OBSERVATIONS OF THE SOLAR MEAN MAGNETIC FIELD AT THE SAYAN OBSERVATORY DURING 1982–1984

V. M. GRIGORYEV and M. L. DEMIDOV

*Siberian Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (SibIZMIR),
U.S.S.R. Academy of Sciences, Irkutsk 33, P.O. Box 4, 664033, U.S.S.R.*

Abstract. This paper presents some results of observations of the mean magnetic field of the Sun as a star (SMMF) at the Sayan Observatory during 1982–1984. A description of the instrument is given, as well as some major points in the technique of data acquisition and treatment such as calibration, zero-level control, etc. The comparison of a new SMMF series with observations from the Wilcox Solar Observatory showed a high correlation between the two series ($\rho = 0.88$) but with a rather great difference in amplitudes. We discuss time variations of SMMF, both long-term caused by the magnetic field evolution with the activity cycle and those of shorter time-scales caused by solar rotation.

1. Introduction

The study of the disk-average magnetic field of the Sun (henceforth referred to as the SMMF, the Solar Mean Magnetic Field), i.e., the magnetic field of the Sun as a star, together with observations of solar magnetism of different spatial scales is a challenging astrophysical problem.

In the case of SMMF measurements the Sun is treated under the same conditions as other stars. Such measurements, therefore, contribute to a better understanding of the nature of stellar magnetism and, in particular, the high-priority problem of activity cyclicity. Some aspects of this question have been treated by Durney and Stenflo (1972) and examined in greater detail in reviews of Stenflo (1981) and Baliunas and Vaughan (1985).

While being an integrated characteristic of the Sun, the SMMF cannot be unrelated to other general parameters (rotation rate, luminosity, radius, etc.), which may change with time and, more specifically, with the activity cycle (cf. Livingston and Duvall, 1979; Howard and LaBonte, 1983; Singh *et al.*, 1984; Gilman and Howard, 1984; Howard, 1984). The mechanisms for the interrelation between changes of the SMMF and such variations of global parameters of the Sun are largely unclear and need to be investigated.

In a series of papers (Sheeley *et al.*, 1985; DeVore *et al.*, 1985; Sheeley and DeVore, 1986a, b) SMMF observations have been advantageously used in the determination of differential rotation, meridional circulation and magnetic field diffusion coefficients through numerical simulations of the evolution of newly emerged magnetic flux in active regions (see also Sheeley *et al.*, 1983).

SMMF observations are important in studies of solar-terrestrial relationships because the interplanetary magnetic field that determines many geophysical effects is intimately associated with the SMMF (Wilcox *et al.*, 1969; Severny *et al.*, 1970; Wilcox,

1971; Scherrer, 1973; Scherrer *et al.*, 1977a, b). A model combining the sector structure of magnetic fields on the Sun with its general dipole field to explain a broad class of phenomena observed has been developed by Svalgaard *et al.* (1974).

The above-mentioned examples demonstrate the importance of systematic, regular, long-term SMMF observations. A unique (nearly 20 years now) series of such observations was initiated by Severny at the Crimean Astrophysical Observatory in 1968 (Severny, 1969). Beginning in October 1970 such measurements have also been made at the Mt. Wilson Observatory (Scherrer, 1973) and, since May 1975, at the Stanford University Solar Observatory (Wilcox Solar Observatory at present). Regrettably, SMMF observations in Crimea were abandoned in 1977.

It is now being planned to establish in the Soviet Union, on the basis of a telescope developed at SibIZMIR (Grigoryev *et al.*, 1981), a network of magnetographs for low-spatial resolution observations of magnetic fields (and velocities), and SMMF measurements will be incorporated in the mandatory observing programme. The instrument and the observing technique have been developed at the Sayan Observatory. As usual, observations have been made in the 5250.2 Å line of Fe I and it has been assumed that the possible changes of the line profile due to the effect of the magnetic field (Brunning and LaBonte, 1985) and telluric blends (Livingston and Wallace, 1985) are small and are taken into account by the calibration procedure.

This paper presents some results of new SMMF observations which were obtained during 1982–1984. In particular, by comparing a new series with data from the Wilcox Solar Observatory we find quite a high correlation between the two sets of data but with a significant, 1.5-fold, difference in the amplitude scale. Since the technique of our observations differs from previous methods of observing the SMMF, it will be discussed in some detail below.

2. The Instrument

The Crimean method of illuminating the spectrograph slit in SMMF observations (by use of flat mirrors of the telescope only, without forming a solar image) has, despite its attractive simplicity, also some disadvantages. Firstly, a rather small amount of light comes into the spectrograph when a 'parallel' beam is employed. Secondly, if the angular aperture of the spectrograph is, as is usual, greater than $0°.5$, then its resolving power and the collimator efficiency in such a mode of observation are not used to the best advantage. Methods implemented for SMMF observations at the Mt. Wilson and Wilcox Solar Observatories do not largely suffer from the above-mentioned limitations. Therefore, these methods, with certain modifications, have served as the basis for developing and constructing the Solar Telescope for Operative Predictions, STOP (Grigoryev *et al.*, 1981). This SibIZMIR-produced instrument is specially designed for magnetic field and line-of-sight velocity observations with low spatial resolution.

The optical system of the instrument is depicted in Figure 1. Solar tracking is accomplished by means of a Jensch-coelostat (Jensch, 1959), with its mirrors 30 cm in diameter. From the coelostat the horizontal light beam is fed to a dublet objective 18 cm
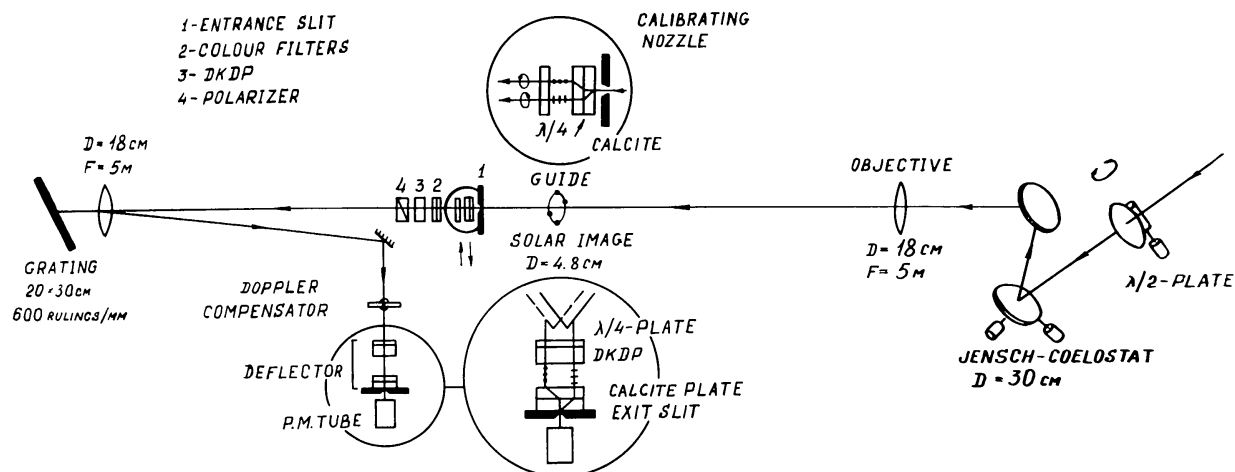
Fig. 1. General scheme of the solar telescope of operative predictions (STOP) at the Sayan Observatory that is being used for observations of the magnetic field of the Sun as a star.

in diameter and 5 m focal length. In the focal plane of the objective at the edges of the solar image (48 mm in diameter) there are photoelectric guiding detectors, whose error signals – once amplified – are fed to the coelostat mirror correction drives. The photoelectric guider and the objective lens are both mounted on special carriages which may move freely on optical bench rails along the telescope's axis. As the objective moves away from the position at which the focal point corresponds to the spectrograph entrance slit (which normally has height 1 mm, width 0.2 mm), the light from increasing areas on the Sun will enter the spectrograph (dispersion 0.4 Å mm^{-1} in the fifth order). Behind the entrance slit there is a special calibration attachment which is easily placed into the beam as well as withdrawn from it. The spectrograph also includes the following, sequentially positioned elements: a set of light filters, an electrooptical DKDP crystal, a polarizer, an objective lens, a diffraction grating, a diagonal mirror, a line-of-sight velocity compensator plate, a deflector (comprising an appropriately oriented $\lambda/4$ phase plate, an electrooptical crystal, and a calcite plate), an exit slit (of 0.15 mm width), and a photoelectrical detector. The signal from the photomultiplier is fed to the A/D converter. The subsequent treatment in the measuring channel is done in digital form.

A square-wave, 90° phase-shifted voltage (of up to 2.0 kV) is fed to the modulator and deflector crystals. This ensures four states of the 'modulator-deflector' system. At the first step of modulator operation the deflector 'interrogates' the wings of one σ-component of the Zeeman pattern (intensities J_1 and J_2 are measured). At the second step those of the other component (J_3 and J_4) are being measured. The intensities measured are used to form signals for the magnetic field,

$$S_H = (J_1 - J_4) + (J_3 - J_2), \tag{1}$$

the line-of-sight velocity,

$$S_v = (J_1 + J_4) - (J_3 + J_2), \tag{2}$$

and brightness,

$$S_J = J_1 + J_2 + J_3 + J_4 . \tag{3}$$

In order to compensate the field signal for the brightness variation, expression (1) is divided by the brightness value (3) and the result is produced as output on a recorder for subsequent treatment. Velocity and brightness signals are also registered on recorders.

As is evident in Figure 1, the first optical element in our telescope is a half-wavelength phase plate (25 cm in diameter), which is mounted on the coelostat on a special bracket and may be placed into and withdrawn from the beam. The plate is installed in front of the coelostat mirror so that the beam reflected from this mirror should not pass through it on its way to the second mirror. It is used to control the magnetograph zero level as will be described in the next section.

3. Some Questions of the Observational Technique

Measuring the global magnetic field of the Sun is a rather complex observational task because the typical strength of the SMMF is very small ($\lesssim 1$ G). In order for such measurements to be reliable one has to solve a number of complicated problems which are insignificant when larger-magnitude fields are being measured. Quite a number of questions concerning the technique of magnetographic measurements have been investigated in considerable detail by Scherrer (1973), Dittmer (1977), and Duvall (1977). The observations on STOP have some special features, which we will discuss below.

3.1. Spectrograph slit illumination

The STOP optical scheme has been designed such that it permits solar observations with different spatial resolutions to be made using the same objective lens. This is achieved by illuminating the slit with a light beam of a different degree of defocusing,
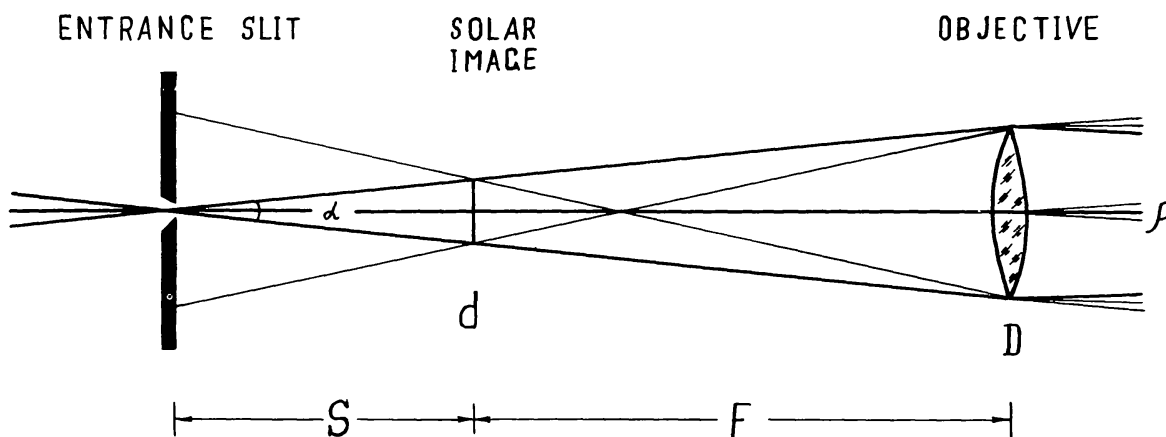

Fig. 2.   A scheme illustrating how the spectrograph entrance slit is illuminated by a defocused solar image in SMMF observations.

with the objective lens being displaced along the optical axis. As the objective moves away S cm (see Figure 2) from the position at which the focused image is maintained exactly on the spectrograph slit, the angular size of the area of the solar image, the light from which enters the spectrograph, is defined by

$$\alpha = \text{arc tg} \left(\frac{SD}{F(F + S)} \right), \tag{4}$$

where F is the focal length of the objective, and D is its diameter. The amount of defocusing which is needed for integrating an area on the solar surface of diameter α is then

$$S = (F^2 \, \text{tg} \, \alpha)/(D - F \, \text{tg} \, \alpha) \, . \tag{5}$$

For full-disk observations of the Sun (Figure 2 corresponds to this case), assuming its diameter equals $0°53$, we find that the required amount of defocusing is 180 cm. The cone angle of the light beam incident, in this case, in the spectrograph, is $1°52$, and this is, of course, slightly smaller than the spectrograph aperture ($2°06$) but is, however, considerably larger than the apparent angular size of the Sun. It appears that the light gain is also quite appreciable. It is easy to infer that a 7.7-fold amount of light (without taking account of the reflection off the objective) enters the spectrograph as compared with a 'parallel' beam, when the scheme of SMMF observations described earlier is employed.

However, due to limitations on the optical bench length at the STOP, the maximum possible distance for the objective is merely 145 cm (instead of the required 180 cm), so the entire disk becomes inaccessible to observation. The spectrograph receives light from only 0.86 of the radius of the disk, the remaining edge area being beyond the field of view. Direct measurements of brightness showed that in such a regime of illumination the amount of light is 7 times greater as compared with the use of a 'parallel' beam (the objective being removed from the beam).

3.2. THE INSTRUMENTAL WEIGHT FUNCTION OF BRIGHTNESS

When doing SMMF observations, all points of the solar image are involved in the formation of a magnetograph signal with a weight proportional to the brightness. Consequently (see Scherrer, 1973), the limb-darkening function must be the main weighting function. However, because under real conditions different optical elements are used along the path of the light to the photoreceiver, the actual weight function may differ from a theoretical one (Allen, 1973). Thus, Dittmer (1977) showed that the use of an image slicer leads to a rather peculiar form of the brightness distribution over the solar disk sensed by the photoelectric multiplier.

Investigations of the instrumental weight function of brightness on STOP have demonstrated its rather good correspondence to the limb darkening function. The measurements were made in the SMMF observation mode (with the objective displaced 145 cm) with the aid of a small diaphragm (1.5 mm in diameter) in an opaque screen
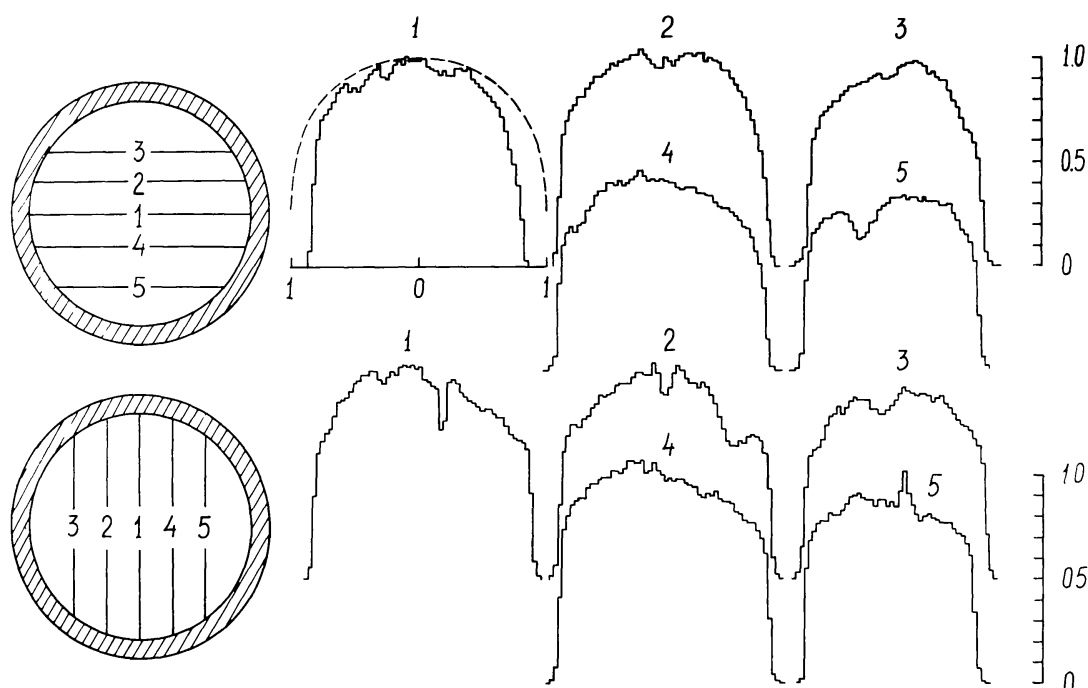
Fig. 3.   The determination of the instrumental weight function of brightness of a telescope. The figure (left) shows the lines of scanning by a small diaphragm (see the text) the solar image in the horizontal and vertical directions and (right) the brightness (as sensed by the photoelectric multiplier) with such a scanning of the continuous spectrum near 5250 Å. The scanning was performed repeatedly in each scan, respectively, from west to east (from left to right, in the figure) and from south to north (from top to bottom). The curves show the mean measurements normalized to the brightness at the disk center. There were no sunspots on the disk present during the measurements. Optical defects are responsible for the nonuniformities in the brightness distribution. A dotted line in the first horizontal scan shows the theoretical limb-darkening function (Allen, 1973). Shaded areas at the left show the region that remains outside the field of view in SMMF observations on STOP.

placed in the solar image plane. Figure 3 (left) shows how scanning lines of this diaphragm are arranged on the solar disk. The shaded region near the limb corresponds to the area which, as mentioned above, remains beyond the field of view of the spectrograph in such mode of observation. The figure (right) shows brightness records corresponding to such scans. It is evident that in addition to the smooth behaviour of the brightness variation corresponding to the limb-darkening function, there are individual (and sometimes rather appreciable) 'valleys' and 'peaks'. Effects of sunspots and sky opaqueness have been eliminated, and curves represent averages of repeated scans. Such an uneven distribution of brightness is due to defects in the optical elements of the telescope.

Because the distribution of magnetic fields on the solar surface is extremely inhomogeneous, the influence of instrumental weight functions might affect SMMF measurements quite considerably (cf. Scherrer, 1973; Kotov and Severny, 1983).

3.3. CALIBRATION

Calibration of the instrument is a necessary procedure in the observations. A variety of calibration methods for solar magnetographs have been described in papers by Nikulin

(1960), Severny (1967), Scherrer (1973), Dittmer (1977), and Howard *et al.* (1983). We have originally used a traditional approach, i.e., we produced in the spectrograph focal plane an artificial displacement of the line and recorded in its wings the differences in light intensities, with a polarization attachment $(P + \lambda/4)$ that makes the light circularly polarized, and which is installed in front of the modulator. Line displacement was accomplished through scanning the focused solar image along the equator or by rotating through a certain angle the plane-parallel glass plate of the line-of-sight velocity compensator.

However, since November 1983, in doing SMMF observations we have employed a new calibration method that is, we believe, a more accurate and convenient one. Behind the entrance slit of the spectrograph (see Figure 1) in front of the modulator is placed the calibration attachment comprising a calcite prism that causes the spectral lines to split into two components (the amount of splitting being determined by the thickness of calcite), and a $\lambda/4$-phase plate that circularly polarizes the orthogonally linearly-polarized beams originating from calcite. Thus the Zeeman effect is being imitated. The amount of spreading of the light beams in the calibration attachment does not exceed 0.1 mm, and the direction of the light path remains almost unaltered, so that the operating conditions of the magnetograph during calibration are identical to the real observing conditions. This is an important advantage of our calibration procedure. The amplitude of the calibration signal corresponds to a strength of 476 G. The thickness of the calcite prism was chosen such that measurements were made along the linear portion of the calibration curve. The integration time of the calibration signal is 0.1 s and the length of a record is about 1 min. Calibration is normally done before making SMMF measurements and is repeated afterwards.

3.4. ZERO LEVEL CONTROL

Under real conditions the magnetograph signal depends not only on the magnitude of the magnetic field on the Sun but also on many other factors (instrumental polarization, adjustment accuracy of the electrooptical modulator, etc.), whose contributions are sometimes difficult to separate from the solar signal if no special measures are taken. This problem is particularly acute in the case of weak magnetic fields when the spurious signal may be comparable to or even greater than the solar signal. This is the situation with SMMF observations, as the field strength does not exceed several Gauss.

Different observatories are using different methods of zero level control. Thus, the Mt. Wilson Observatory (Scherrer *et al.*, 1973) takes as the zero level the level of a signal recorded with the modulator switched-off. However, a more promising method seems to be one employing a magnetically insensitive line because in this case allowance is made for almost all sources of zero level displacement, including the instrumental polarization as well. For this purpose, the Crimean (Kotov and Severny, 1983) and Stanford (Scherrer *et al.*, 1977b) observatories are employing the 5124 line of Fe I whose profile is sufficiently close to that of the working 5250 line of Fe I.

With the STOP we have implemented a fundamentally different method of determining the zero level (Grigoryev *et al.*, 1983). The basic strategy of the method is as

follows. During a certain period, of the order of 10 to 15 min (the integration time of a single measurement is 94 s), the SMMF is being recorded in the usual way. After-wards, a $\lambda/2$-phase plate is placed in front of the coelostat and new records are made during 10 to 15 min. The half-wave plate makes the polarization directions of the Zeeman splitting σ-components reverse, and this of course leads to a change of sign of the magnetograph signal but only of the part which is determined by the magnetic field. However, the displacement of the signal due to the instrumental polarization and electronics effects remains (in a certain approximation, of course) unaltered.

Thus, we can write the following expressions for the magnetograph signals: in the case of observations without a phase plate

$$S_H = H + \Delta, \tag{6}$$

and with a plate

$$S'_H = KH + \Delta. \tag{7}$$

Here Δ is the amount of zero-level displacement, and $K = \cos \delta$, where δ is the magnitude of delay between the o- and e-beams in the phase plate. For a half-wavelength plate we have $K = -1$. From Equations (6) and (7), it is easy to obtain simple expressions for the desired quantities

$$H = (S - S')/(1 - K) \tag{8}$$

and

$$\Delta = (S' - KS)/(1 - K). \tag{9}$$

In order to realize the method described above a plate of a sufficiently large size is required such that it may cover the entire used surface of the coelostat mirror. We have used polymer films previously subjected to suitable expansion. After careful measure-ments of birefringence and homogeneity in a large number of samples (Demidov and Skomorovsky, 1982), we selected a polypropylene film which was used to manufacture a working plate 25 cm in diameter. The value of phase shift for that film for the wavelength of 5250 Å corresponds to $K = -0.98$, i.e., the plate may be considered a half-wavelength one.

Experience of SMMF measurements on STOP has shown that even during 10 min the level of the signal can sometimes vary rather significantly. Therefore all observations are processed* taking account of the trend in the records.

4. Observational Data and Their Analysis

Under favourable weather conditions and with the instrument in normal operation, SMMF observations on STOP, according to the technique presented above, were

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* Since 1985 we have essentially used a continuous 'zero' control when measurements with and without a $\lambda/2$-phase plate alternate every minute (this time can vary). As the plate moves in the light beam between the fixed end positions, the magnetograph's measuring channel is switched off (for about 2 s).

usually made once a day or, on some occasions, several times a day. A routine observing program included a number of successive operations such as getting the instrument ready for operation (warming-up of equipment, checking the telescope and other instruments for adjustment, filling the spectrograph, setting the working 5250.2 line of Fe I symmetric to the photometer slit), calibration records with the modulator switched-off and in a fully-operating mode with the calibration attachment placed into the beam (such records are also used for adjustment purposes, to obtain maximum calibration signal and optimum values of control voltages on the modulator and the deflector as well as for estimating instrumental noise), and the magnetic field observations themselves using a $\lambda/2$-phase plate for zero level control. The above-mentioned operations usually require about an hour to be performed.

The typical r.m.s. amount of noise that is determined by the spread of measured points with respect to the regression line, is ± 0.08 G, and the signal accumulation time is 94 s. However, evaluation of the measurement accuracy based on the analysis of SMMF observations during a sufficiently long time interval, a day, for example, seems to be more relevant. Figure 4 shows results of several such measurements obtained with STOP on 1 October, 1982. The r.m.s. error of the mean value (denoted by MF in the figure), determined by the spread of strength values, is ± 0.12 G. It is this value that should be regarded as the real accuracy of our SMMF measurements.
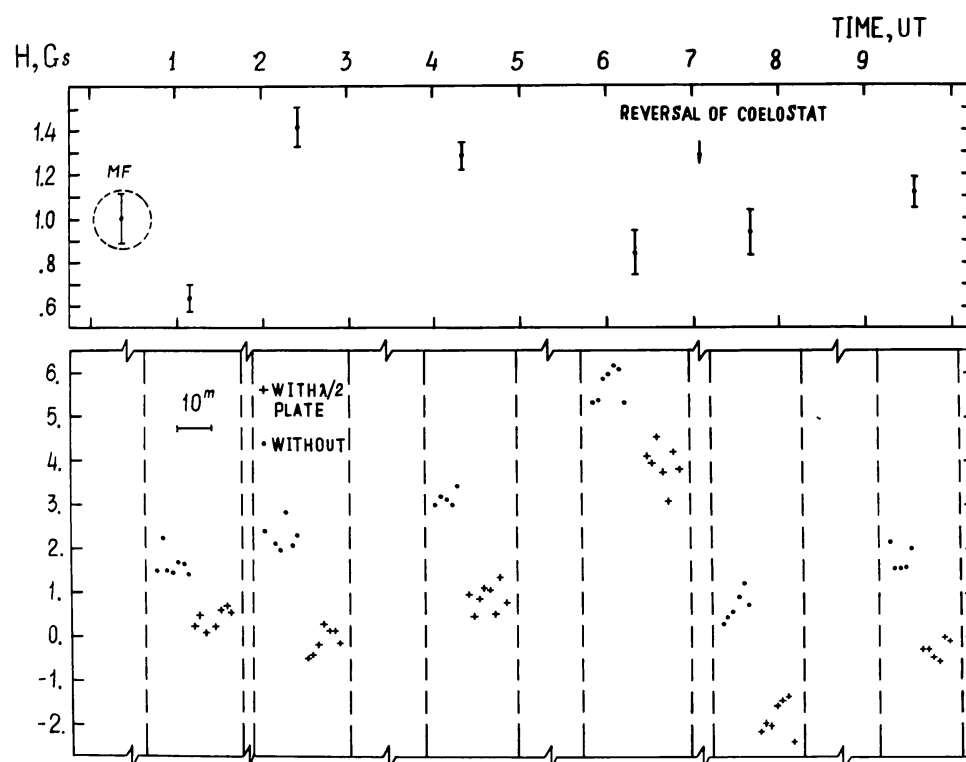

Fig. 4.   Several consecutive measurements of the SMMF on 1 October, 1982. The figure (bottom) shows the original measurements with and without a phase $\lambda/2$-plate and (top) the final values, with the r.m.s. error (MF) of ± 0.12 G characterizing the accuracy of the Sayan observations. The arrow indicates the time the coelostat mirror was reversed, which was accompanied by an abrupt change in the position of the zero level.

The lower part of Figure 4 presents the measurements obtained with a phase $\lambda/2$-plate and without it. The results calculated from Equation (8) (with the trend included, as mentioned above) are shown at the top of the figure. It is seen that the displacement of the true zero-level may greatly exceed the solar signal. It should also be noted that our observations have shown a significant difference in zero-level positions determined by our method and from records of the signal with the modulator switched-off. An inspection of the figure reveals that the zero-level drifts appreciably with time and
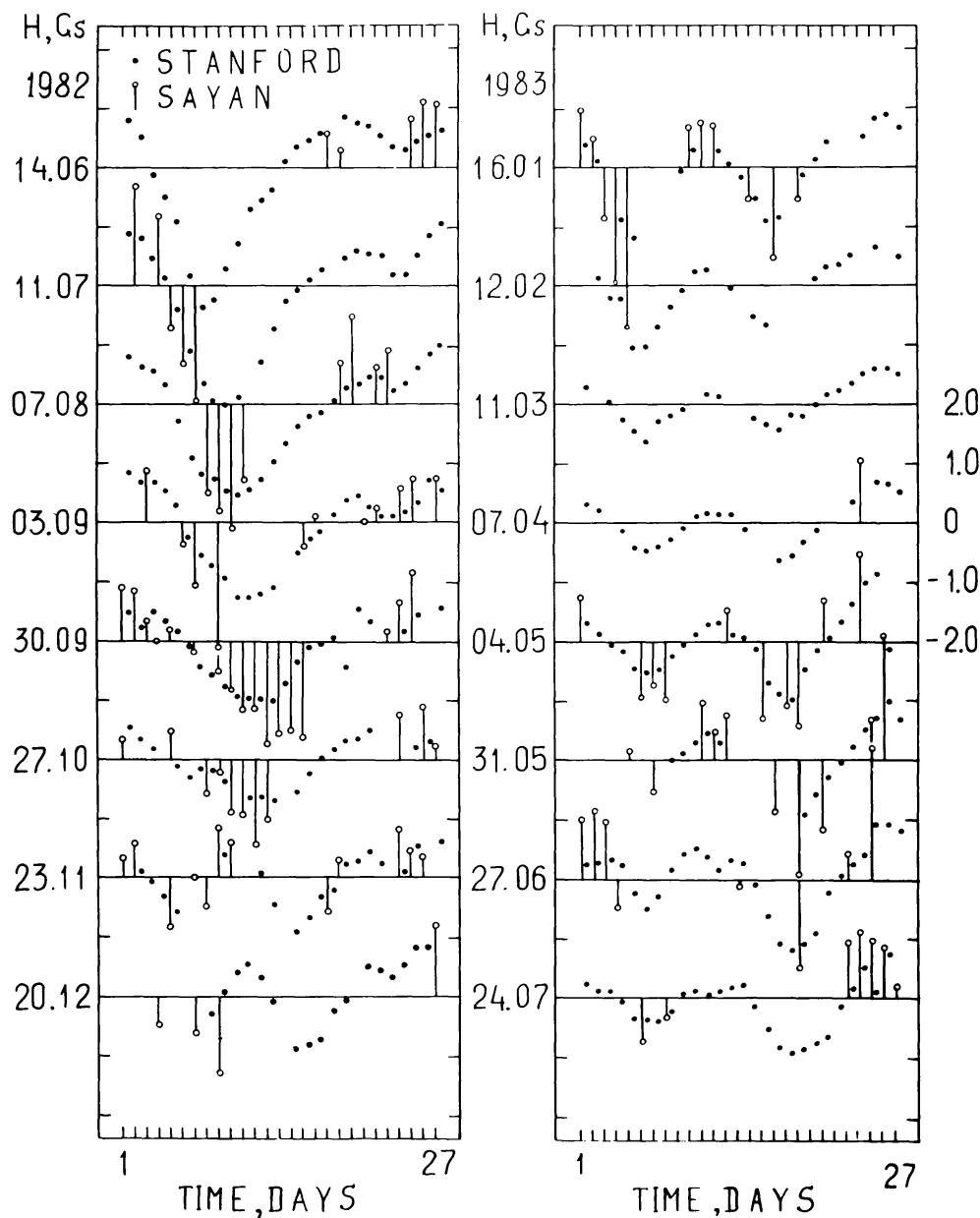

Fig. 5a.

Fig. 5. Sets of SMMF observations at Wilcox Solar Observatory (Stanford) and Sayan Observatory (Sayan) during 1982–1984: (a) for the interval from 14 June, 1982 to 19 August, 1983; (b) for the interval from 20 August 1983 to 24 October, 1984.

changes its position abruptly after reversal of the coelostat mirror. This indicates that the instrumental polarization of light due to reflections off the coelostat mirrors is largely responsible for the displacement of the zero level and its variation with time.

Figure 5 shows the entire Sayan set of data analyzed in this paper (all in all, 279 values) covering the time interval from 1 July 1982 to 17 October, 1984; all SMMF measurements were reduced to the same type of calibration. Figure 5(a) refers to the first half of this period, and Figure 5(b) refers to the second half. For comparison, these figures also show measured results from the Wilcox Solar Observatory. Because general
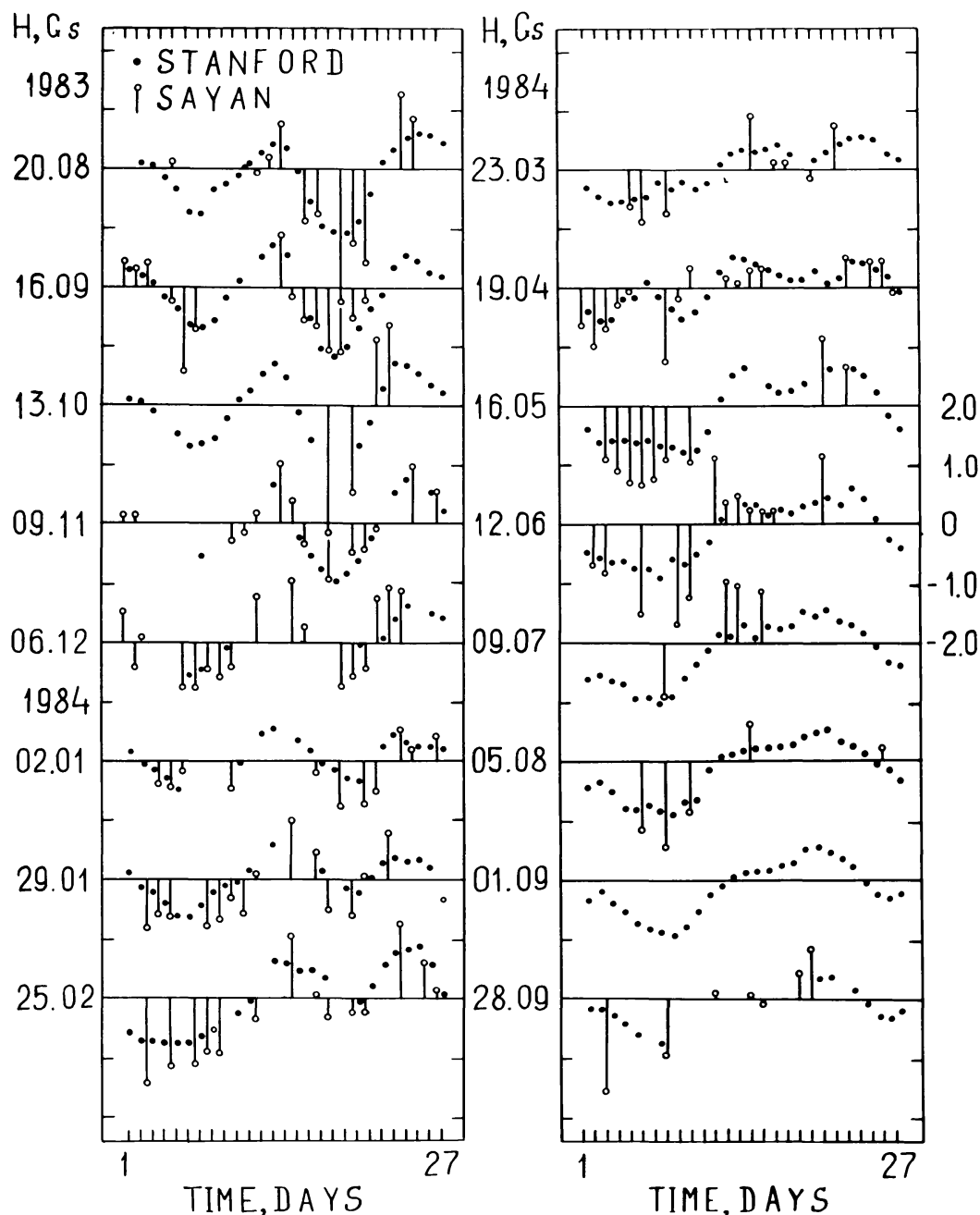

Fig. 5b.

physical considerations lead us to expect that the time variations, as a rule, are rather smooth, as shown by the Stanford observations, in contrast to those from the Sayan Observatory, this indicates a greater accuracy of the Stanford measurements. Poor weather conditions in the Sayan Mountains during the period being analyzed led to the fact that our observations are not so regular as one would like. Some gaps in the observations were also introduced by instrument failures. However, despite considerable gaps in the Sayan observations, it is apparent that with certain differences the general character of both series is similar, while the amplitudes differ considerably. Figure 6 shows a precise comparison of the observations (a total of 228 pairs of numbers). The correlation coefficient of the two data sets is sufficiently high and is 0.88;
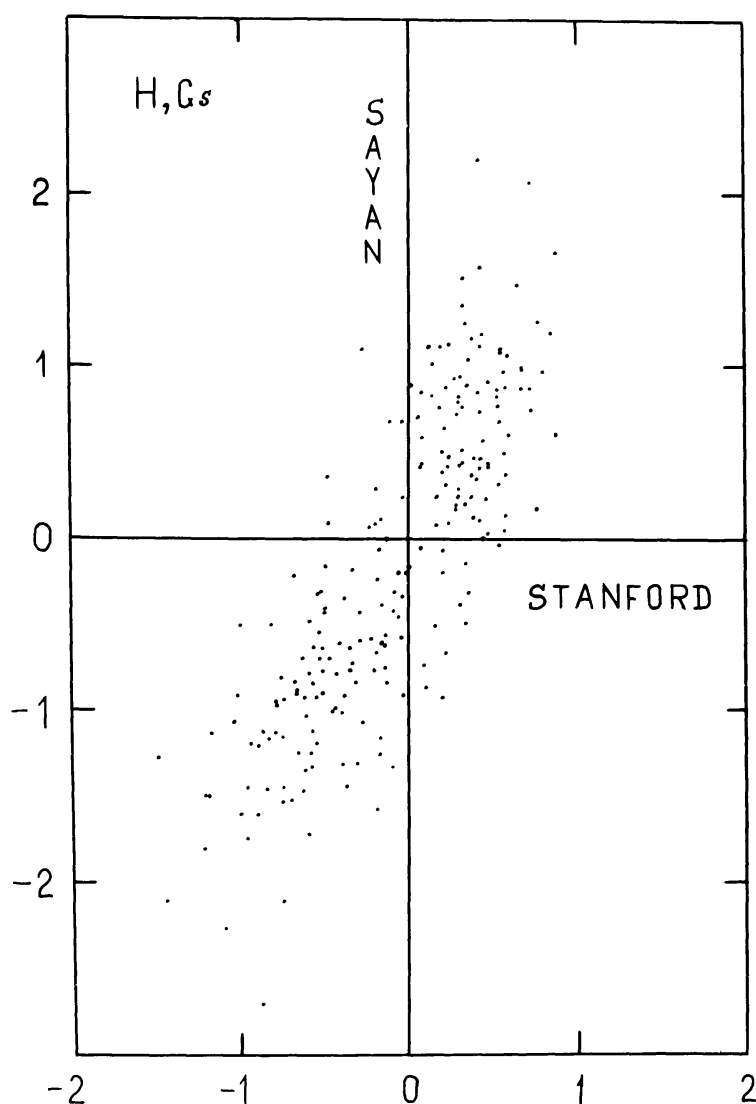

Fig. 6.   The comparison of SMMF observations at Wilcox Solar Observatory (Stanford) and the Sayan Observatory (Sayan) during the time interval being analyzed. In all, there are 228 pairs of numbers, the correlation coefficient is 0.88, and the linear regression equation has the form

$$H_{\text{Sayan}} = 1.51 \, H_{\text{Stanford}} + 0.01.$$

the equation of linear regression has the form

$$H_{\text{Sayan}} = 1.51 H_{\text{Stanford}} + 0.01 .$$ (10)

Such, largely very good agreement between the two sets of observations (in contrast to, for example, results of a comparison made by Scherrer *et al.* (1977a) between SMMF observations from Crimea and Mt. Wilson) might be due to the fact that the optical schemes of our instruments ensure much greater luminous fluxes, which reduces significantly the noise level and improves the reliability of the measurements. The systematic difference of the data amplitudes is within the estimate of the possible differences of SMMF observations on different telescopes, as reported by Scherrer *et al.* (1977b). It is due to the difference in instrumental weight functions between Sayan and Stanford (see Dittmer, 1977, Figure 18(a)). Use of different calibration methods, however, might lead (as was demonstrated, specifically, by the practice of STOP observations) to difference of no more than 15 to 20%.

Previously, Kotov and Demidov (1980) and subsequently, using a large data set, Kotov and Levitsky (1983a) showed that the mean SMMF strength changes appreciably with the activity cycle. Thus it was found that the total flux (or more precisely, the flux disbalance recorded by SMMF measurements) reaches greatest values during years of maximum solar activity and decreases by almost a factor of three during low activity. A similar result concerning the variation in total flux of surface magnetic fields over the activity cycle was obtained by Howard and LaBonte (1981, 1983), who showed that a gradual increase in the flux by about three times is also occurring from minimum to maximum activity epochs. However, apart from this agreement as documented in the papers just cited, there are also some differences, which is generally not surprising because they analyze related but different parameters. In particular, unlike the almost uniform growth of flux as reported by Howard and LaBonte (1981, 1983), measurements of the SMMF (which is determined, as demonstrated by Scherrer (1973), mainly by magnetic fields of the central area of the Sun $0.6\,R_\odot$ in radius) show the presence of a secondary maximum of strength in 1974. This observation allowed Kotov and Levitsky (1983a) to suggest the presence of quasi-periodic 5-year variations of the SMMF amplitude which are also present in cosmic-ray intensity variations.

In this connection, it would be interesting to analyze the behaviour of the SMMF mean strength during the years of 1982–1984, which constitute an epoch of solar activity decline, with the use of a new set of data, namely that from the Sayan Observatory. According to the above-mentioned pieces of evidence, a flux decrease should be expected during these years. The results are shown in Figure 7. The upper part shows the values of absolute (with the sign neglected) strength $\overline{|H|}$ of the SMMF, and the lower part gives the yearly mean values of $\overline{H}$ with the sign included. The zero-difference of $\overline{H}$, as indicated by the Sayan and Stanford sets, is evidence of a predominance of negative-polarity fields, in contrast to the positive displacement (by 0.04 G) of the Stanford measurements during 1975–1976 as pointed out by Scherrer *et al.* (1977b). On the whole, Figure 7 strongly suggests that despite the rather great difference of numerical values (in 1983 the values of $\overline{|H|}$ differed by a factor of 2 between the Sayan Observatory
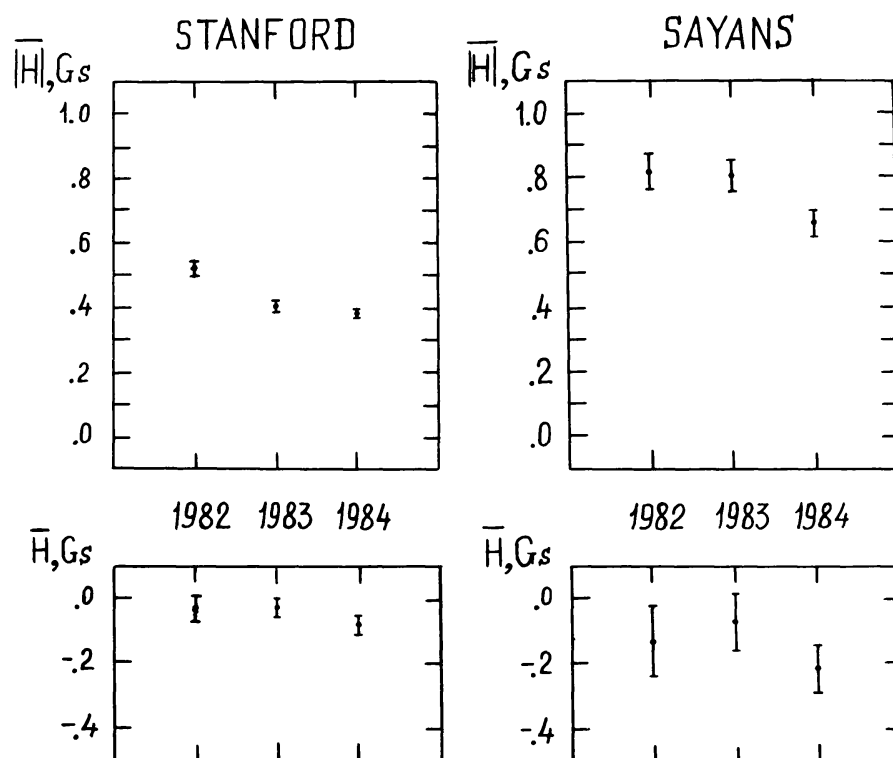
Fig. 7.   The upper two plots show the time variation of yearly mean values (from 1 July in 1982 and till 17 October in 1984) of absolute strength of the SMMF as measured at Wilcox Solar Observatory (Stanford) and at the Sayan Observatory (Sayan). The lower two plots represent the behaviour of the SMMF mean strength (disbalance) during the same period of time.

and Stanford), both sets of observations exhibit a similar character of SMMF variations with time, i.e., a decrease in the absolute strength and a decrease of $\overline{H}$.

In addition to studying long-term variations of the SMMF, it seems also quite important to investigate its faster variations (Severny, 1969; Svalgaard and Wilcox, 1975; Kotov and Demidov, 1980; Kotov and Levitsky, 1983a, b, c, 1984; Kotov and Severny, 1983). SMMF variations with a period of 1 year deserve much attention, as demonstrated by Kotov *et al.* (1981) and Kotov and Levitsky (1984), as well as the discrete character of the power spectrum of SMMF variations, shown by Kotov and Levitsky for the range of periods close to the period of synodic rotation of the Sun. In order to search for periodicities in the variations of the Sayan data set, we have used the method of correlation periodogram analysis (Kopecký and Kuklin, 1971), which is particularly convenient when handling data sets with many gaps. Results are shown in Figure 8, showing quite well the discrete character of peaks in the region of 27 days, among which the main peak corresponds to the period of 26.8 days, while periods of the strongest adjacent peaks consist of 25.7, 27.9, and 29.4 days. The short duration of our series (covering an interval of 840 days) does not permit us to achieve the same resolution in frequency as obtained at Crimea (Kotov and Levitsky, 1983b, c; Kotov and Severny, 1983) in the analysis of a 14-year series of SMMF. It seems likely that this as well as the fact that our data refer to another time interval and have been obtained
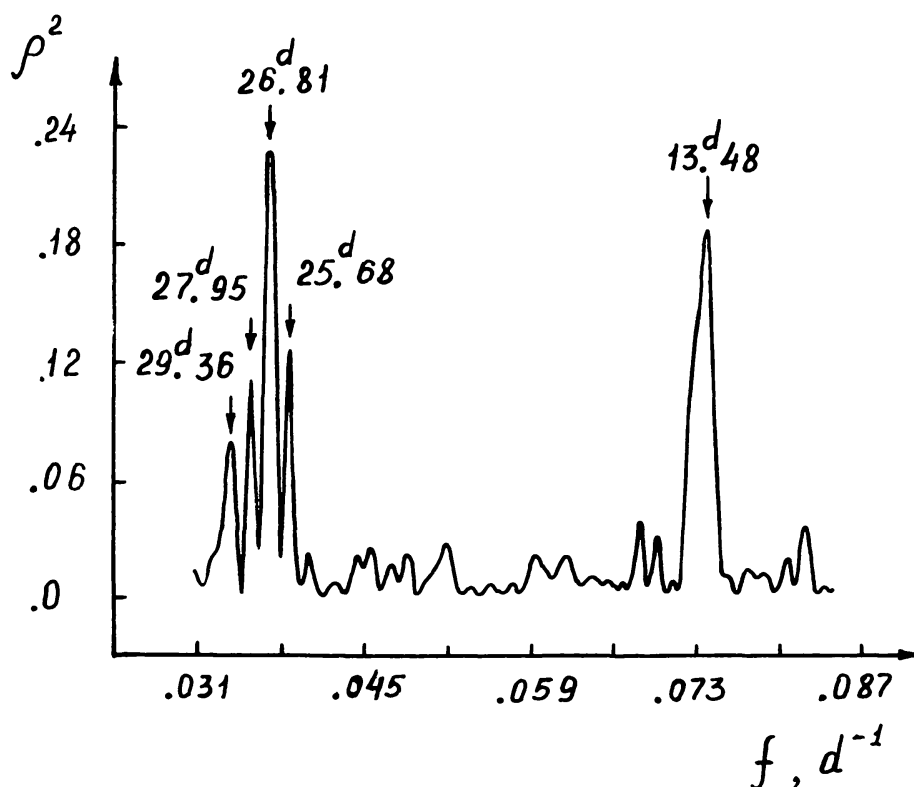
Fig. 8   CPGA – the spectrum of main periods of SMMF variations during 1982–1984 constructed from Sayan Observatory observations.

on a new telescope (the instrumental weight function) account for the smaller number of peaks in our spectrum and some differences in the values of periods. A peak of a rather large amplitude with a period of 13.48 days that has appeared in the spectrum seems to be due to the four-sector structure characteristic of the SMMF in 1983.

Kotov and Levitsky (1983c, 1984) suggest that such a discrete peak structure is due to the zonal character of the differential rotation of the Sun (similar to, for example, Jupiter), with a high degree of coherence of solid-body rotation within the zones on long time intervals. It should be noted, however, that there have been also other attempts (Kuklin, 1983; Sheeley and DeVore, 1986b) to explain the observed periodicities of SMMF variations.

We must also mention the possibility of shorter-period variations, of the order of several hours or less, existing in the SMMF variations. Severny (1971) also noted the presence of rapid SMMF variations. Based on long-term continuous observations in the Crimea and at the Mt. Wilson Observatory Kotov *et al.* (1976) showed the existence of SMMF oscillations with a period of 160 min which seem to be associated with the well-known global oscillations of the Sun of such a period. Ioshpa *et al.* (1973) suggest the existence even of five-min oscillations of the SMMF. Our long-term field records also indicate the existence of oscillations of different periods, but the solar origin has not yet been established.

5. Conclusions

Thus, with the commissioning of the Sayan Observatory's new instrument designed for special-purpose observations of the Sun with low spatial resolution (in addition to doing SMMF observations, STOP is also used to observe background magnetic fields and, on some occasions, rotation and oscillations), it has become possible to obtain a new series of observations of the magnetic field of the Sun as a star. Because our instrument employs several techniques different from those at other observatories (Crimea, Mt. Wilson, Wilcox Solar Observatory), considerable attention has been devoted to them in the present paper.

Data used in the present paper are SMMF observations during 1982–1984 (from 1 July, 1982 to 17 October, 1984) totaling 279 measurements. The comparison with the Stanford data for the same period showed a high (0.88) correlation of the two series but with a systematic difference of amplitudes: on the average, we are measuring fields of a magnitude larger by a factor of 1.5 than those at Stanford. In this connection, we recall that according to Kotov and Severny (1983), Crimean measurements of the SMMF exceed those from Stanford by a factor of 2, while Mt. Wilson measurements exceed those from Stanford by a factor of 1.22. We believe that such a difference may be hardly attributable to different calibration methods applied at different observatories and, to all likelihood, is due to the influence of instrumental weight functions.

In the last few years, substantial modifications have been introduced to the observational technique on STOP as well as to the electronics. In particular, we have adopted a continuous control of the zero level during the observations and have organized the recording of information by a method similar to that applied after the Mt. Wilson magnetograph was updated (Howard *et al.*, 1983). At present four values of the intensity in the wings of the σ-components are recorded on magnetic tape, and the remaining subsequent processing is done on a computer. The noise level has been reduced considerably.

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