*The Magnetic and Velocity Fields of Solar Active Regions*
*ASP Conference Series, Vol. 46, 1993*
*Harold Zirin, Guoxiang Ai, and Haimin Wang (eds.)*

# OBSERVATIONS OF WAVES AND OSCILLATIONS IN THE SOLAR MAGNETIC FINE STRUCTURE

B. FLECK AND F.-L. DEUBNER
Institut für Astronomie und Astrophysik der Universität Würzburg, Am Hubland, 8700 Würzburg, F.R.Germany

W. SCHMIDT
Kiepenheuer-Institut für Sonnenphysik, Schöneckstraße 6, 7800 Freiburg, F.R.Germany

## ABSTRACT

We study the oscillatory behaviour of small-scale magnetic flux-tube concentrations and their immediate surroundings by analysing high spatial resolution time series of spectra of four Zeeman sensitive lines (Fe I 5247.1, Cr I 5247.6, Fe I 5250.2, Fe I 5250.7) taken simultaneously in left-hand and right-hand circularly polarized light with the Echelle spectrograph at the Vacuum Tower Telescope in Izaña, Tenerife. The velocity field inside the magnetic elements is dominated by the 5-min oscillations which also show up as periodic variations in the relative amplitude asymmetry of the Stokes V profiles. In other parameters as for instance the Stokes V peak separation we cannot detect an oscillatory component. Neither the magnetic line ratio nor the thermal line ratio is affected by the 5-min oscillations, although the latter reveals remarkable spatio-temporal variations.

## INTRODUCTION

The fundamental role of small-scale magnetic elements with regard to the structure and dynamics of the solar atmosphere has been widely recognized (cf. e.g. the reviews by Schüssler 1990, Spruit and Roberts 1983, or Stenflo 1989). In this paper, we are concerned with a particular aspect of the physics of the solar magnetic fine structure, namely the oscillatory behaviour. Solanki (1986) concluded from the large width of spatially and temporally averaged Stokes V profiles obtained with the FTS at Kitt Peak National Solar Observatory that there exist large amplitude oscillatory mass motions of up to 3.5 km/s in magnetic fluxtubes. One of the aims of this project is to find direct evidence of such mass motions in form of periodical changes in the shape of temporally and (at least partially) spatially resolved Stokes V profiles.

## OBSERVATIONS

Our observations were obtained in November 1990 with the Echelle spectrograph at the Vacuum Tower Telescope in Izaña, Tenerife. We recorded time series of left- and right-hand circularly polarized spectra in the 5247/5250 region. As detectors we used two 1024×1024 CCD cameras. The polarization analyser consisted of a superachromatic $\lambda/4$-plate in front of two crossed calcites as a beam splitter.

The time series we present in this paper was taken in an active plage region near disc center ($\mu \approx 0.98$). It consists of 530 frames taken at intervals of 12 s with an expoxure time of 0.75 s. The nominal spatial and spectral resolution are 0.17 arcsec/pixel and 3.4 mÅ/pixel, respectively. The seeing conditions during the $1^h\ 46^{min}$ observing run varied between "very good" and "fair" (1-2 to $3^+$).

## RESULTS AND DISCUSSION

In Figure I we display the spatio-temporal varations of the Stokes V amplitude (a), the thermal line ratio $V_{Fe5247.1}\,/\,(0.75 * V_{Fe5250.6})$ (b), the Stokes V zero-crossing wavelength of Fe 5250.2 Å (c), and the relative amplitude asymmetry $\delta a_r = \frac{a_b - a_r}{a_b + a_r}$ of Fe 5250.2 Å (d). All the magnetic elements measured in this series have the same polarity. As is immediately obvious in Figure Ic, the velocity field in the magnetic fine structure is dominated by the 5-min oscillations. A similar behaviour was found before already by Giovanelli et al. (1978), Wiehr (1985), Fleck and Deubner (1991) and Fleck (1991). The RMS of the velocity fluctuations is about 220 m/s only. This is almost a factor of 2 smaller than corresponding values of quiet sun data, and, what is more, is too small by more than one order of magnitude to account for the large width of the Stokes V profiles obtained with the FTS. This implies, that the large amplitude non-stationary mass motions proposed by Solanki (1986) — if they exist — either take place on extremely small spatial scales ($\ll 250$ km) or have very short periods, i.e. very short vertical wavelengths (cf. Solanki and Roberts 1992). It is interesting to note in this context that the RMS values derived from the spatial low resolution observations cited above are much the same as those from our high spatial resolution time series. One might indeed expect such an agreement, if the large scale spatial coherence evident from Fig. Ic can be considered typical.

The average zero-crossing wavelength is redshifted by about 190 m/s with respect to the average Stokes I profile. This is due to the convective blueshift suppressed in the magnetic fine structure. The apparent redshift in the magnetic elements is also visible in the Doppler shift of the Stokes I profiles.

The 5-min oscillations not only lead to a Doppler shift of the Stokes V profiles but also influence their shape, in particular their asymmetry (see Figure Id). Figure II shows the power spectra of $V_0$ and $\delta a_r$ together with the phase difference between these two parameters, and the coherence. Both power spectra reveal a distinctive power maximum near 3.2 mHz, fall off rapidly with increasing frequency, and reach their noise level at about 10 mHz. So we do also see high frequency waves; their amplitude is rather low, however. Of particular interest is the distinctive phase difference of about 50° between $V_0$ and $\delta a_r$ which slightly increases with increasing frequency (according to our sign convention we

https://doi.org/10.1017/S0252921100029754 Published online by Cambridge University Press

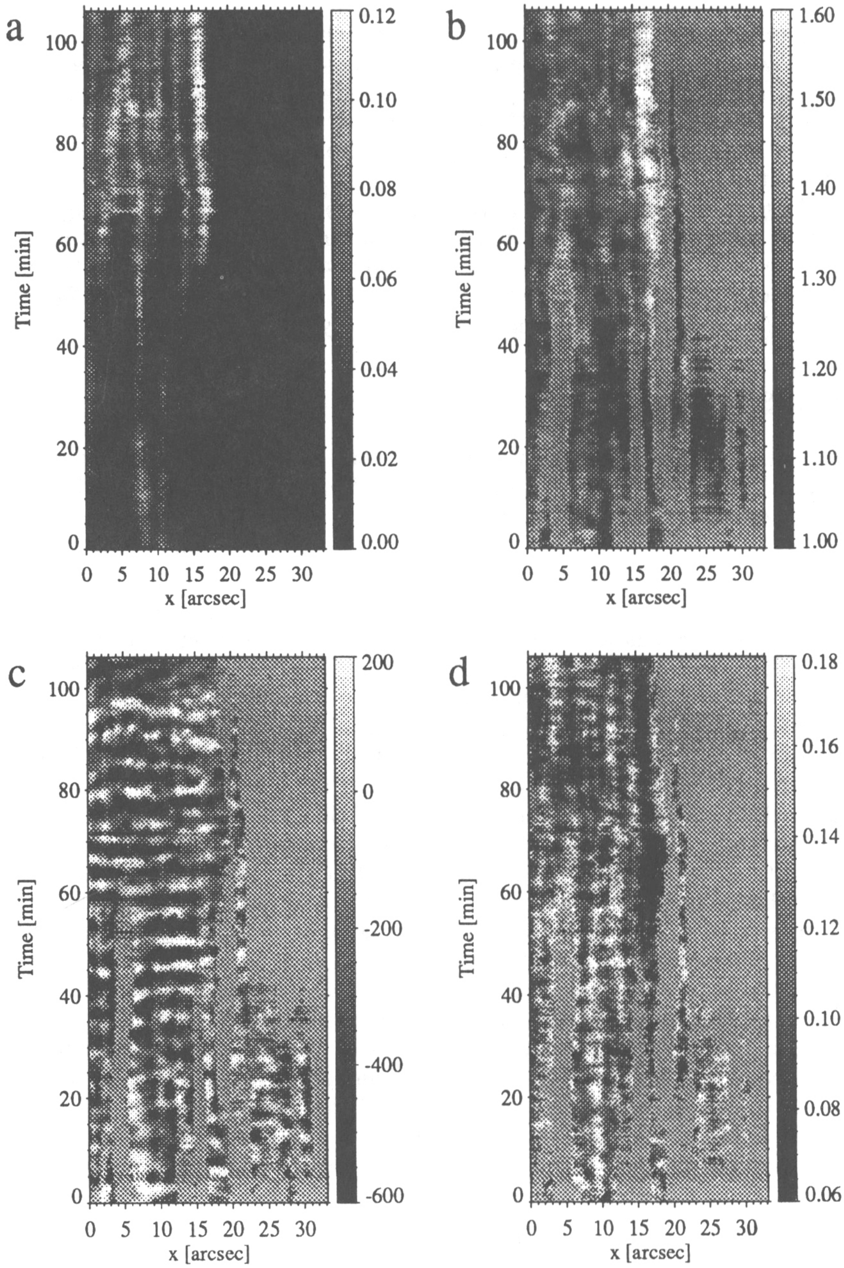


FIGURE I Spatio-temporal varations of the Stokes V amplitude (a), the thermal line ratio (b), the Stokes V zero-crossing wavelength (c), and the relative amplitude asymmetry $\delta a_r = \frac{a_b - a_r}{a_b + a_r}$ (d).

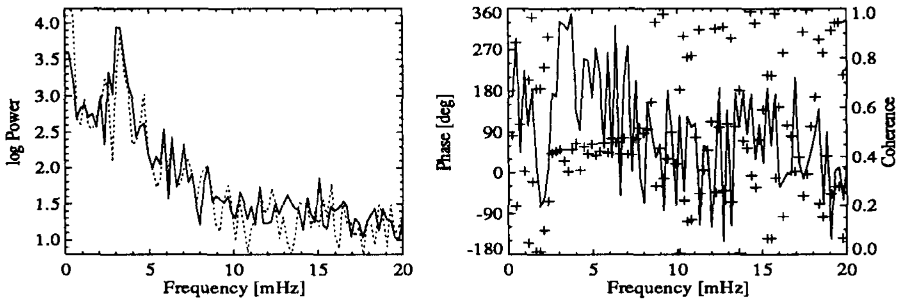


FIGURE II Left panel: temporal power spectra of the Stokes V zero-crossing $V_0$ (solid line) and the relative amplitude asymmetry $\delta a_r$ (dotted line). Right panel: phase difference (crosses) and coherence (solid line) between $V_0$ and $\delta a_r$.

observe a positive phase if blue shift leads positive amplitude asymmetry). This finding certainly merits a thorough theoretical analysis combining MHD- and spectral line synthesis calculations. We also want to point out that we observe a clear anticorrelation of the stationary Stokes V amplitude and the asymmetry. Indications of such a behaviour have already been found by Fleck (1991) with a completely independent data set.

In Figure Ib one can find the first spatio-temporal diagram of the thermal line ratio. The intrinsic differences between the various magnetic structures are much larger than variations caused by the 5-min oscillations (see e.g. the structure at $x \approx 16"$ in the upper half of Fig. I where the Stokes V signal is strongest and the thermal line ratio becomes very large; in the continuum intensity this structure is darker than average). The absence of an oscillatory signature indicates that the temperature variations associated with the 5-min oscillations are negligible compared with the intrinsic temperature variations of the magnetic elements. The magnetic line ratio does not reveal any systematic variations.

A more detailed paper is in preparation for *Astronomy and Astrophysics.*

## REFERENCES

Fleck, B.: 1991, *Rev. Mod. Astron.* **4**, 90

Fleck, B., Deubner, F.-L.: 1991, in *Mechanisms of Chromospheric and Coronal Heating*, eds. P. Ulmschneider, E.R. Priest, R. Rosner, Springer, p. 19

Giovanelli, R.G., Livingston, W.C., Harvey, J.W.: 1978, *Solar Phys.* **59**, 49

Schüssler, M.: 1990, in *Solar Photosphere: Structure, Convection and Magnetic Fields*, ed. J.O. Stenflo, IAU-Symp. No. 138, Kiev, p. 161

Solanki, S.K.: 1986, *Astron. Astrophys.* **168**, 311 p. 103

Solanki, S.K., Roberts, B.: 1992, MNRAS **256**, 13

Spruit, H.C., Roberts, B.: 1983, *Nature* **304**, 401

Stenflo, J.O.: 1989, *Astron. Astrophys. Rev.* **1**, 3

Wiehr, E.: 1985, *Astron. Astrophys.* **149**, 217