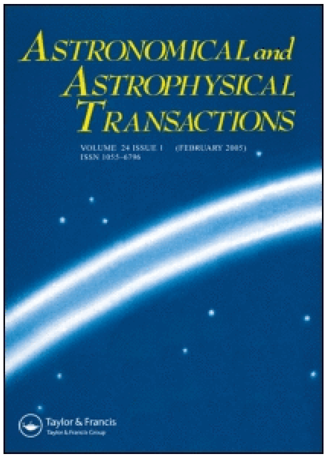

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Some of the main properties of the fine structure of solar magnetic fields as deduced from low spatial resolution stokesmeter observations at the stop telescope of the sayan observatory

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SOME OF THE MAIN PROPERTIES OF THE FINE STRUCTURE OF SOLAR MAGNETIC FIELDS AS DEDUCED FROM LOW SPATIAL RESOLUTION STOKESMETER OBSERVATIONS AT THE STOP TELESCOPE OF THE SAYAN OBSERVATORY

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With the purpose of gaining a better understanding of large-scale solar magnetic fields, we investigated some of the main properties of their fine structure. The study was based on using stokesmeter observations of the Stokes I- and V-parameters in the line of FeI 525.02 nm from the STOP telescope of the Sayan observatory covering a time interval from April to November 1999. Using extensive statistical material (totaling over 120 full-disk stokesgrams with a resolution of 2 arc min) we determined the most informative parameters of the V-profiles such as the asymmetry in amplitudes and areas, and Doppler shifts with respect to the I-profiles of the observed spectral line. The results are compared with findings reported by other authors.

KEY WORDS Sun, magnetic fields, Stokes parameters

1 INTRODUCTION

Large-scale magnetic fields (LSMF) which are commonly used in reference to the fields observed with a resolution of 2–3 arc min, are one of the most important objects of study in solar physics. Investigating them is important for a better understanding of the nature of solar magnetism, the periodicity of activity, and of the various problems in the physics of the interplanetary medium and in geophysics. Until the present, however, the nature of LSMF remained a puzzle. Specifically, it is still unclear what small-scale structures determine the magnetic flux imbalance in the aperture – whether kilogauss inclusions or a weak homogeneous background, or both. On the other hand, through the use of low spatial resolution it is possible

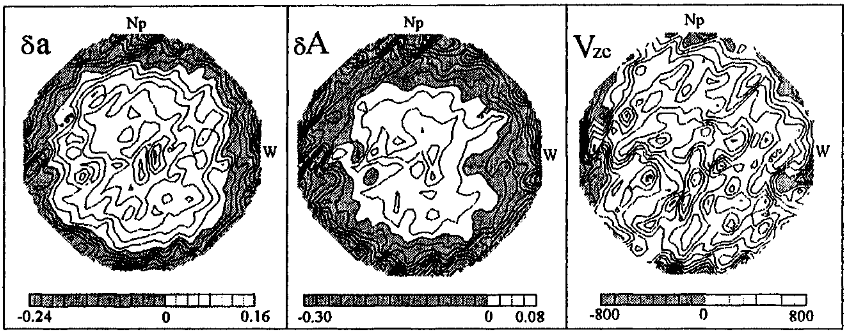

Figure 1 Distribution maps, across the solar disk, for the values of the asymmetry of the Stokes V profiles in amplitudes (δa) and area (δA), and for the Doppler zero-crossing shift of the V parameter with respect to the observation line center (V_{ZC}). The parameters δa, δA and V_{ZC} were obtained from an average (for April–November 1999) stokesgram.

to statistically approach a general problem of the fine structure of the solar magnetic field as this would reveal the main, overall properties of magnetic tubes. The best tool for solving these problems is the analysis of the I-, Q-, U- and V-profiles of Stokes parameters of magnetically sensitive lines. Such measurements became possible with the introduction, in 1998, of the CCD-stokesmeter at the STOP telescope of the Sayan observatory (SSO) (Peshcherov, 1998). This paper is devoted to a statistical analysis of such observations covering the time interval from April to November 1999.

2 OBSERVATIONS AND RESULTS OF ANALYSIS

This study used 120 recorded distributions of the I- and V-profiles of Stokes parameters across the solar disk (stokesgrams). The area 1nm wide that is recorded by the CCD-array contains several Fraunhofer lines; in this paper, however, we report results for the line of FeI 525.02 nm that is most frequently used in solar magnetic field observations. The time taken to measure a single point was 8–10 s, and the total time taken to record a full stokesgram (with a maximum number of points on the disk $N = 241$) was about 2 hours. The V-parameters in the data set being analyzed totaled about 30000; however, upon discarding weak and noisy profiles (with more than one zero-crossing shift within the half-width of the spectral line), 19727 reliable V-profiles were left for the subsequent analysis. In this manner, V-profiles corresponding to strengths of 0.5 G or higher were used.

The important parameters of the V-profiles which are determined by dynamic characteristics of material and of the magnetic field in the object of observation are: the asymmetry of amplitudes $\delta a = (a_b - a_r)/(a_b + a_r)$, where a_b and a_r are, respectively, the amplitude of the 'blue' and 'red' components of the V-profile; the asymmetry of areas $\delta A = (A_b - A_r)/(A_b + A_r)$, where A_b, and A_r, are the

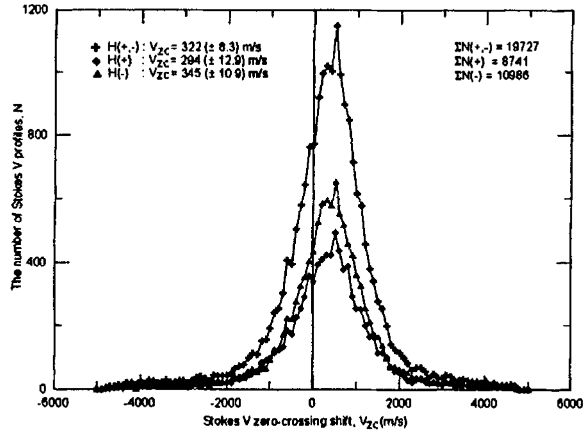

Figure 2 Histograms of the values of the parameter V_{ZC} (zero-crossing shift), the value of the wavelength difference (expressed in velocity units) between the center of the I-profile and the zero-crossing shift of the V-profile. The data are given separately for the positive and negative polarities of the magnetic field, and without separation. The positive values of V_{ZC} correspond to a blue shift, i.e. to the fall of material in magnetic elements.

areas of the 'blue' and 'red' components of the V-profiles; and V_{ZC} (zero-crossing shift), the wavelength difference (expressed in velocity units) between the zero-crossing shifts of the V-profiles and the line center (center of the I-profile). Visual inspection of the individual stokesgrams shows a great variety of forms of V-profiles and of their relative shifts (with respect to the center of I-profiles). To ascertain the general characteristics of the V-profiles, we constructed an average stokesgram (for the period under investigation) which was used to construct distribution maps, across the solar disk, of the above mentioned parameters (Figure 1). All subsequent calculations were carried out on the basis of these maps.

Histograms of the values of V_{ZC} are presented in Figure 2, separately for the positive and negative polarities of the magnetic field, and without separation. The sign and magnitude of the magnetic field were determined from the value of the splitting of the sigma-components through a simulation of the magnetographic mode with the parameters of the photometer slits that were used at the STOP previously. An examination of Figure 2 reveals that the Sun exhibits a large spread in the values of V_{ZC}, and there is no dependence on the magnetic field polarity. The downward velocity of material in magnetic elements (if it is assumed that this determines the zero-difference of V_{ZC}) averages 320 m s^{-1}.

The asymmetry parameters of the V-profiles, δa and δA, are important quantities characterizing the relationship between magnetic field gradients and line-of-sight velocities in the aperture of observation (Steiner, 1999). Histograms of these values are presented in Figure 3. It is evident that despite the large scatter of the values of δa and δA, their zero-difference – according to our data – is not large, on average.

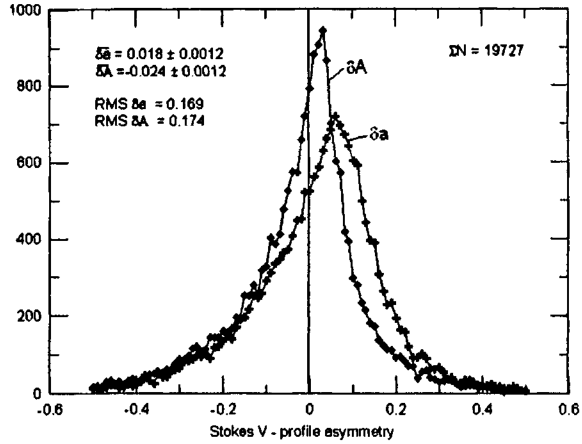

Figure 3 Histograms of the asymmetry parameters of V-profiles: δa – amplitude asymmetry, δA – asymmetry of areas.

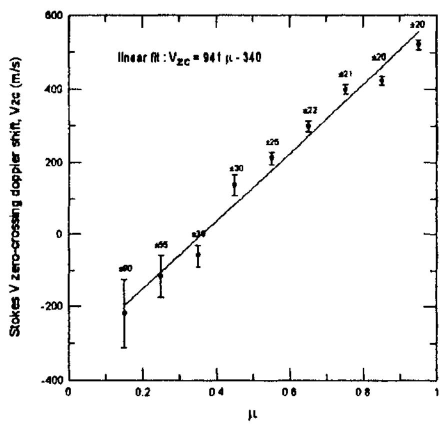

Figure 4 Dependence of the parameter V_{ZC} on μ, where μ is the heliocentric angle.

To develop reliable models for magnetic elements that determine the properties of polarized emission, it is important to know the distribution of the parameters δa, δA and V_{ZC} across the solar disk. Figures 4 and 5 plot center-to-limb variations of these parameters. When constructing Figure 4, no correction was made for the blue shift of the I-profile that is caused by granulation. An examination of Figure 4 reveals that V_{ZC} reaches a maximum value at the disk center, decreases to zero at $\mu \sim 0.2$, and then changes its sign. The character of variation of V_{ZC} versus μ is almost linear, except for the point nearest the null point (and hence more prone to errors). It is interesting to note that this result differs (both in the value and in the variation with μ) from that reported in (Stenflo *et al.*, 1987). Our results also

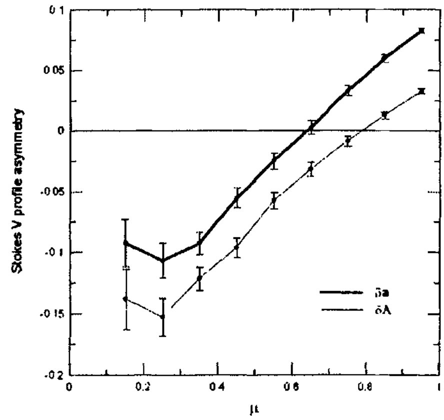

Figure 5 Parameters of the amplitude asymmetry δa and of the asymmetry of areas δA versus μ.

differ from those reported in [Stenflo et al., 1987] as regards the parameters δa and δA. In particular, according to Stenflo *et al.* (1987), there is no transition through zero of the parameter δA, and the variations of δa and δA depending on μ have a different character.

Our results are in significantly better agreement with the data from (Sigwarth *et al.*, 1999) and (Grossmann-Doerth *et al.*, 1996). The reason for such a situation is most likely the special selection of observational material in (Stenflo *et al.*, 1987). In particular, a similar result was obtained by analyzing the dependence of the above-mentioned parameters on magnetic field strengths. With a rather large scatter of the points, there is a clear tendency for the values of δa and δA to increase abruptly at small strengths. This phenomenon appears to be explicable in terms of the model suggested in (Sigwarth *et al.*, 1999) which assumes that at small strengths or with a small filling factor, the polarization parameters are virtually determined by individual magnetic elements.

Thus, a comparison of our results with earlier findings (a summary of them may be found in Steiner, 1999) shows a generally good agreement with more recent work and, to a lesser extent, with the 'older' publication (Stenflo *et al.*, 1987). This may be treated as proving the validity of the statement that LSMF observations also reveal the properties of magnetic flux tubes which are customarily used to interpret observations in local solar features with high spatial resolution. It is interesting to note that the above considerations turn out to be justified even in regard to magnetic field observations of the Sun as a star. However, this issue, and also some other questions, is considered in another paper Zhigalov *et al.* (in these proceedings).

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