FTS MEASUREMENTS OF SOLAR LINE ASYMMETRIES IN QUIET AND ACTIVE REGIONS *

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1. INTRODUCTION

Spectrograms of the solar photosphere almost never show a higher spatial resolution than 0.5 arcsec. Therefore, the properties of solar finestructures, like the granulation, facular points or umbral dots cannot be derived directly with sufficient reliability. Instead, as was demonstrated e.g. by Stenflo et al. (1984), spatially averaged Fourier transform spectra (FTS) with their well known high spectral resolution, their highly symmetric apparatus profile, low scattered light and high S/N ratio can be used as a complementing tool for the diagnosis of atmospheric parameters. The possibility to use many lines measured strictly simultaneously and covering a wide range of excitation potentials, heights of formation etc. represents another advantage of the FTS and at the same time reduces possible errors due to line blending.

The main motivation for the present investigation of plage versus quiet sun line profiles came from the exciting results by Livingston & Holweger (1982) and by Livingston (1983) on the possible cycle dependence of line equivalent widths and asymmetries, as measured in integrated sunlight. It seemed unclear to what extent these effects could be caused by the varying contribution of plages during the solar cycle.

The results shown and discussed in the following represent only the first step in the evaluation of the vast amount of material obtained - and are therefore to be regarded as preliminary.

2. OBSERVATIONS

In the period June 1 to 13, 1984 a series of spectra was observed at the McMath main solar telescope feeding the Fourier transform spectrometer designed and described by Brault (1978). Aided by an improvised slit jaw viewing arrangement (using an Hα Daystar filter) and the daily magnetograms, the entrance slit of the spectrometer, 5 by 25 arsec^2 wide, was "scanned" through various plage regions, avoiding sunspots and pores, and regions of no perceptible activity. For the present investigation a set of 25 spectra taken at cos θ > 0.9, including 5 spectra recorded at disk center, was selected.

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The spectra cover a usable spectral range from λ5050 to λ6650 Å and show a maximum resolving power of 180 000. Most spectra were integrated for 13.7^{m}, a few of them twice as long. In this way S/N ratios beween 2000 and 3000 were achieved.

3. DATA EVALUATION

To estimate the magnetic filling factors α the method first described by Stenflo & Lindegren (1977) was applied. In principle it represents a multi-dimensional regression of a line parameter sensitive to Zeeman splitting (e.g. line width or depth) vs. line strength, excitation potential and effective Landé factor g_{eff}; using a large number of lines of the same ion (here: 180 FeI lines), the generally small effects due to the magnetic field can be isolated and thereby some information obtained on α.

A choice of appropriate values for the line weakening, δ, and the magnetic field strength, B, in fluxtubes yields values of α ranging from 0.001 to 0.22 for the 25 spectra analysed (cf. Figure 1), with a ***relative*** accuracy of approx. ± 0.02. The ***absolute*** accuracy of the α values depends on the choice of δ and B. Schüssler (1986, this conference) pointed out, that also the continuum intensity of the fluxtube emission has to be considered. This fact and a comparison of the present results with those obtained from Stokes I and V measurements by Stenflo & Harvey (1985) leads us to surmise that our α values may be overestimated by a factor of 1.5 to 2, i.e. that the strongest plage region observed in this set had a filling factor α between 0.11 and 0.16. For the rest of the paper we shall use the originally determined α values, but ask the reader to keep this probable correction factor in mind.

For the present analysis 32 weak to medium-strong lines (mostly FeI) were selected. They comprise 3 FeI lines around λ6300 Å studied extensively by Cavallini et al. (1985,1986), a set of 11 lines in the range λ6265 to λ6232 Å used by Gray (1982) in a study of convective velocities in stars, and 17 FeI lines used by Livingston (1983) and Kaisig & Schröter (1983).

4. RESULTS

4.1 Changes of FWHM, equivalent width and line depth with α

An analysis of the relevant line parameters as a function of the filling factor α increasing from 0 to 0.22 yields the following results:

i) Most lines show an ***increase*** of the full width at half of the maximum line depth (FWHM) of 2 to 8% (after subtraction of the Zeeman splitting). A broadening of ≈ 5% is found for the three g=0 lines λ 5576, 5434, 5123 Å, one of which is shown in Figure 1.

ii) A ***decrease*** of the equivalent width, W, is found, ranging from 5 to 10% for weak lines and from 0 to 3% for strong lines, as is shown in Figure 2.

iii) The line depth ***decreases*** by between 5 and 17%, where the latter value applies to the FeI line λ5250.2 Å.

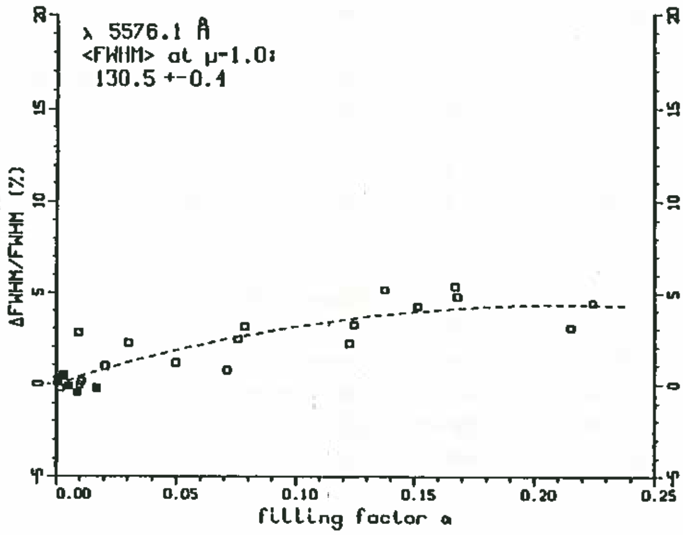

Figure 1: Variation of line full width at half maximum (FWHM) with magnetic filling factor α. The variations are referred to the average <FWHM> of the 5 spectra taken at disk center ($\alpha \lesssim 0.01$, solid squares).

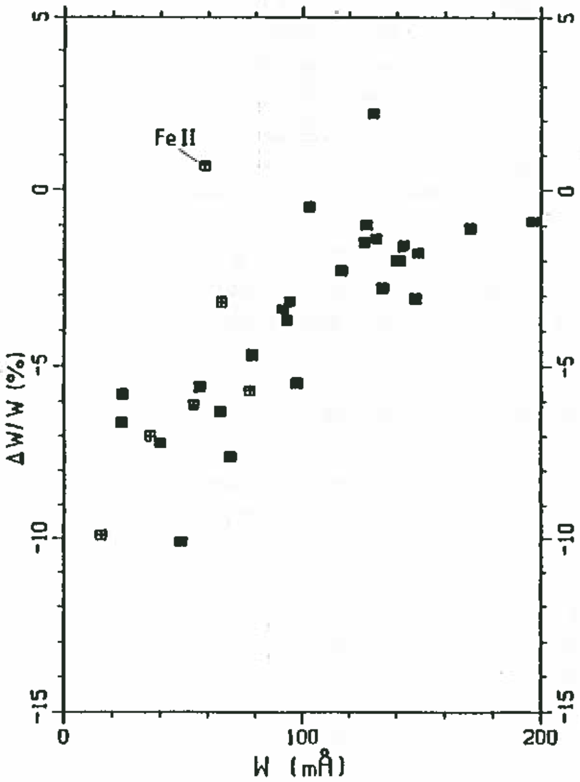

Figure 2: Difference between equivalent widths for filling factor $a \simeq 0.22$ and $\alpha \simeq 0.0$ as function of the equivalent width. Solid squares refer to FeI lines.

4.2 Changes of the line bisector

Basically two aspects are of interest, when discussing bisector variations: their absolute wavelength position and their shape.

A preliminary analysis of our data indicates that the lowest bisector points coincide within ± 1 mÅ for spectra of small, intermediate and high filling factors.

For the investigation of the *shape* of the bisectors the following definition, characterizing the lower and the upper part, was introduced:

i) the wavelength difference between the average of the lowest three bisector points and the point at relative intensity 0.7 (i.e. $\lambda_{min} - \lambda_{0.7}$) was calculated and denoted ∇;

ii) the wavelength difference between the bisector points at relative intensities 0.7 and 0.9 (i.e. $\lambda_{0.7} - \lambda_{0.9}$) was calculated and denoted Δ.

A typical result is presented in Figure 3, referring to the FeI line λ5250.7 Å. The rather smooth and consistent decrease of the bisector "curvature" in the lower part ("∇") from 5 to 2 mÅ is clearly shown (dashed line), as well as an increase of the bisector wavelength difference in the line wing ("Δ", dotted line) from -7 to -9.5 mÅ. In Figure 4 the change of the C-shape with α is shown as a function of the equivalent width for all lines investigated. Similar to the definition given above the open symbol "∇" denotes $\lambda_{min}-\lambda_{0.7}$ for $\alpha \simeq 0$ and the bar ending in the filled symbol "▼" its variation towards $\alpha \simeq 0.22$, whereas the symbol "Δ" represents the value $\lambda_{0.7}-\lambda_{0.9}$ for $\alpha \simeq 0$ and the corresponding bar ending at "V" its variation towards $\alpha \simeq 0.22$. All lines of $W > 100$ mÅ show the well known "straightening" of the lower part of the bisector, as already seen by Livingston (1982), Kaisig & Schröter (1983), Brandt & Schröter (1984), Cavallini et al. (1985) and others. However, as a novel feature a conspicuous "steepening" of the bisector in its upper part is found: more than one dozen of the line bisectors exhibit an increase of the red-shift in the line wing by 2 to 4 mÅ.

5. DISCUSSION AND CONCLUSION

The results presented here are in agreement with those obtained by Immerschitt & Schröter (1986, this conference), who studied the behaviour of the FeI line λ5576.1 Å in plage regions of different Ca^{+}-K-strength.

Two components may be responsible for the modification of the averaged line profiles in active regions: a possibly modified structure of the convection pattern around the fluxtubes or the contribution of the fluxtubes themselves - or both. In an investigation of velocity fields using high spatial resolution spectrograms, Mattig & Nesis (1976) claim to have found higher r.m.s. velocities in small scale structures in active regions. The increase of line width we observe is consistent with the results by Mattig & Nesis (1976). On the other hand, Cavallini et al. (1986) can explain the results of their interferometer spectra of low spatial re-

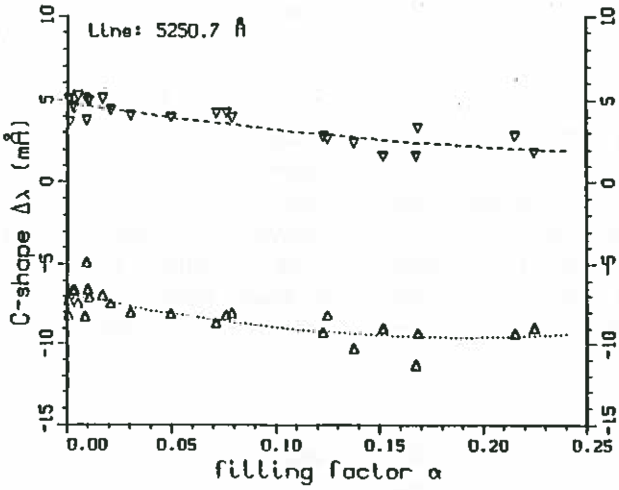

Figure 3: Differences between bisector wavelengths at different intensity levels as function of the filling factor α. Upper curve: $\lambda_{min}-\lambda_{0.7}$; lower curve: $\lambda_{0.7}-\lambda_{0.9}$.For definition cf. text.

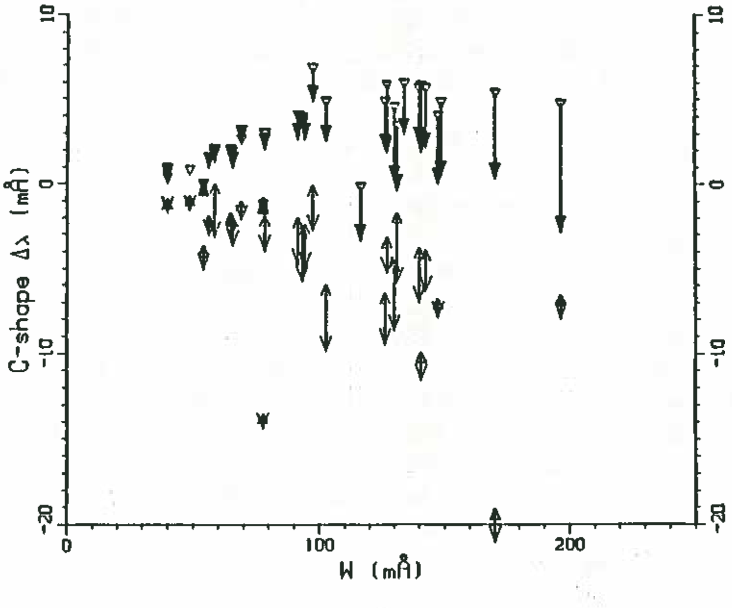

Figure 4: Change of average bisector C-shape from α≃0.0 to α≃0.22 as function of equivalent width.
Symbols:"∇" = $\lambda_{min}-\lambda_{0.7}$ averaged for spectra of α≃0.0; "▼" = same for α≃0.22; "Δ" = $\lambda_{0.7}-\lambda_{0.9}$ averaged for spectra of α≃0.0; "V" = same for α≃0.22. For details cf. text.

solution only by conjecturing "fluxtubes with zero downflow and partially inhibited convection", thus partially contradicting the findings by Mattig & Nesis (1976).

In searching for an explanation of the increased bisector red-shift found in the line wings one should bear in mind that this part of the bisector very probably stems from the contribution of the intergranular lanes. Therefore, the effect found here may hint at increased downward flows in intergranular lanes in active regions - the fluxtubes being excluded as candidates for downflows by Solanki (1986). Such downflows in field free regions near fluxtubes had been postulated earlier by Frazier & Stenflo (1978) and in the theoretical models of Deinzer et al. (1984).

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