AN INVESTIGATION OF THE SUN-AS-A-STAR MAGNETIC FIELD THROUGH SPECTROPOLARIMETRIC MEASUREMENTS

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Abstract. We discuss some properties of the Sun-as-a-star magnetic field (SSMF) from measurements of the Stokes I and V profiles observed in several spectral lines simultaneously at the Sayan Observatory during 1999–2001. The data are analyzed both in terms of the Stokesmeter and magnetographic measuring techniques. Using, together with the SSMF observations, quasi-simultaneous measurements of V-profile distributions across the solar surface with an angular resolution of 100 arc sec we have shown that the SSMF signal is determined largely by the central area of the disk within 0.5 solar radius. We have explored the correlation and regression relations in different combinations of four Fraunhofer lines near the line Fe I λ525.021 nm and concluded that fine-structure elements with kilogauss strengths are main sources of the SSMF signal. We have obtained statistical estimates of asymmetry parameters and relative shifts of the Stokes V-profiles, which indicate the presence of dynamic processes in the magnetic elements. The relation between the Sayan and Stanford SSMF measurements is analyzed.

1. Introduction

The possibilities of solar magnetic field diagnostics have been significantly increased during the last two decades with the implementation of high-precision spectropolarimetric methods and the development of polarized radiative transfer theory (see reviews by Stenflo, 1994; Collados, 1999; Socas-Navarro, 2001; and others). Most of the advantages of new facilities have, however, been applied to occasional observations with rather high spatial (angular) resolution and to areas with fairly strong magnetic fields. It is also of great importance to carry out synoptic observations over the entire solar disk, both with high (Kitt Peak and Mt. Wilson Observatories), and low (J. Wilcox Solar Observatory (WSO), Stanford) spatial resolution, as well as observations of the Sun-as-a-star magnetic field (SSMF) which are being done at the following observatories: Crimean Astrophysical Observatory (CrAO), Sayan Solar Observatory (SSO), and WSO. In addition, Stokesmeter observations of the full solar disk are made at the STOP telescope of the Sayan observatory (Peshcherov *et al.*, 1999; Demidov *et al.*, 2001) since 1999 on a regular basis recording in several lines simultaneously (in 1 nm wide band) the Stokes I- and V-profiles in two modes of observation: (1) measurements of the solar-disk distribution of large-scale magnetic fields (LSMF) with

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a resolution of 100 arc sec, and (2) observations of the SSMF. Some of the results obtained from such Stokesmeter observations of the LSMF were reported by Demidov *et al.* (2001). The objective of this paper is to present the main results of SSMF observations for March 1999–April 2001.

SSMF observations were initiated in 1968 at CrAO (Severny, 1969) and continued on a regular basis for several years (Kotov and Demidov, 1980; Kotov and Severny, 1983). During 1970–1982, SSMF measurements were carried out on a relatively regular basis at Mount Wilson Observatory (Scherrer, 1973; Kotov *et al.*, 1992, 1998). Since 1975 (Scherrer *et al.*, 1977a) until the present (WSO web-site, *Solar-Geophysical Data*), the most regular data series has been provided by WSO. Less complete but still on a relatively regular basis, SSMF observations are being done at SSO (Grigoryev and Demidov, 1987; Demidov and Grigoryev, 1998). After a long interruption, SSMF measurements have also been resumed at CrAO (Kotov, Haneychuk, and Tsap, 1999), though not as regularly as before.

SSMF observations make it possible to judge the Sun as a variable magnetic star. Of special interest is the attempt (useful for stars as well) to use SSMF observations to study differential rotation (Hejna and Wöhl, 1993). The relatively short time required for a single recording of the SSMF (normally a few tens of minutes) can ensure (especially through the combination of observations at different observatories) a long-term, sufficiently homogeneous data series. Such a series (covering more than 30 years to date) provides a unique possibility for investigating time variations of the SSMF, both long-term variations caused by the periodicity of activity, and shorter-period variations caused by solar rotation (Kotov and Demidov, 1980; Kotov and Severny, 1983; Kotov and Levitsky, 1983; Kotov, 1987; Rivin and Obridko, 1992; Kotov *et al.*, 1998; Kotov, Haneychuk, and Tsap, 1999; Mordvinov and Plyusnina, 2000; Haneychuk, 2000). The high correlation of the SSMF with the sector structure of the interplanetary magnetic field (Severny *et al.*, 1970; Wilcox, 1971; Scherrer *et al.*, 1977b; Kotov and Demidov, 1980) makes SSMF observations of importance also from the geophysical standpoint, in particular in tackling some of the problems of the Space Weather program. A further aspect of SSMF observations, implying the possibility of determining mean statistical (averaged over the full disk) parameters of fine-structured magnetic elements (FSME) will be illustrated by the results of this study.

All previous observations of the SSMF were based on magnetographic measurements in only one spectral line: Fe I λ525.021 nm (except for Demidov, 1998). Since the beginning of regular Stokesmeter measurements of the SSMF at SSO in 1999 it became possible to obtain information about the distribution of the Stokes I- and V-profiles simultaneously for several spectral lines. Usually the observations are done around the line Fe I λ525.021 nm; on occasion, however, measurements are made (for experimental purposes) in other spectral bands, in particular around the lines of Fe I λ630.15 nm and Fe I λ630.25 nm.

The STOP Stokesmeter uses a TOSHIBA TCD CCD linear detector (29 mm long). The pixels are 200×8.0 μm (height × width) in size. The signal is digitized by a 12-bit AD converter. The polarization analyzer (PA) consists of an electrooptical $KD^{*}P$ crystal and a polarizing prism. It is fed by a square-wave voltage, whose amplitude is varied according to temperature (within ± 25 °C). To make the best use of the dynamic range of the CCD, the PA operating frequency (compared with previous magnetographic measurements) was reduced more than an order of magnitude so that the exposure time, depending on solar brightness, is 70–80 ms (normally 50 ms for LSMF observations).

Since SSMF measurements involve extremely small degrees of polarization, it is of critical importance to correctly take into account the numerous distorting instrumental factors. As the observations showed, an especially acute problem was optical interference arising in the PA. It was found that instrumental problems can be taken into account in the best way (as in the case of magnetographic observations) through the use of a $\lambda/2$ plate that is intermittently placed into the beam directly in front of the coelostat. All observations are done both with and without the plate. The numerical processing then effectively filters out the ‘useful’ signal and eliminates the numerous ‘spurious’ signals. Usually, the integration time for one position of the $\lambda/2$ plate is 10 s. The total recording time is however more than 15 min, because many frames are recorded to improve the S/N ratio. The resulting r.m.s. noise in the continuous spectrum is $V/I_c = 2 \times 10^{-5}$, which corresponds to $B = 0.05$ G. In the case of long accumulation times (which is often the case if the weather permits), a higher accuracy can be achieved.

We used two approaches to determine the effective SSMF strength. One approach involved simulating the operation of the magnetograph with the parameters of the ‘exit’ slits corresponding to previous magnetographic measurements with STOP, namely, with the distances of the inner and outer edges of the slits from the line center equal to 1.4 pm and 5.6 pm, respectively. The strength, thus determined, provides continuity of observations with STOP, and will be used in subsequent sections. The other approach is based on using the property of linear dependence of the V-profile amplitude on the magnetic field strength for sufficiently small strength values (see, for example, Figure 2.2 in Solanki, 1993 and Equation (12.1) in Stenflo, 1994). We calculated the mean values of the amplitudes of the blue and red components of each particular profile, and the strength values were determined from empirically determined relations. For the line Fe I λ525.021 nm, the relation used has the form

$$V/I_c = 5 \times 10^{-4} B, \tag{1}$$

where B is the magnetic field strength in gauss. The nearly twofold difference of the numerical coefficient in (1) from that reported in (Stix, 1991; formula (3.82)) seems to be accounted for by the difference between the line’s parameters in our actual SSMF observations and those assumed by Stix (1991).

Naturally, it is of interest to ascertain the way in which the strengths determined by these two methods correlate. The result of such a comparison (for the line of Fe I λ525.021 nm) is presented in Figure 1, in which the symbols B_M and B_A designate

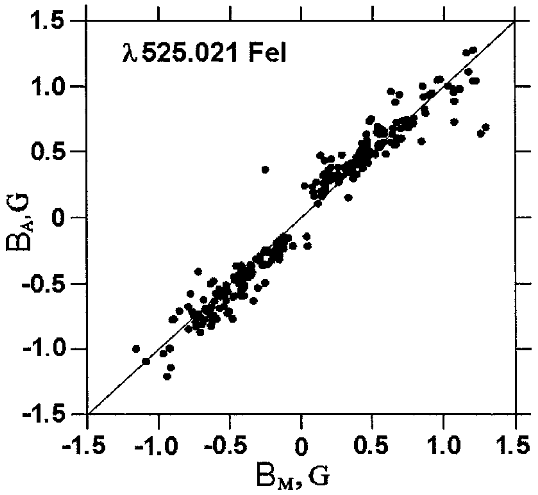


Figure 1. Comparison of the SSMF strengths determined through a simulation of the magnetographic mode of measurement (B_M) and by formula (1) (see the text) from the amplitudes of V-profiles (B_A). The *inclined line* shows the 45° reference.

the strengths determined, respectively, by the first (magnetographic) and second (amplitude) methods. The agreement is good. Some exceptions occur for points that correspond to anomalously large shifts of the V-profiles.

2. Formation Zones of the SSMF Signal

By definition (and by the method of observation, of course), the SSMF implies that the full visible solar disk is involved in the formation of the signal. Of course, for a number of reasons such as limb darkening, rotation, or instrumental effects, the contributions from different zones (weighting functions) are different. Strictly speaking, it is only at CrAO where the Sun is being observed as a star – in a parallel beam; all other observatories use (to increase the light flux) additional optics that have some influence on the measurements. For STOP some effects of the optics on the SSMF measurements have been discussed (Grigoryev and Demidov, 1987; Demidov, 1996; Demidov and Grigoryev, 1998). A special investigation of the question of the zones responsible for the formation of the SSMF signal (observations at MWO) was made by Scherrer, Wilcox, and Howard (1972) and Scherrer (1973). By comparing the calculated (from MWO magnetograms) values of the magnetic flux from circular zones of the solar disk with the sector structure of the interplanetary magnetic field, it was found (Scherrer, Wilcox, and Howard, 1972) that the best correlation occurs with the flux from the central zone of radius $r_z = 0.5\ R_\odot$. By comparing zonal magnetic fluxes with SSMF measurements, it was found (Scherrer, 1973) that the best agreement (with the correlation coefficient

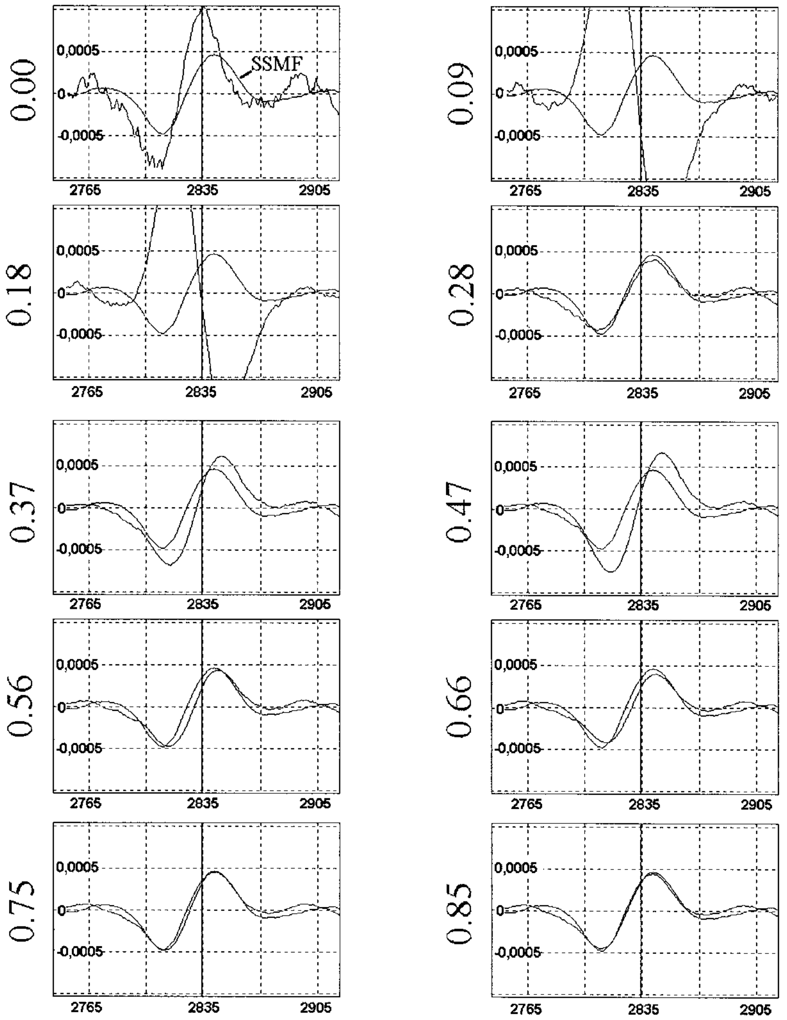


Figure 2. Example of a comparison (for Fe I λ525.021 nm) of the 'integral' V-profile (same in all panels) obtained in SSMF observations on 19 September 1999, with the V-profiles obtained by averaging the LSMF stokesgrams over the zones of the solar disk of a different radius. The radii of such zones in fractions of the solar radius are presented at the left for the corresponding panels. The vertical Y axis of the plots gives the circular polarization V/I_c and the horizontal X indicates the wavelength in CCD pixels.

$\rho = 0.5$) is attained when $r_z = 0.6\ R_\odot$. With an increase of the radius of the zone from this value, the correlation decreases to $\rho = 0.37$, when $r_z = 1.0\ R_\odot$.

Because STOP performs (with a small time difference) Stokesmeter observations of both the SSMF and LSMF, the question of the contribution of different zones can be solved by comparing an 'integral' V-profile (SSMF observations) with V-profiles obtained by averaging over different areas. In Figure 2 we show

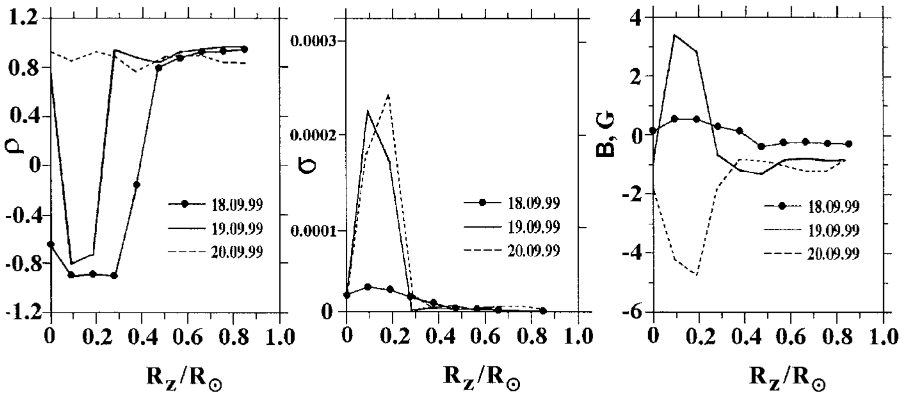


Figure 3. Comparison (using the data from three days) of the 'integral' V-profile and 'zonal' V-profiles (see the text) from: (a) (*left panel*) the correlation coefficient ρ, (b) (*middle panel*) the r.m.s. value of profile differences σ, and (c) (*right panel*) the magnetic field strength B.

the line Fe I $\lambda525.021$ nm for one of the days of observation. It is seen that good agreement occurs when $r_z = 0.37\ R_\odot$, and that an addition of more outer zones affects the result only slightly. This conclusion is also borne out by a more detailed quantitative analysis. Figure 3 shows the results from comparing the 'integral' and 'zonal' V-profiles (again for the line Fe I $\lambda525.021$ nm) using three criteria: (a) the correlation coefficient ρ; (b) the r.m.s. value of deviations σ; and (c) the magnetic field strength B. It is evident that in all three cases the best agreement is attained when the size of the averaging region $r_z \leq 0.5\ R_\odot$ or less. Limb zones have no substantial effect on results. Of course, this is true only in a statistical sense – there is a definite influence of the limb (especially polar) zones. This may result in (as suggested by, for example, Rivin, 1997) an annual SSMF periodicity (although this effect has been given an alternative explanation – Kotov, Levitsky, and Stepanyan, 1981; Kotov and Levitsky, 1985).

Apart from the question of the spatial location of the SSMF sources we need to address the question of their physical origin. Is the dominant contribution from strong magnetic fields concentrated in small-scale magnetic elements or, on the contrary, from weak magnetic fields occupying most of solar surface (see possible magnetic distribution functions in Stenflo, 2001)? A possibility of removing the influence of sunspots was shown by Kotov, Stepanyan, and Sherbakova (1977). A very powerful tool for solving this problem that has long been successfully applied (Howard and Stenflo, 1972; Stenflo, 1973) is the 'line ratio method', with which a comparison is made of measurements made in lines with different sensitivities to the magnetic field. In regard to the SSMF magnetographic observations, this method has been used by Demidov (1998). A more effective analysis is made in the next section using Stokesmeter measurements.

TABLE I

Basic data for the spectral lines used.

λ, nm	El.	EP, eV		J		Mult. No.	Transition	g_{eff}	W, pm
		low	high						
524.705	Fe I	0.09	2.44	2	3	1	$a^5D - z^7D^0$	2.0	5.9
524.756	Cr I	0.96	3.31	0	1	18	$a^5D - a^5P^0$	2.5	7.6
525.021	Fe I	0.12	2.47	0	1	1	$a^5D - z^7D^0$	3.0	6.2
525.065	Fe I	2.19	4.64	2	3	66	$a^5P - y^5P^0$	1.5	9.9

3. Comparison of SSMF Observations in Different Spectral Lines

We have carried out most SSMF observations in spectral lines adjacent to the traditionally used line Fe I λ525.021 nm. Here we analyse four lines summarized in Table I. The simplest interpretation is possible with measurements in lines of the same multiplet with similar atomic parameters but with differing Landé factors g. In the present case these are, of course, the lines Fe I λ524.705 nm ($g = 2.0$), and Fe I λ525.021 nm ($g = 3$), i.e., the magnetic line ratio that was used by Stenflo (1973). However, for purposes of making a more detailed diagnostics of magnetohydrodynamic conditions for the formation of polarized radiation, comparisons of observations in other combinations of spectral lines are also highly useful.

We calculated the regression relations and determined the correlation coefficients for all combinations of the spectral lines in Table I. The calculations were performed both separately for different years (in order to identify possible time variations caused by changes (with the solar activity cycle) of the relation between the strong and weak components of the magnetic field) and for the entire set of observations. An important result was the high (with the exception of comparisons using the line of Cr I λ524.756 nm – to be discussed below) correlation between the lines, which indicates good accuracy of the measurements. An important factor in this case is, of course, the simultaneity of the measurements (unlike observations with the magnetograph) in the different lines. The presence of systematic differences in different lines is quite natural and presents valuable information that requires a physical explanation.

For illustrative purposes, regression dependencies are shown in Figure 4 for combinations of the Fe I λ524.705 nm line with the three other: Cr I λ524.756 nm, Fe I λ525.021 nm, and Fe I λ525.065 nm. A summary of the numerical results of the statistical analysis for all combinations of the lines is presented in Table II separately for each year, as well as for the entire data set. It is evident from the plots and table that when observations in the line Cr I λ524.756 nm are used, there is a large scatter (the correlation coefficient is smaller). The interpretation of this

TABLE II

Results of correlation and regression analyses of SSMF Stokesmeter measurements in different spectral lines. $A(\pm\Delta A)$, $K(\pm\Delta K)$ are parameters of the linear regression equation $B_{\mathrm{line}Y} = A(\pm\Delta A) + K(\pm\Delta K)B_{\mathrm{line}X}$, ρ is correlation coefficient.

λ, X	λ, Y	Year	N	K	ΔK	A	ΔA	ρ
524.705	524.756	1999	172	0.84	0.05	0.04	0.06	0.62
		2000	156	1.24	0.04	0.06	0.04	0.92
		2001	39	1.37	0.21	0.12	0.15	0.31
		1999–2001	367	1.08	0.04	0.05	0.04	0.76
	525.021	1999	172	0.93	0.01	0.00	0.01	0.99
		2000	156	0.94	0.02	0.02	0.02	0.98
		2001	39	0.90	0.02	−0.01	0.02	0.99
		1999–2001	367	0.93	0.01	0.01	0.01	0.98
	525.066	1999	172	1.93	0.02	−0.02	0.02	0.99
		2000	156	1.92	0.05	0.00	0.05	0.95
		2001	39	1.85	0.08	−0.02	0.06	0.96
		1999–2001	367	1.92	0.02	−0.01	0.03	0.97
524.756	525.021	1999	172	1.11	0.07	−0.05	0.06	0.61
		2000	156	0.76	0.02	−0.02	0.03	0.95
		2001	39	0.65	0.10	−0.09	0.10	0.32
		1999–2001	367	0.87	0.03	−0.03	0.03	0.77
	525.066	1999	172	2.30	0.14	−0.12	0.13	0.58
		2000	156	1.55	0.04	−0.09	0.06	0.95
		2001	39	1.35	0.21	−0.19	0.20	0.26
		1999–2001	367	1.78	0.06	−0.10	0.07	0.76
525.021	525.066	1999	172	2.07	0.02	−0.02	0.02	0.99
		2000	156	2.04	0.04	−0.05	0.04	0.98
		2001	39	2.06	0.09	0.00	0.06	0.96
		1999–2001	367	2.06	0.02	−0.03	0.02	0.98

result is still unclear, but it is most probable that the scatter is due to the difference in the formation of Cr I and Fe I lines.

Of the greatest interest are, of course, the results derived from comparing our SSMF measurements in the lines Fe I λ525.021 nm and 524.705 nm. Figure 5 presents a scatter-plot comparison. This figure and the corresponding data from Table II indicate a ratio significantly smaller than unity: $B_{525.021}/B_{524.705} = 0.93$ $(\pm\, 0.01)$. This result can be regarded as evidence that strongly (with $B \approx 1$ kG) contributes to the SSMF observations. If the calculations made by Veretsky and Demidov (2001) in terms of a two-component model are used, our value of the

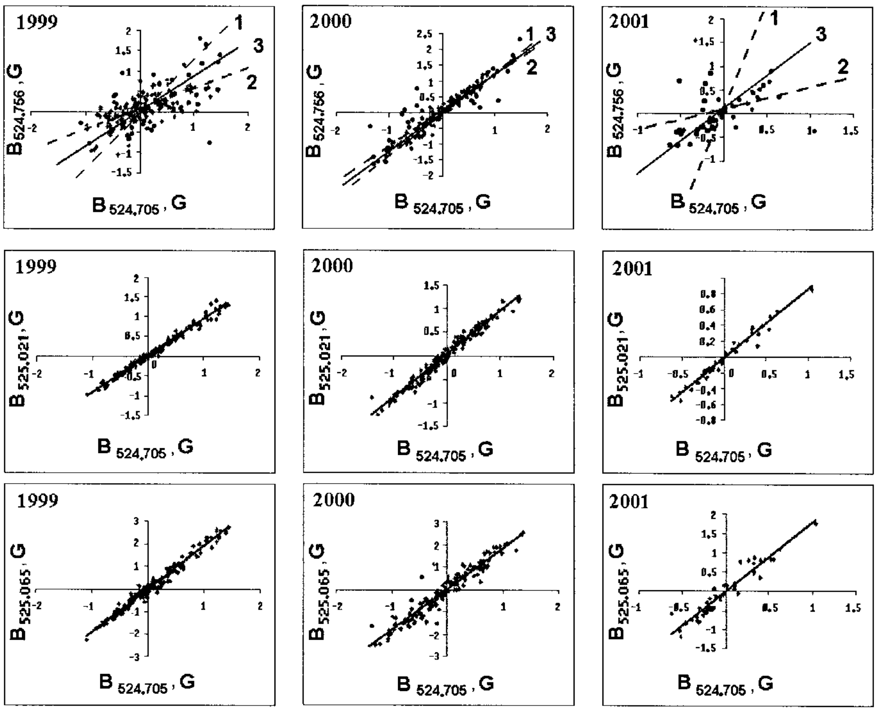
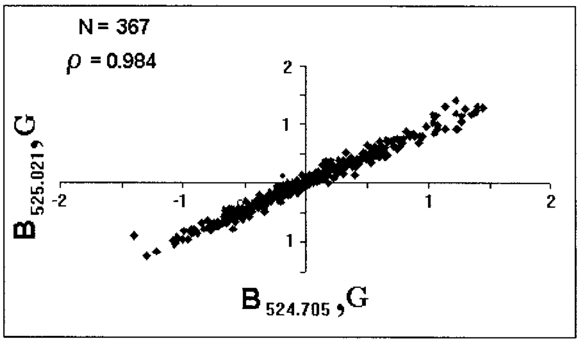


Figure 4. Comparison (separately for individual years) of the SSMF observations in three combinations of spectral lines. In the top panels, where the scattering of the points is rather high, three regression lines are shown: (1) x vs. y; (2) y vs. x; (3) reduced major axis. If only one regression line is shown, it has been determined by the reduced major axis method.



$$B_{525.021} = 0.01(\pm 0.01) + 0.93(\pm 0.01) \times B_{524.705}$$

Figure 5. Comparison (using the entire data set analyzed) of the SSMF observations in the lines Fe I λ524.705 and 525.021 nm.

magnetic ratio can be ‘ascribed’ to the magnetic strength $B \approx 900$ G. It is understandable that this value should be regarded as a tentative one.

4. Asymmetry Parameters of the *V*-Profiles

V-profiles of a ‘classical’ symmetric form, corresponding to theoretical calculations in terms of homogeneous models, are seen only very rarely in the SSMF and LSMF observations. Sometimes V-profiles assume an anomalous form - either with an extremely large asymmetry or with several zero-level crossings. Likely formation mechanisms for such complicated V-profiles are discussed, in particular, in papers of Bernasconi and Solanki (1996), Ploner *et al.* (2001), and Steiner (2001). We filter out such anomalous profiles to derive the asymmetry parameters. As a criterion the profiles were excluded from subsequent analysis if, when approximated by a polynomial of degree 5, they did not satisfy at least one of the two criteria: (a) there occurs only one zero-level crossing; (b) the amplitude of any one of the components must not be less than $V/I_c = 2 \times 10^{-5}$. It is interesting to note that the application of these criteria to different lines on the same days of observation often led to different results. The most typical situation is where V-profiles are moderately asymmetric and are shifted with respect to the I-profile. For a quantitative description of the asymmetry (Stenflo, Solanki, and Harvey, 1987) it is customary to use the following parameters: the amplitude asymmetry $\delta a = (a_b - a_r)/(a_b + a_r)$, and the area asymmetry $\delta A = (A_b - A_r)/(A_b + A_r)$, where a_b and A_b are, respectively, the amplitude and area of the blue (shorter-wavelength) lobe of the V-profile, and a_r and A_r represent the red lobe. The value of the relative shift of V-profiles is the wavelength difference (usually expressed in Doppler velocity units) between the center of the I-profile and the point at which the V-profile intersects the zero level. This zero-crossing shift is denoted V_{zc}. The center of the I-profile in the present case is defined as the middle of the space between the ‘exit slits’ established by simulating the line-of-sight velocity compensator of magnetographs using the balance of light fluxes.

A relatively large number of investigations have been devoted to the analysis of asymmetry parameters and V_{zc} in different lines and in different kinds of observation (see references in Steiner, 1999). In theoretical interpretations of observed values of these parameters it is customary to invoke (an alternative approach is developed by Sanchez Almeida, 1999) the hypothesis that in flux tubes and their neighborhoods there exist significant magnetic field and line-of-sight velocity gradients that are caused by intense dynamic processes.

The results of our analysis of δa, δA, and V_{zc} for our SSMF observations in the four lines are given in Figure 6, showing the histograms together with the main parameters, as well as in Table III, where all the statistical information is assembled. The results show that all lines and all parameters have a very large scatter; however, the mean values (which are different for the different lines) differ from

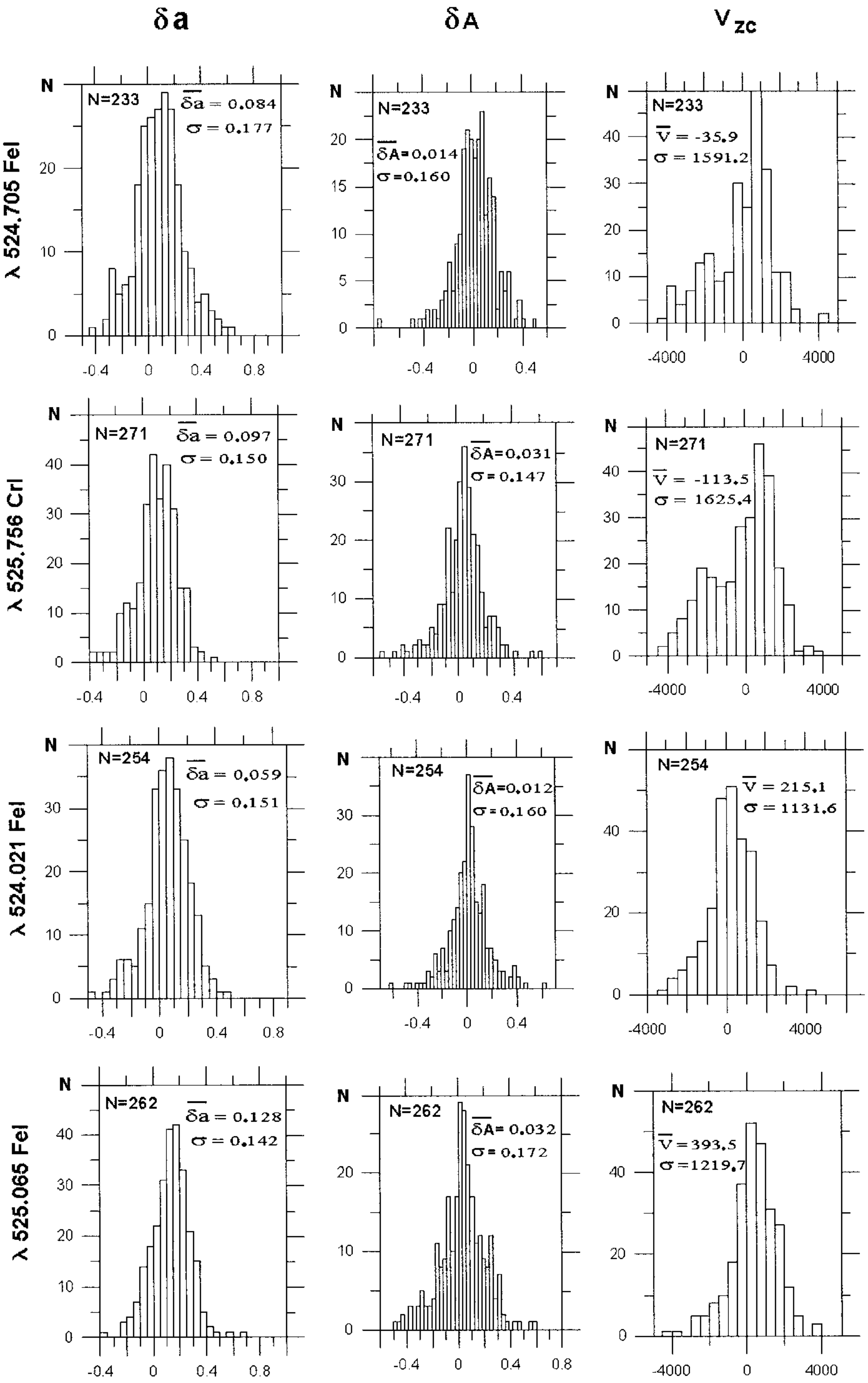


Figure 6. Histograms of the amplitude δa and area δA asymmetries, and of the V_{zc} parameter (m s^{-1}) in the SMMF observations for the four spectral lines.

TABLE III

Stokes V-profile asymmetry parameters for the SSMF observations. N – number of data, MV – mean value. The 1σ errors in the mean values are indicated in parenthesis.

λ, nm	N	δa		δA		V_{zc}, m s^{-1}	
		MV	r.m.s.	MV	r.m.s.	MV	r.m.s.
Fe I 524.705	233	0.084 (0.012)	0.177	0.014 (0.011)	0.160	−36 (104)	1591
Cr I 524.756	271	0.097 (0.009)	0.150	0.031 (0.009)	0.147	−113 (99)	1625
Fe I 525.021	254	0.059 (0.010)	0.151	0.012 (0.010)	0.160	215 (71)	1131
Fe I 525.065	262	0.128 (0.009)	0.142	0.032 (0.011)	0.172	394 (75)	1220

zero significantly. One result was a surprising: for the ‘twin’ lines Fe I λ524.705 and λ525.021 nm the values of the parameters were significantly different.

An interesting result found by analyzing the parameters δa, δA, and V_{zc} in earlier work for observations with higher spatial resolution (Grossman-Doerth, Keller, and Schüssler, 1996; Sigwarth *et al.*, 1999; Demidov *et al.*, 2001) was a steep increase in amplitude and dispersion with decreasing of the magnetic field strength. Our data for the SSMF showed the same behavior, in spite of the large scatter of the data caused by the high noise level. This is illustrated by Figure 7 (left panel), in which δA is plotted versus B for the line Fe I λ525.021 nm. Such results raise the question of the influence of noise, since the noise in δA increases with decreasing B in qualitatively the same way as the data. Detailed analysis of this question for the high spatial resolution observations has been done by Grossman-Doerth, Keller, and Schüssler (1996). They compared the results of observations in two spectral lines with different magnetic sensitivity. To demonstrate that our results are not caused by noise, we have calculated the distribution of the r.m.s. errors of the mean value. In order to make these errors visible, they were multiplied by a factor of 10 and are shown in the scatter-plot by the dashed line.

5. Discussion and Conclusion

We have presented, for the first time, the main results obtained from Stokesmeter measurements (Stokes I- and V-profiles in four lines in the vicinity of Fe I λ525.021 nm) by the SSMF at the STOP telescope of the Sayan Observatory for the time interval from March 1999 to April 2001. In comparison with the previous

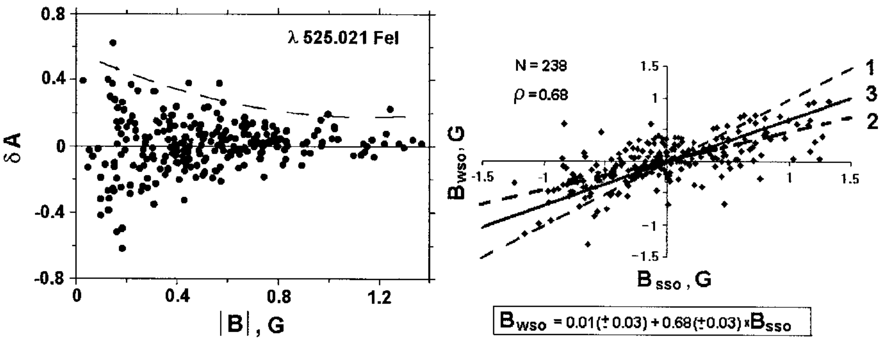


Figure 7. Left panel: comparison between the area asymmetry δA and the magnetic field strength $|B|$. The *dashed line* shows the distribution of standard errors of the mean values multiplied by 10 (to be visible on the scale of the figure). *Right panel:* comparison of the SSMF observations from WSO and SSO. The notation for the lines is the same as in Figure 4. See text for further explanation.

magnetographic work, the Stokesmeter approach allows the research on the SSMF to be advanced to a qualitatively new level.

We have carried out a detailed statistical analysis of the numerous SSMF observations in different combinations of spectral lines (see Table I). The analysis revealed a high correlation between three lines of Fe I, which indicates a high accuracy and reliability of the measurements. Comparisons of the measurements with data taken in the line Cr I λ524.756 nm show a larger scatter, which seems to be caused by the different formation properties of this line in the solar atmosphere. The significant difference of the 'magnetic line ratio' from unity, $B_{525.021}/B_{524.705} = 0.93\,(\pm 0.01)$, can be regarded as evidence for kilogauss magnetic fields with small magnetic filling factors.

For the first time (with respect to the SSMF), we have analyzed the asymmetry parameters δa (the amplitude asymmetry of the blue and red lobes) and δA (the area asymmetry) and the relative shifts V_{zc} of the V-profiles. These parameters show a large scatter, but their mean values differ significantly from zero. This result for the SSMF, which is similar to those obtained previously in observations with high spatial resolution, is evidence for small-scale dynamic processes of interaction between the radiation field, solar plasma motions and magnetic fields. This indicates how such MHD processes can be explored on other stars.

Naturally, it is of interest to examine the question how our new Stokesmeter measurements of the SSMF are correlated with the data from WSO, which have been the most long and homogeneous time series so far. Such a comparison is necessary, in particular, for covering the gaps when developing a merged data series for subsequent analysis of the time variations. Using our observations in the line Fe I λ525.021 nm, the result of such a comparison is presented in Figure 7 (right panel). With the correlation coefficient between the data sets equal to $\rho = 0.68$ (the number of point pairs being $N = 238$), the equation of linear regression, calculated using the reduced major axis method, has the form

$$B_{\mathrm{WSO}} = 0.01\,(\pm 0.03) + 0.68(\pm 0.03)\,B_{\mathrm{SSO}}. \tag{2}$$

This regression is shown in Figure 7 (right panel) as the solid line, while the regressions x vs. y and y vs. x are shown as (1) and (2) dashed lines.

The correlation coefficient is not very large, but good for the type of experimental data that are analyzed. The scatter of the points can have many causes. e.g. the non-simultaneity of the measurements (the longitude difference between SSO and WSO is about 8 hours) and the differences in the instrumental weighting functions across the solar disk. The question of the systematic difference between different observatories (not only between WSO and SSO as in our case, but for others as well, see for an example the compilation of data by Demidov, 2000) cannot be answered yet. The reason, why the slope in Equation (2) is 0.68 and not unity could be due to different methods of calibration and monitoring of the zero-level position. The great importance of the zero-level problem for the interpretation of magnetic field observations (especially for weak fields) has been stressed in a number of papers starting with Stenflo (1968, 1970) and Howard and Stenflo (1972). In the paper by Demidov (1996) it was demonstrated that in SSMF observations the determination of the zero level by different methods gives very different results. Nevertheless the obtained coefficient of 0.68 can be used to generate a merged series of SSMF observations from SSO and WSO, to be used for subsequent analysis.

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