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CONCERNING TIME VARIATION OBSERVATIONS OF THE GLOBAL MAGNETIC FIELD OF THE SUN

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Abstract. This paper is devoted to an analysis of some technique questions inherent in the problem of detection of weak periodic variations of the magnetograph signal in observations of large-scale magnetic fields on the Sun. Namely, using observational data obtained at the Sayan observatory STOP telescope (Grigoryev *et al.*, 1981; Grigoryev and Demidov, 1987), we address the question of the dependence of signal strength variations in observations of the global magnetic field of the Sun on some other parameters recorded during observations: brightness, the position of the zero level, and the ratio of intensities of the splitting components. It is pointed out that, although the influence of these parameter variations can occur at several frequencies, the least reliable are long-period oscillations of the magnetic field with periods $P > L/2$, where L is the realization length. The most reliable for the data being analyzed are field variations with periods of 29 and 80 min, and the proximity of the latter to the harmonic of the well-known 160-min pulsations of the Sun suggests their possible relationship, but further investigations are needed.

1. Introduction

The question of the existence on the Sun of fast time variations of large-scale magnetic fields, including the magnetic field of the Sun as a star (MFSS), which cannot be explained directly by rotation, has long been actively discussed (Severny, 1971; Ioshpa, Obridko, and Shelting, 1973; Scherrer *et al.*, 1977; Kotov, 1990; Kotov, Severny, and Tsap, 1976, 1983; Demidov, Kotov, and Grigoryev, 1990; etc). The presence of such variations and relevant research can become a new, powerful diagnostic tool for investigating the solar interior. It is with this purpose that MFSS variation measurements with very high sensitivity were scheduled as a part of the GOLF experiment under the SOHO Project (Gabriel *et al.*, 1990). However, ground-based observations of this kind still remain important.

Measuring the presumed variations of the global magnetic field, as a consequence of the obvious smallness of their amplitudes, is a very complicated scientific and technical problem. The problem becomes still more involved by the fact that the magnetograph signal depends not only in part on the magnetic field strength (H), but also on many other factors: brightness (I), spectral line profile parameters, zero level position H' (which, in turn, is determined by a variety of many other factors), etc. The functional relationship of all these parameters is very complicated and is not known with certainty to date; therefore, in the general case we cannot point conclusively to the reason for the magnetograph signal variations. So for detection of the magnetic field variations, which are free from the influence of other parameters, it seems quite appropriate to use, as a first step, the following

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empirical approach: taking into account the amplitude and statistical significance – those peaks on the power spectrum (PS) of the magnetic field variations should be considered realistic which are not present in PS of other parameters. Here an attempt has been made to use such an approach, as applied to the observations from the STOP telescope at the Sayan Observatory.

2. Observations and Results

The observing scheme, used in this work for investigation of time variations of the global magnetic field of the Sun, was similar to that used earlier by Grigoryev and Demidov (1991). Specifically, in order to increase the light flux, the measurements were made only from a central area with a diameter $\frac{1}{2}$ of the total solar diameter rather than from the full solar disk, as in the usual MFSS observations. This was achieved by suitable defocusing of the solar image through a displacement of the objective lens. As shown by Scherrer (1973), the MFSS signal is mostly generated by such a region of the solar disk.

The observations were carried out, as usual, in the λ525.02 nm Fe I line, with the time of elementary signal accumulation being 32 s. The zero-level position was monitored by means of a halfwave phase plate ($\lambda/2$) which was periodically introduced into the light beam in front of the coelostat; as the plate was moving (during about 2 s), the measuring channel was turned off. The zero-level position for each pair of measurements was determined as the average of measured strengths with and without the plate. For the subsequent spectral analysis, the data were averaged over 9 points, which corresponds to a time sample of 5.09 min. In this case, the mean error of measurements (determined by the spread in individual nine 32-s points) was about 3 μT.

For analysis in this paper two sequences of observations with the best quality (of a duration of 6 hours each), made by the author on 30 and 31 March, 1991, were selected. The results of the observations are shown in Figure 1: (a) time series of field strength for 30 March; (b) for 31 March; and (c) coherent power spectrum (according to the algorithm by Deming, 1975) of these two series after the corresponding parabolic trends are removed. The mean values of the measured strengths were -86 μT and -94 μT for 30 and 31 March, respectively. The full solar disk observations gave for those days -55 μT and -87 μT, respectively. It is interesting to note that the MFSS observations from Stanford gave -79 μT and -87 μT for those days.

To assess the origin and the reliability of the observed variations of the magnetograph signal the above described approach was used. Namely, for every day of observations, corresponding PS were calculated and were compared for the strength H as well as for the other parameters. Based on existing possibilities for the appropriate analysis, parameters were used which can be determined directly from measured data. These parameters are: brightness, I (an average of four values of intensity in the wings of the sigma components), the intensity ratio at two steps of modulator operation (following Demidov (1987), we designate this parameter, which characterizes 'perfection' of the polarization analyzer operation, as β), and the zero-level position H'.

Without giving here for reasons of economy any illustrative material, PS for I and β are characterized by the presence of dominant peaks only in the low-frequency regions, with periods of 260 (30 March) and 186 (31 March) min for I and, respectively, 260 and 237 min for β. Such peaks (with periods $P > L/2$, where L is the series length) appear to be caused by the fact that time variations of these parameters are not sufficiently exactly described by parabolas (note, that before calculations of PS the parabolic trends were removed in all data sets). This result, within the framework of the criterion adopted in this paper, does not permit us to consider strength variations with periods in excess of half the series time to be real. At the same time, higher-frequency field variations may, perhaps, be considered as being free from the influence of β and I.

As far as the zero level is concerned, the situation is reasonably simple for the data for 30 March, namely a single peak with a period of 173 min is dominant there, and such a peak is absent from field variations (a group of peaks with periods from 22 to 163 min and with amplitudes of 2–3 μT is identifiable). For 31 March, the situation is more complicated. On that day, with actually no trend in the original data, the spectrum of zero level variations showed the presence of oscillations both in a low-frequency region (with periods of 200, 106, and 75 min) and in a higher-frequency region with periods ranging from 12 to 15 min. Following the adopted criterion, peaks with periods of 40, 35, 28 min and, possibly, with periods of 83 and 64 min can be accepted as reliable.

Next, we will be using the following criterion (which, of course, cannot be recognized as being faultless): we will consider only those field variation periodicities to be plausible which are present in spectra from both days of observations. Hence it will turn out that only oscillations with periods of 28–29 min are reliable; with some reservations, the same statement can also be made in regard to oscillations with a period of about 80 min (there is a peak with a period of 77 min for 30 March and with a period of 83 min for 31 March).

The physical origin of the above oscillations is a very involved question (further investigation is needed), and we will not go into it in this paper. But the proximity of the 80-min period to the harmonic of the well-known 160-min oscillation suggests their possible relationship. It is also interesting to note that this period was credited as being one of the most reliable ones in MFSS variations in an earlier paper of Demidov, Kotov, and Gregoryev (1990). It is also conceivable that the 29-min period is also a harmonic of the quasi-hour oscillations, which were pointed out in some publications. Finally, it should be noted that as a consequence of the limited amount of observational data used in this paper, there is little point in making any conclusive judgement about the reality of the detected magnetic field variations. However, the method of analyzing the magnetograph signal and the

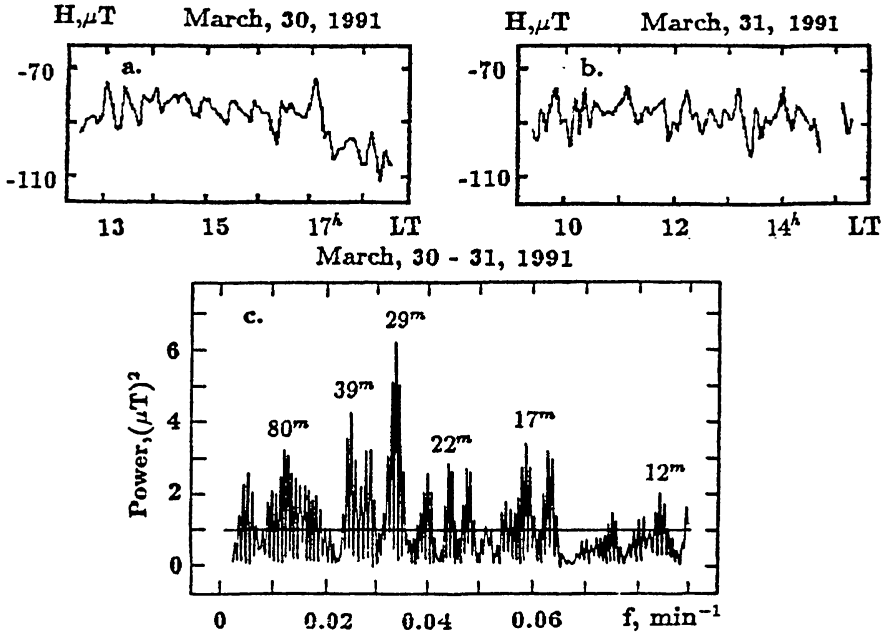

Fig. 1. The sets of measured values of the magnetic field strength, averaged over five-minute intervals, for the observations on the STOP telescope of 30 March, 1991 (a), and 31 March, 1991 (b); the abscissa axis indicates the local time; (c) the coherent power spectrum of those two days of the observations.

parameters recorded simultaneously (which are responsible for systematic magnetograph errors) that was used in this paper, is of unquestionable value and will be used in further research.

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