The Large-scale Magnetic Field in the Global Solar Cycle: Observational Aspects

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Abstract: The global solar cycle is considered as an interaction of 3 types of activity: at low-latitude (sunspots), at high-latitude (polar faculae) and the weak magnetic field. The properties of single and 3-fold reversals of the polar magnetic field are considered. The variation spectrum of the large-scale magnetic field of the Sun is analyzed in the range of 1–30 nHz. A dependence between the rate of a poleward meridional flow and phase of the global cycle is discussed.

1. Introduction

The studies of the magnetic field in polar faculae, their latitude distribution with the phase of the cycle (Sheeley, 1976, Makarov *et al.*, 1987, Wang *et al.*, 1989), of the ephemeral active regions and X-ray bright points (Martin and Harvey, 1979, Golub *et al.*, 1977), of the latitude distribution of the coronal brightness in the 5303Å line (Leroy and Noëns, 1983; Makarov *et al.*, 1987; Wilson *et al.*, 1988) and of the migration of the magnetic neutral lines (Makarov and Sivaraman, 1983, 1986, 1989a,b) show that a toroidal component of the magnetic field B_φ is present over all latitudes on the Sun. The synoptic view of the solar cycle (Makarov and Sivaraman, 1983, 1989a,b) shows that the epoch of the reversal of the polar magnetic field heralds the beginning of the global solar activity processes. Starting from this epoch the first type of magnetic activity, in the form of high-latitude B_φ, begins to show up at latitudes from 40° to 70°, as polar faculae migrate poleward. The second type of magnetic activity (sunspots) starts when activity of the first type is at its peak, and drifts equatorwards.

The third type of activity is connected with the dynamics of the radial component of a weak magnetic field. This type of activity shows up in dynamics of the zonal and sector structures of the solar field and also the interplanetary magnetic field (Makarov and Sivaraman, 1989b).

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2. Interaction of three types of magnetic activity of the sun

Each type of activity is connected with one each other and has its own peculiarities. The entire magnetic flux on the Sun varies by a factor 2–3 from minimum to maximum of solar activity (Howard and La Bonte, 1981). This means that a latitude redistribution of the magnetic flux with the phase of the global cycle takes place. The cycle of the background magnetic field is connected with a sunspot cycle and the polar faculae cycle .

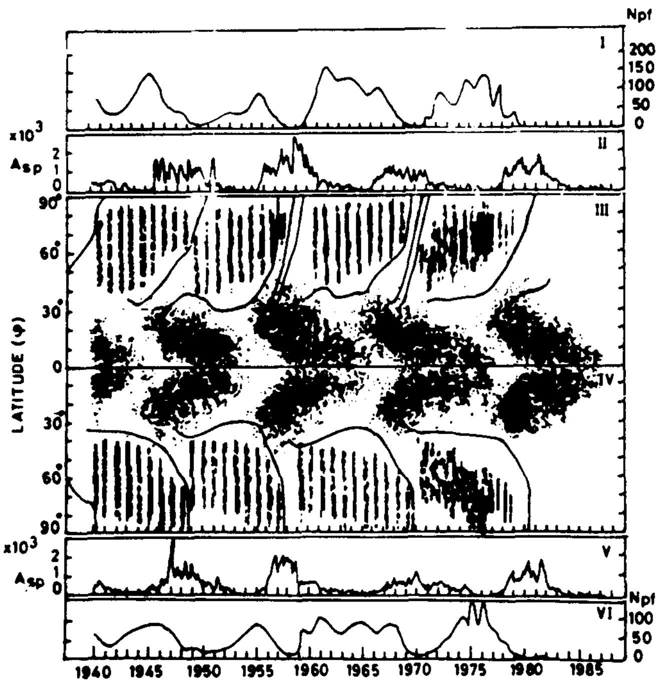

Fig. 1. Three types of magnetic activity in the global solar cycle : the low-latitude (A_{sp}-sunspots, boxes II–V) ; high-latitude (N_{pf}-polar faculae , boxes I, III–IV, VI) and the migration trajectories of neutral lines of the large-scale magnetic field to show the epochs of polar magnetic field reversals, boxes III–IV.

The unipolar faculae have a polarity orientation identical to that of the background field at latitudes > 40°. In the bipolar faculae the preceeding polarity is identical to that of the background field. The polarity orientation of those bipoles is opposite to that of the spots of the same cycle, but identical to the polarity orientation for bipolar spots of the next following cycle (Martin and Harvey, 1979; Makarov and Makarova, 1987; Wang *et al.*, 1989). In other words, while faculae of the (N+1) cycle make their appearance at high latitudes, activity of the preceding cycle (N) is still present at lower latitudes in the sunspot phase. This is similar to the behaviour of ephemeral active regions .

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So, the new cycle shows up first as faculae at high latitudes and leads the sunspot phenomenon by 5–6 years. Each has a duration of 11 years, but occurs at separate latitudes, displaced from each other by 5–6 years within a 22 year magnetic cycle . The duration of this global cycle turns out to be 16–18 years (Wilson *et al.*, 1988, Makarov and Sivaraman, 1989b).

3. Single and three-fold field reversal cycles

During the last years considerable information has been derived both from the full disc magnetograms as well as the Hα synoptic charts (Makarov and Sivaraman, 1989a). On the Hα charts one can see that the polemost filament reaches the pole first and causes the reversal of the polar field. This is the picture when a single fold reversal takes place in both hemispheres. It was observed after the maximum activity in odd sunspot cycles Nos 11(1872.3), 13(1895.0), 15(1918.7), 17(1940.1), and 21(1981.8). There are instances when a three-fold reversal occurs in one of the hemispheres. In such cases all three filament bands travel to the respective poles one after the other and cause a three-fold reversal. This took place in the even cycles in the Southern hemisphere Nos. 12(1928.5), 18(1949.0), and 20(1970.6). This means that the 22-year solar magnetic cycles begin with a cycle in which a three-fold reversal is observed in one of the hemispheres. A single reversal takes place in the succeeding 11-year cycle . The phenomenon of the three-fold reversal in both hemispheres has not been observed during the last 115 years (see the paper by Benevolenskaya, these Proceedings).

One can note that the timescale of latitude zone evolution in a single field reversal is about 22 years, but in the case of a three-fold field reversal it is about 10–12 years. The velocity of the poleward motion is increased from $5\,\mathrm{ms}^{-1}$ to $40\,\mathrm{ms}^{-1}$ with a steep rise in the sunspot activity in the case of a three-fold field reversal.

4. Spectrum of solar large-scale magnetic field variations in the frequency range 1–30 nHz

From the Hα charts for the period 1910–1985 we have calculated the distribution of the dominant polarity area over every 10° latitude zone. Figure 2 shows the complete power spectra for all latitudes. Besides Hale's magnetic cycle, whose duration is 20 years there are additional quasi-periods of 7.0, 3.4, 2.5 and 1.7 yrs. The last period of 1.7 years, which is of greatest interest (Makarov *et al.*, 1985), was detected from quasi-periodic oscillations in the latitude zones from Hα charts.

The periods 3.4 and 7.0 yrs corresponds to the amplitude modulation of the principal period 1.7 yrs, which in the evolution of background magnetic fields corresponds to a time interval between the zones of alternating polarity of the magnetic field. It determines the quasi-period of the high-frequency component. This enabled us to show topologically that single and three-fold polarity reversals of the solar magnetic fields can result from an interaction of two types of

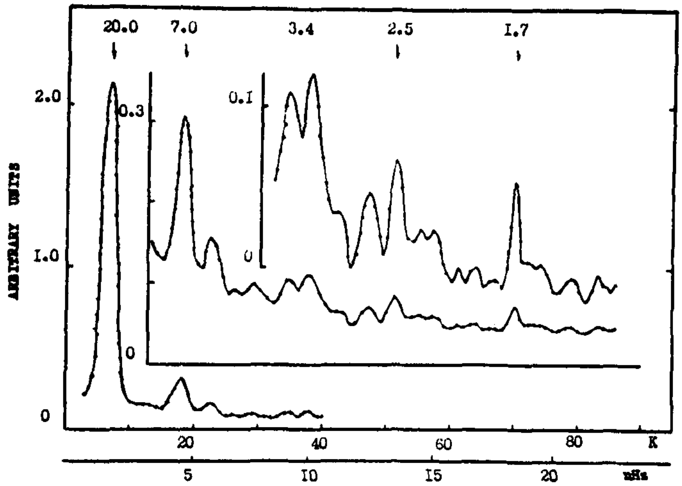

Fig. 2. The power spectra of solar large-scale magnetic field variations for the period 1910–1985.

magnetic field: a low-frequency component with period of the order of 20 yrs and a high frequency component, period of the order of 1.7 yrs (Belevolenskaya and Makarov, 1990).

5. On the correlation between the sunspot cycle and polar-faculae cycle at the current cycle 22

For the period 1940–1985 we have found a high degree of correlation (0.76 to 0.85) between the variations of monthly numbers of polar faculae N(t) and sunspot areas S(t) (Makarov *et al.*, 1989). The correlation was maximal for a value Δt ranging from 5.2 to 6.2 yrs. This time is the interval between the finish of the polar magnetic field reversal and the beginning of a new sunspot cycle . We have compared the sunspot activity with that of polar faculae when Δt = 6.6 yrs for current cycle 22, see Fig. 3. It is seen that the activity fluctuations in polar zones are repeated in 6 years in sunspot fluctuations. The most powerful activity burst may be expected at the end of 1991 or beginning of 1992. Regrettably the connection between the 1st and 2nd type of activity has not been explained so far.

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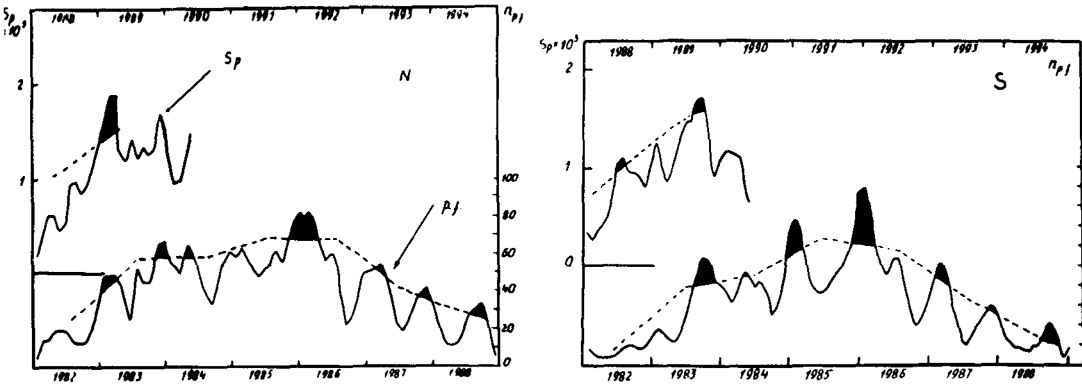

Fig. 3. Relation of the polar faculae number N_{pf} to the sunspot area cycle S_p in the current 22nd global solar cycle from the Kislovodsk solar station data.

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