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Polar magnetic field reversals on the Sun

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Abstract. The polar magnetic fields on the Sun have been an attractive subject for solar researches since Babcock measured them in solar cycle 19. One of the remarkable features of the polar magnetic fields is their reversal during the maxima of 11-year sunspot cycles. I have present results of the investigations of the polar magnetic field using *SOHO*-MDI data. It is found, that the polar magnetic field reversal is detected with MDI data for polar region within 78°–88°. The North Pole has changed polarity in CR1975 (April 2001). The South reversed later in CR1980 (September 2001). The total unsigned magnetic flux does not show the dramatic decreasing during the polar reversals due to omnipresent bi-polar small-scale magnetic elements. The observational and theoretical aspects of the polar magnetic field reversals are discussed.

Keywords. Sun: magnetic fields, Sun: photosphere, Sun: activity

1. Introduction

The investigation and further discussions about Polar Magnetic Field Reversals on the Sun began since a small report in Science was published by Harold D. Babcock and William C. Livingston in 1958. They announced that observations of solar magnetic fields at South pole had reversed their polarity by June 1957. To understand the origin of the polar magnetic field reversals many investigators employed the mean-field dynamo theory (e.g., Dikpati *et al.* 2004). The surface-diffusion or transport models explain the polar magnetic field reversals as a result of turbulent diffusion, differential rotation and meridional circulation (Leighton 1964; Leighton 1969; Wang *et al.* 1989). Fox *et al.* (1998) described the evolution of the large-scale fields and their association with polar coronal holes. Their question was whether the polar fields resulted from the local polar dynamo or not. There is no a certain answer to this question. However, Durrant *et al.* (2002) have observed that high-latitude flux emergence can effect the evolution of individual high-latitude plumes, but this flux does not seriously affect the whole reversal times of the polar magnetic field. Nowadays, we understand that a process of polar magnetic field reversals is a complex phenomena including different physical processes in the convection zone, photosphere and corona (Schrijver *et al.* 2002; Fisk & Schwadron 2001; Benevolenskaya *et al.* 2001 Benevolenskaya *et al.* 2002; Gopalswamy *et al.* 2003).

2. Polar reversals in cycle 23 and small-scale magnetic elements

The total magnetic flux $F_r = F_+ + F_-$for polar caps $(\pm(78° - 88°)$ is present in Figure 1a (left panels). The positive and negative fractions of the magnetic flux are $\frac{F_+}{F_r}$ and $\frac{F_-}{F_r}$. The time of reversals can be determined at $\frac{F_+}{F_r} = 0.5$ 1975 ± 2 or $\frac{F_-}{F_r} = 0.5$ or using value of total signed magnetic flux (Figure 1c, left panels)). This was in CR 1980 ± 2 for the southern magnetic field, it is about 1975 ± 2 in the North (Figure 1a, left panel). This is close to the periods obtained by Durrant & Wilson (2003): CR 1975 ± 2 in North and CR 1981 ± 1 in South.

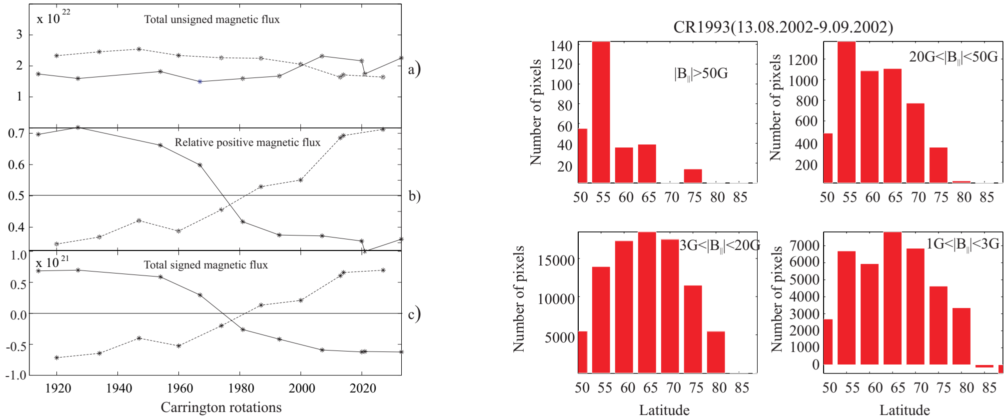

Figure 1. *Left panels:* (a) The total unsigned magnetic flux of the radial field component in the latitude zones from 78° to 88° in Northern (*solid line*) and Southern Hemispheres (*dash lines*); (b) The relative positive polarity parts of magnetic flux in Northern (*solid line*) and Southern (*dash line*) hemispheres; (c) The total signed magnetic flux. The polar magnetic field reversal was in CR 1975 ± 2 (March 2001) in the North and in CR 1980 ± 2 (September 2001) in South. *Right panels:* Differences between the number of pixels with negative and positive polarity after the polar magnetic field reversals for carrington rotation 1993 (CR 1993)in North.

The solar magnetic field and, in particular, the polar magnetic field, is dominated by small magnetic elements of mixed polarities as has been shown by Severny (1965), Lin *et al.* (1994), and Benevolenskaya (2004). Magnetic flux of small scale bi-polar elements contribute to the total unsigned magnetic flux, but how they affect the polar magnetic field reversals is not yet clearly understand. The difference between the number of magnetic elements of negative and positive polarity as a function of latitude shows the dynamic of the magnetic elements. The evolution of the elements of strong and the weak magnetic field after the polar magnetic field reversals in North is considered in Figure 1 (right panels). The number of elements of weak magnetic field ($1\,G < |B_{||}| < 3\,\mathrm{G}$) displays a delay in the changing of their polarity to compare with elements of strong magnetic field (Figure 1, right panels) in the line-of-sight component.

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