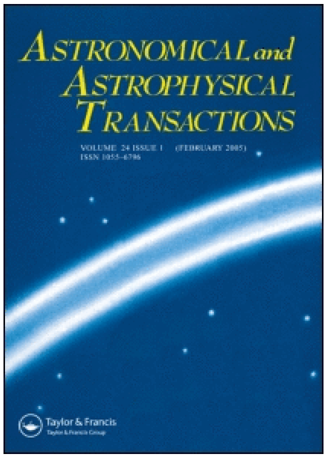

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ANOMALOUS MAGNETIC FIELD OF THE SUN AT THE BEGINNING OF CYCLE 23

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Measurements of the mean magnetic field (MMF) of the Sun from 1968–1999 showed that (1) the Sun's magnetic field has a predominance of S-polarity, (2) it changes with periods 1.04, 1.60 and 23 yr, (3) the yearly-mean index of MMF energy reached the peak value in 1991, and after that (4) a significant decrease of MMF was observed. It is supposed that (a) the magnetic asymmetry of the Sun is a fundamental property of solar magnetism, (b) there are near-resonances between the MMF and orbital motions of Mercury, Venus and Earth which arose at early stages of formation of the Solar system, and (c) cycle 23 will display an anomalously low magnetic and sunspot activity.

KEY WORDS The Sun, magnetic field, variability, cycle

Measurements of the mean magnetic field (MMF) of the Sun-as-a-star have been made since 1968 at four sites: CrAO, Mt. Wilson, WSO and Sayans (Severny, 1969; Scherrer *et al.*, 1977; Grigoryev and Demidov, 1987; Kotov *et al.*, 1998). In all, $N = 11802$ daily measurements of the longitudinal component H were obtained over the last 32 years. We merged all the MMF measurements into a single time series 1968–1999 with an RMS value $\Delta = 0.63$ G.

One outstanding problem of solar magnetism is the existence of a solar magnetic 'monopole', i.e. the predominance of one or other polarity over large portion of the solar disk during several solar rotations (Wilcox, 1972; Kotov and Levitsky, 1985; Demidov, 1996). It seems interesting thus to find the average value of H for the whole 32-year interval:

$$\langle H \rangle = -0.021 \pm 0.007(\mathrm{G}). \tag{1}$$

The mean magnetic 'monopole' of the Sun therefore has S-polarity and deviates from zero at about 3σ C.L. But the most puzzling is the evidence that magnetic disbalance of the Sun changes with a quasi-period of 22–23 yr, (see Figures 1 and 2 and also Grigoryev and Demidov, 1989; Kotov *et al.*, 1998). This requires theoretical explanation.

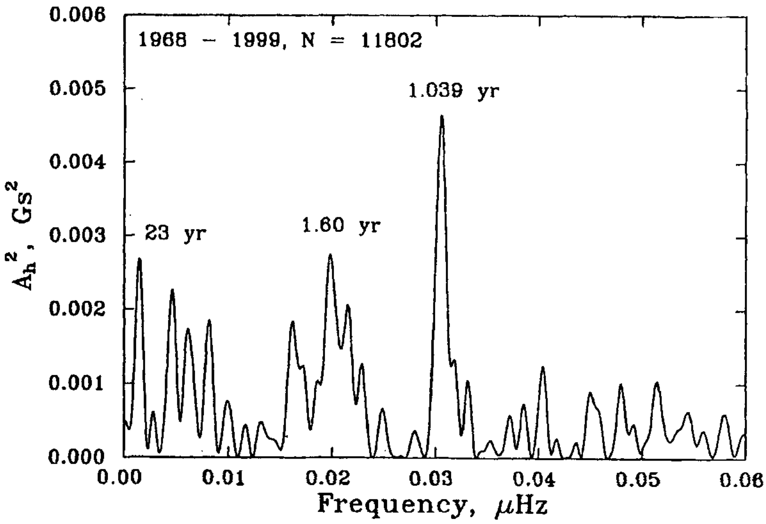

Figure 1 Power spectrum of MMF of the Sun, 1968–1999 ($N = 11802$).

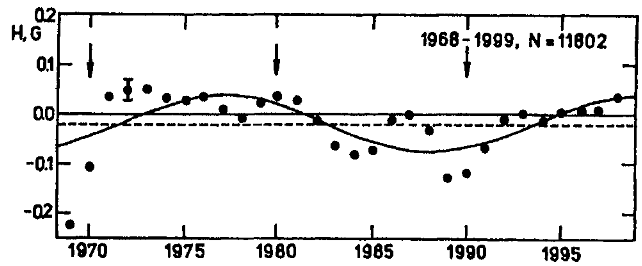

Figure 2 Time behaviour of the solar magnetic 'monopole'. Horizontal dashed line corresponds to the mean level of MMF for the total 32-yr time span, solid curved line is a best-fitted sinusoid (with 22-yr period). The time interval for averaging $\tau = 3$ yr; the vertical arrows indicate polarity reversals of the Sun's polar fields.

Other two dominant peaks in Figure 1, with periods 1.04 and 1.60 yr. correspond to 'magnetic' resonances of the Sun with orbital motions of Earth and Venus. They arose plausibly during distant times of the protoplanetary nebula.

In the power spectrum of MMF for higher frequencies (not shown here) the strongest feature corresponds to a period of equatorial rotation

$$P_\odot = 26.916 \pm 0.016(\mathrm{d}). \tag{2}$$

The corresponding sidereal period, $P'_\odot = 25.069 \pm 0.015$ d, happens to be in near-resonance 7 : 2 with the period of orbital motion of Mercury ($P_M = 87.969$ d):

$$\frac{2 \times P_M}{P'_\odot} = 7.018 \pm 0.004. \tag{3}$$

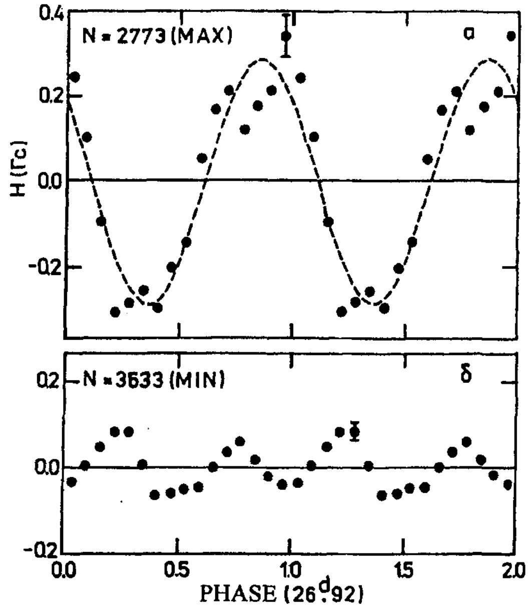

Figure 3 The mean curves plotted with period $P_\odot = 26.92$ d for epochs of (a) maximum and (b) minimum of solar activity. The number of MMF measurements $N = 2773$ (a) and $N = 3633$ (b).

We suggest that this resonance also emerged in the distant past – at the early stages of formation of the Solar system.

It is well known that average strength and RMS value of MMF change significantly with the phase of the 11-year cycle (see, e.g., Rivin and Obridko, 1992). So, it seems interesting to plot the mean MMF curves with dominant period $P_\odot \approx 26.92$ d, but separately for maxima and minima of sunspot activity. These curves are shown in Figure 3 (with zero phase fixed everywhere on 1 January 1968). One can see that the maximum epoch is characterised by the presence of a remarkable 2-sector structure, while the minimum epoch, by a 4-sector structure of small 'peak' amplitude.

For the year 1999, instead of a 2-sector structure, we found four sectors which are characteristic of solar minima (see Figure 3*b*). But, in contrast to 1999, the measurements performed at two previous pre-maximal epochs, 1979 and 1989, exhibited a distinct 2-sector structure (like that shown in Figure 3*a*) with large harmonic amplitude ($A_h = 0.41 \pm 0.08$ G) as expected for pre-maximum and maximum epochs.

We conclude that 1999 was an anomalous year and further suppose that the coming of maximum of cycle 23 will be late by about one year – when compared with the majority of recent predictions (see, e.g., Li, 1997; '*Solar Geophys. Data Prompt Reports*').

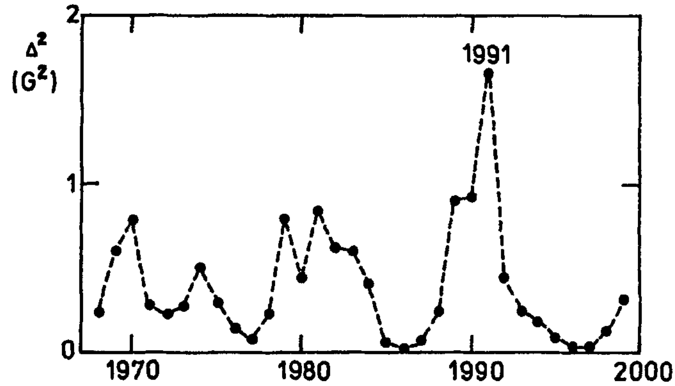

Figure 4 Time variation of the annual index of MMF energy $E = \Delta^2$. The most pronounced maximum of E was observed in 1991.

This is also supported by analysis of the annual 'index of MMF energy', $E = \Delta^2$. Changes of this index during the last 32 years are shown in Figure 4 where we see the remarkable maximum of the loss of solar magnetic energy in 1991. After that we observe a prolonged minimum of E and, consequently, of MMF strength. As a result, the E index in 1999 was about 2.6 times lower than that observed in similar situations in two previous cycles, 21 and 22.

We conclude that magnetic field of the Sun, as observed prior to 2000, demonstrated quite anomalous behaviour. The remarkable magnetic 'explosion' of the Sun in 1991 (Figure 4) means that substantial magnetic energy was expelled from the Sun into interplanetary space by the solar wind. The solar dynamo however may not be effective in supplying new magnetic flux to the photosphere. Accordingly, during the last several years we did observe an outstanding minimum of MMF. We suppose therefore that (a) cycle 23 will have low magnetic and sunspot activity – at least much lower than those of cycles 21 and 22 – and (b) the maximum of the cycle 23 will come not in 2000 but most likely near the middle of 2001.

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