where, \(x\) represents the fluctuations of the continuum, and \(y\) the line broadening or the equivalent width of the line, respectively. In Fig. 1 we realize immediately 1) the negative gradient of the FWHM regression line, 2) the significant difference in the gradient for the two absorption lines, where the stronger gradient was obtained for the magnetically nonsensitive line \(\lambda 4912.03\ \text{Å}\) and 3) practically the missing gradient in the regression line of the equivalent width. The stronger gradient of the magnetically nonsensitive line\(\lambda 4912.03\ \text{Å}\) signifies an enhancement of the line broadening, FWHM, in the intergranular space of \(\approx 20\ \text{mÅ}\) compared to the line broadening in the bright elements. On the other hand, the weaker gradient of the weaker absorption line \(\lambda 4311.54\ \text{Å}\) exhibits a difference between the FWHM values in the granules and those in the intergranular space which can be up to \(\approx 12\ \text{mÅ}\).

![Graphs showing FWHM and Equivalent Width fluctuations](image)

Fig. 1: Regression lines of \((\text{FWHM}_i, I_i), (\text{Equivalent-Width}_i, I_i)\) for the lines: \(\lambda 4911.54\ \text{Å}\), and the magnetically nonsensitive line \(\lambda 4912.03\ \text{Å}\).

What mechanism can explain the extra broadening of the absorption lines in the intergranular space? Because the center of the magnetically nonsensitive line is formed at a height of \(\approx 150\ \text{km}\) its broadening reflects certainly the dynamical state of these layers which are turbulent \((\text{cf. Nesis and Mattig 1989; Komm et al. 1990})\). Furthermore, in spectrograms of high spatial resolution, Nesis et al. (1992) observed rapid changes of the line wiggles (from blueshift to redshift) at the border of granules to the intergranular space indicative of shear instability which represents another source of turbulence in the intergranular space. Accordingly, we believe that the extra broadening of the magnetically nonsensitive line \(\lambda 4912.03\ \text{Å}\) in the intergranular space reveals the existence of enhanced nonthermal velocities in the dark regions of the overshoot layers \((\text{cf. Nesis et al. 1990})\). This statement is corroborated by our findings concerning the broadening of the line \(\lambda 4911.54\ \text{Å}\). This line is a weak one, and reflects, therefore, the dynamical state of the layers just above the convective layers. Here, we find still the ordered large-scale granulation pattern \((\text{cf. Nesis et al. 1988})\) i.e. practically the absence of turbulence. The
extra broadening of the weaker line has to be, therefore, smaller than that of the stronger line, which corresponds to our findings. According to Holweger and Kneer (1990) a steep gradient of the line-of-sight velocity in the intergranular space causes the extra broadening of lines. However, in a first glance, the absorption lines used in this investigation do not demonstrate any well marked asymmetry.

Fig. 2 shows the results of fitting the two sets (Center-Line-Depth, I) and (Wing-Line-Depth, I), to a straight-line model \( y = a + b \cdot x \) (regression line) where \( x \) represents again the continuum fluctuations and \( y \) the center and wing line depth, respectively. The regression lines in Fig. 2 show 1) a positive gradient and 2) a strong difference between the gradients of both absorption lines. The stronger gradient corresponds to the magnetically nonsensitive stronger absorption line \( \lambda \) 4912.03 Å. The positive gradient signifies the decrease of the line depth in the dark regions compared to the line depth in the bright elements; the line becomes weaker in the intergranular space. Beyond that we recognize that the regression lines of the line wing depth show a gradient which is practically half the gradient of the regression lines of the center line depth. This is reasonable if we take into account that the wing line depth is measured at the same position as the FWHM.

![Fig. 2: Regression lines of (Center-Line-Depth, I) and (Wing-Line-Depth, I), for the lines: \( \lambda \) 4911.54 Å, and the magnetically nonsensitive line \( \lambda \) 4912.03 Å.](image)

**SUMMARY**

Summarizing we can say that the stronger magnetically nonsensitive line \( \lambda \) 4912.03 Å and the weaker line \( \lambda \) 4911.54 Å demonstrate in the intergranulum the same behavior concerning the line broadening the line depth and the equivalent width: 1) an extra line broadening compared to the granulum 2) an extra reduction of the center line depth compared to the granulum followed by 3) an extra reduction of the line wing depth (half of the reduction of the line center depth), and 4) practically the same equivalent width in granulum and
intergranular space. Because the equivalent width of the lines remains practically the same in the granulum and intergranular space, the depth reduction of the absorption line in the intergranular space has to be compensated by an enhancement of its broadening. The enhancement of the FWHM of the lines due to unambiguous existence of turbulence (nonthermal velocities) in the intergranular space fulfills this compensation.

REFERENCES