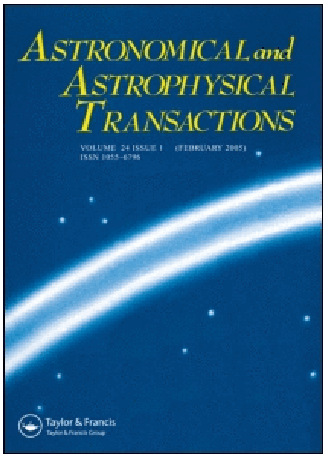

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RELATIONSHIP BETWEEN THE MEAN SOLAR MAGNETIC FIELD STRENGTH AND THE STOKES V-PARAMETER DISTRIBUTION

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This paper examines some of the properties of the Solar mean magnetic field (SMMF) that are brought to light by Stokesmeter (Stokes V-parameter) observations in the FeI line λ525.02 nm. Stokesmeter SMMF measurements are compared with magnetographic data, based on observations from the STOP telescope at the Sayan solar observatory as well as from the J.Wilcox Solar Observatory. It is shown that the character of the Stokes V-parameter distribution in the line profile is determined by the distribution of large-scale fields across the solar disk, especially in the central zone.

KEY WORDS Sun, sun-as-a-star, magnetic fields, Stokes parameters

1 INTRODUCTION

Most information about solar magnetic fields is presently furnished by telescopes equipped with polarimeters based on CCD-receivers. The benefits of such instruments are compelling since they provide information about the distribution of Stokes parameters (I, Q, U and V – in the general case, and I and V – in the case of longitudinal field measurements), usually in several spectral line profiles simultaneously. Stokesmeter data of this kind have been instrumental in significantly enhancing the possibilities of creating realistic physical models of the various solar features. However, CCD-Stokesmeter investigations have been carried out solely with high ($\approx 1''$) spatial resolution until very recently. On the other hand, observations of large-scale solar magnetic fields (LSMF), i.e. of the background (BMF) and solar mean (SMMF) magnetic fields, were carried out (at, for example, the Crimea, Stanford, and Sayan observatories) with magnetographs which were previously highly progressive and informative but are out of date at present. LSMF measurements, as a special kind of observation, are still of high priority. For that reason, there is no need to give proof to the fact that introducing Stokesmeter techniques into LSMF research practice is a highly challenging task.

Such research was initiated by the authors at the STOP telescope of the Sayan solar observatory (SSO) (Peshcherov et al, 1998, 1999). This paper is the first to outline the main results of Stokesmeter observations regarding the SMMF. It is pertinent to note that STOP is currently the only instrument to secure Stokesmeter observations of the SMMF.

2 OBSERVATIONS AND RESULTS

The length of the CCD linear sensor used at STOP is such (2.9 cm, 3614 pixels) that the dispersion of 0.04 nm mm^{-1} makes it possible to observe a spectral region of width $\sim$ 1 nm. However, this paper is based on using data concerning measurements in a single lime, FeI λ525.02 nm, because it is in this line that SMMF measurements were made (except for (Demidov, 1998)) at different observatories during the past years. Observing intervals from April 1, 1999 to November 30, 1999 were used in the analysis (totalling 152 measurements) when the measurements were carried out on the most regular basis. Because of the obviously small SMMF strength ($\sim$ 1 G) and the small amount of light, to ensure reliable recordings of the Stokes V-parameter, longer (than in, for example, the case of the BMF) signal accumulation times were used. Specifically, the typical accumulation time of a single measurement (per clock cycle of the electro-optic analyser of polarization, EOAP) was 70 ms, the accumulation time in a single position of the half-wave ($\lambda/2$) phase plate was $\sim$ 10 s, and the total observing time was $\sim$ 15–20 min. The RMS noise of Stokes in a continuum is $V/I_c \sim 2 \times 10^{-5}$, which corresponds to the strength $H \sim 0.05$ G. Such, very high, accuracy of polarimetric measurements makes it possible to detect the SMMF strength sufficiently reliably in most cases.

In practice, the numerous SMMF observations have shown that the profiles of the Stokes V-parameter (V-profiles) can have quite varied shapes ranging from 'classical' to 'anomalous'. Figure 1 illustrates examples of several V-profiles of the SMMF for five days of observation, from September 13 to 20, 1999. For the corresponding days, the right-hand part of this figure presents the magnetograms of BMF taken at the J. Wilcox Solar Observatory (WSO) and at the SSO observatory. Inspection of this figure (especially taking into account the time difference between the observations at WSO and SSO) reveals that the shape of the V-profile depends on the BMF distribution across the solar disk, especially in the central part. A special analysis has shown that even a simple averaging of the V-profiles over the solar disk (on the basis of the Stokesgrams obtained at STOP) leads to a mean V-profile which is in good agreement with the observed integral V-profile. The correlation coefficient between calculated and observed profiles was as high as 0.85.

Clearly it is of interest to ascertain the correspondence of the new, Stokesmeter observations of the SMMF with the magnetographic measurements. Based on our own data, this was done by comparing the strengths calculated from the mean amplitudes of V-profiles (H_A), and through numerical simulation of the magnetographic

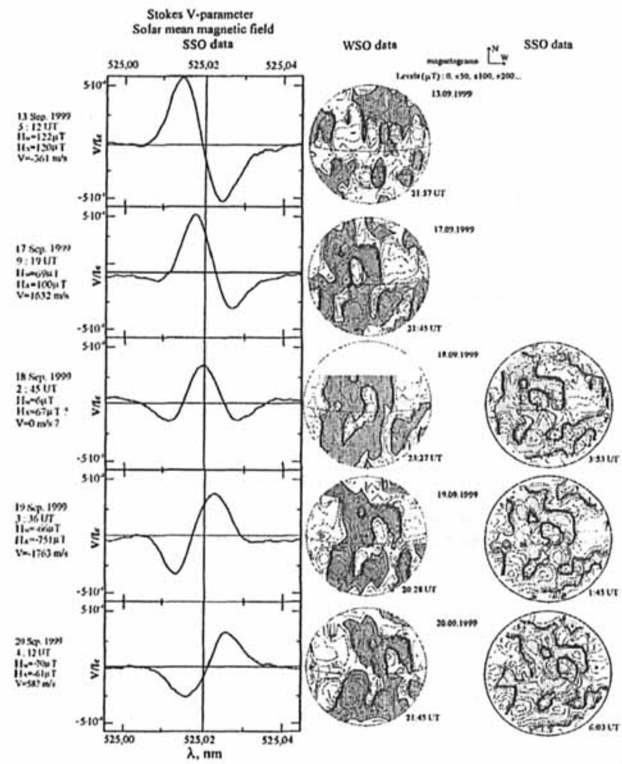

Figure 1 Comparison of the V-profiles in the solar mean magnetic field (SMMF) observations and of the distributions of background magnetic fields, based on the data from WSO (J. Wilcox Solar Observatory) and SSO (Sayan solar observatory). Shown on the left of each panel: date of observations; time of SMMF observations at SSO; effective SMMF strength H_M determined from the shift of the splitting sigma-components (see the text); field strength H_A determined from the (mean) amplitude of the V-parameter; velocity V_{zc} corresponding to the wavelength difference between the line centres (vertical bars in the middle of each panel) and the point of intersection of the V-profile through zero.

signal (H_M). In the former case, use was made of the empirically determined relationship that the amplitude of the 'correct' V-profile $V/I_c = 5 \times 10^{-4}$ corresponds to a strength of 1 G. In the latter case, we determined the effective line splitting at the locations of the 'spurious' slits of the magnetograph (with the parameters of the earlier magnetographic system of STOP). Results of the comparison of H_A and H_M are shown in Figure 2. With $N = 152$ pairs of points, and a correlation coefficient $\rho = 0.94$, the linear regression equation has the form

$$H_A = -2.5 + 1.17 H_M. \tag{1}$$

This suggests that, except for a few points, the agreement of H_A and H_M is very good. The data, according to which H_A and H_M differ significantly, correspond to

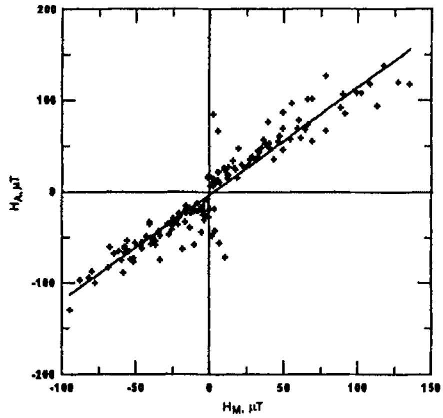

Figure 2 Comparison of the SMMF strengths determined from the amplitudes of the Stokes V-parameters, H_A, and by numerical simulation of magnetographic measurements, H_M, with the 'slit' parameters corresponding to the earlier STOP design.

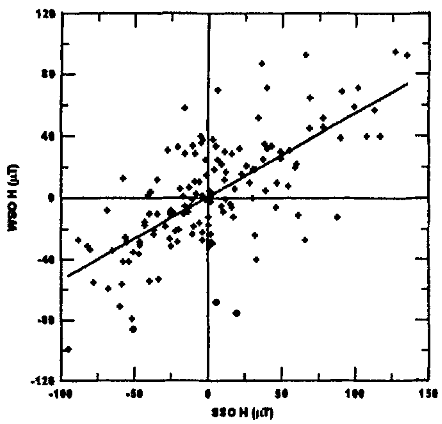

Figure 3 Comparison of the SMMF observations from the Sayan solar observatory (SSO) and J. Wilcox Solar Observatory (WSO) for the time interval from April 01, 1999 to November 30, 1999.

the cases of 'special' V-profiles, specifically with large (which is strange and curious *per se*) relative displacements of the I- and V-profiles.

We also carried out a comparison of the Stokesmeter and magnetographic SMMF measurements by a different method; specifically, through comparison of our (SSO) data with the SMMF measurements from WSO. Apart from the aspect under discussion, such a comparison is of important independent significance. In particular, for problems of investigating the time variations of the SMMF (Kotov *et al.*, 1998), comparing the data from different observatories is of prime importance. Results derived from such a comparison for the time interval analysed are shown in Figure 3. With $N = 142$ pairs of points, and a correlation coefficient $\rho = 0.62$, the linear regression equation has the form

$$H_{\mathrm{WSO}} = 0.82 + 0.54 H_{\mathrm{SSO}} \,. \tag{2}$$

As has been pointed out above, detailed information about the distribution of Stokes parameters in line profiles makes it possible to make reliable assessments not only of the magnitude of the magnetic field but also of the thermodynamic conditions in the object of observation. Especially informative in this regard are the parameters of the amplitude asymmetry (δa) and of the asymmetry of the areas (δA) of V-profiles, as well as the value of the difference of wavelengths between the line centre and the point of intersection of the zero-level V-parameter by the V-profile (V_{zc} – zero-crossing shift). As regards the SMMF, it is difficult to speak of any particular object of observation (there is a contribution from all parts of the solar disk here); nevertheless, it is interesting to estimate the values of these parameters in this case as well. According to our data, the values of these quantities were: $\delta a = 0.25$; $\delta A = 0.01$; and $V_{zc} = 0.3$ km s^{-1}. It is surprising that these values are sufficiently close to those reported by other authors for particular 'local' solar features (see, e.g., Table 1 in (Steiner, 1999)). This suggests that SMMF observations show up the same properties of magnetic flux tubes which account for the characteristic properties of the V-profiles in observations with high spatial resolution.

Acknowledgments

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