INTERANNUAL VARIATION OF SUNSPOT MAGNETIC FIELDS FROM 1924 TO 2004

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Some results of analysis of sunspot magnetic fields, including data from published papers (1000 measurements performed at the Mount Wilson National Observatory during 1924–1956) and data from various databases (20 000 measurements carried out during 1957–2004 at ten astronomical observatories, among them 400 measurements at the Kyiv University Astronomical Observatory) are presented. All the data were obtained using visual observations of the Zeeman splitting in the Fe I $\lambda\lambda$ 525.02 and 630.25 nm lines. The sunspots only with a diameter of penumbra from 30 to 60 arcsec and distance from disc centre less than $0.65R$ were studied. Magnetic field strengths B_{sp} averaged for each year were calculated on the basis of all individual daily measurements to exclude the influence of seasonal astroclimatic changes on quality of the Sun's image and to reduce individual errors. The essential interannual variations of B_{sp} parameter in the range from 22 to 27 cT were found. These variations are about ten times more than standard errors of B_{sp} and have mainly an irregular character. The highest values of sunspot magnetic fields were in about 1943 and 2004 ($B_{sp} \approx 27$ cT).

INTRODUCTION

It is shown in our previous papers [2, 3] that annually averaged values of sunspot magnetic field strength measured from direct observations of the Zeeman splitting should be considered as a new actual heliomagnetic index. This index, B_{sp}, is based on visual or photographical observations in spectral lines with the largest Lande factors g (as a rule, the Fe I $\lambda\lambda$ 525.02 and 630.25 nm lines, $g = 3.0$ and 2.5, respectively) and relates to sunspots of 30–60 arcsec diameter. For smaller sunspots (< 30 arcsec) the magnetic field measurements are not enough reliable owing to image scintillation. On the other hand, sunspots with a diameter more than 60 arcsec occur seldom, and corresponding data could not have a satisfactory statistics for each year.

In this work we present new data expanded for several times and showing the B_{sp} index variations from 1924 to 2004.

OBSERVATIONAL DATA

The work on analysis of instrumental problem of visual measurements of sunspot magnetic field variations was started at the horizontal solar telescope of the Kyiv University Astronomical Observatory [1], and continued [2, 3] using similar data obtained at other observatories, namely, in Crimea, Pulkovo, Ural, Ussurijsk, Irkutsk, Kislovodsk, Shemakha, Troitsk, Potsdam, from the bulletin "Solnechnye Dannye". The present paper also includes the data from the Internet Bases of the Crimean and Pulkovo observatories (see the sites [http://www.gao.spb.ru/] and [http://www.crao.crimea.ua]). In general, all these data include the time interval from 1957 to the present day. To expand the database till 1924, the data by Ringnes and Jensen [4, 5] derived from observational material of the Mount Wilson National Observatory were added.

All named data had not the index B_{sp} in readiness for use, and an additional selection and analysis were needed to extract the necessary information. Total data row includes about 21 000 individual measurements related to sunspots of 30–60 arcsec only.

RESULTS AND DISCUSSION

Our results presenting three-year averaged values of B_{sp} are given in Fig. 1. The typical errors are equal to $\pm$(0.3–0.6) cT from 1924 to 1956 and $\pm$(0.2–0.4) cT from 1957 to 2004. One can see that considerable variations of the magnetic field strengths exist in the range from about 22 to 27 cT, *i.e.*, about ten times more than standard

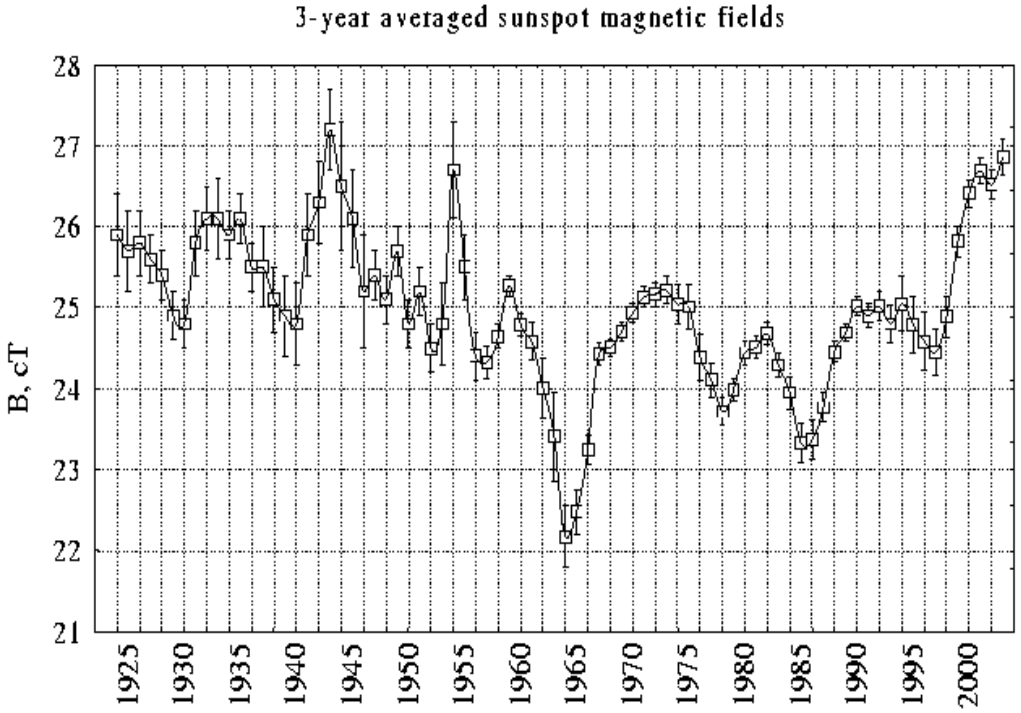

Figure 1. Interannual variations of sunspot magnetic fields during the last 80 years

errors of measurements. From 1924 to 2004 the mean value of magnetic field strength is 25.0 ± 0.1 cT. It is important to note that mean magnetic field values measured for N- and S-polarities separately in 1957–2004 were found as practically the same. This is indicative of a good methodical reliability of the measurements.

It can be seen in Fig. 1 that the magnetic field variations in sunspots have mainly an irregular character. However, there is a tendency of 11-year B_{sp} changes for the last 50 years which have, as a rule, 1–3 years delay relatively to the Wolf number. The B_{sp} peaks are wider than the Wolf maxima for the 20th, 22nd, and 23rd solar activity cycles. Also, secular variations of B_{sp} index with a characteristic period of about 60 years or longer are possible. Observational evidences for a long-term sunspot magnetic field variability (80 years) were found earlier by Ringnes [4].

Another interesting peculiarity of B_{sp} variations is the deep absolute minimum (22.1 cT) in 1964 and three high peaks in 1943 (27.2 cT), 1954 (26.7), and 2003 (26.9 cT). So, at present the annual magnetic field strength in sunspots reaches its highest value since last 50 years. Maybe, this is evidence that the current 23rd cycle of solar activity is some peculiar: it has the highest value of B_{sp}, although its Wolf number W is far from maximal values ($W_{max} = 121$ in 2000). The first B_{sp} peak of 1943 was also in a period of low solar activity ($W \approx 20$). The highest annual Wolf number from 1924 to 2004 was in 1957 ($W_{max} = 190$).

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