

# SUN'S POLAR MAGNETIC FIELD REVERSALS IN SOLAR CYCLE 24

M.I.Pishkalo<sup>1</sup>, U.M.Leiko<sup>2</sup>

Astronomical Observatory of Taras Shevchenko National University of Kyiv,  
Observatorna 3, Kyiv, 04053, Ukraine

<sup>1</sup>pish@observ.univ.kiev.ua, <sup>2</sup>leiko@observ.univ.kiev.ua

**ABSTRACT.** It is known that polar magnetic field of the Sun changes its sign at the maximum of solar cycle. These changes were called as polar field reversals. We investigated dynamics of high-latitude solar magnetic fields separately in northern and southern hemispheres. Solar polar field strength measurements from the Wilcox Solar Observatory and low-resolution synoptic magnetic maps from the SOLIS project and from Helioseismic and Magnetic Imager (HMI) onboard Solar Dynamics Observatory were used. We analyzed total magnetic flux at near-polar zones, starting from 55, 60, 65, 70, 75, 80 and 85 degrees of latitude, and found time points when the total magnetic flux changed its sign. It was concluded that total magnetic flux changed its sign at first at lower latitudes and finally near the poles. Single polar magnetic field reversal was found in the southern hemisphere. The northern hemisphere was characterized by three-fold magnetic field reversal. Polar magnetic field reversals finished in northern and southern hemispheres by CR 2150 and CR 2162, respectively.

**Keywords:** Sun: Solar activity – Solar magnetic fields: Polar field reversals

## 1. Introduction

Polar magnetic fields of the Sun are maximal in solar activity minima and minimal in maxima. Besides, at the epoch of solar maximum polar magnetic fields reverse their sign (Babcock, 1959; Petrie et al., 2014).

Polar magnetic fields are predominantly connected with large-scale dipolar magnetic field of the Sun. Its evolution, in a general way, may be described by the Babcock-Leighton solar cycle mechanism (Babcock, 1961; Leighton, 1969). At the photosphere level the polarity reversal may be described by a surface flux transport process (Wang et al., 1989; Sun et al., 2015).

Polar magnetic field reversals are usually asymmetric (Svalgaard & Kamide, 2013). They occur usually at different time in northern and southern solar hemispheres. Sometimes the polarity reversal in northern or southern hemisphere is three-fold. So, Makarov and Sivaraman (1986, 1989) found that three-fold reversals occurred in solar cycles 16, 19 and 20 in N-hemisphere, and in cycles 12 and 14 in S-hemisphere. In solar cycles 21-23 polarity reversals were single in both hemispheres (see Pishkalo et al., 2005, and references therein).

In the present work we study evolution of near-polar magnetic fields of the Sun at the maximum of the current solar cycle 24 to find the time of polarity reversals.

## 2. Data and analysis

We analyzed data on sunspot number from the SIDC (<http://sidc.oma.be/html/sunspot.html>) and solar polar magnetic field measured in the Wilcox Solar Observatory (WSO, <http://wso.stanford.edu/Polar.html>) near the maximum of sunspot cycle 24.

Low-resolution synoptic magnetic maps from the SOLIS project (Fe I 630.2 nm, 360×180 pixels; [http://solis.nso.edu/0/solis\\_data.html](http://solis.nso.edu/0/solis_data.html)) and from Helioseismic and Magnetic Imager (HMI, 720×360 pixels, <http://jsoc.stanford.edu/data/hmi/synoptic/>) onboard Solar Dynamics Observatory (SDO) were also analyzed in details. We summed up total magnetic flux at near-polar zones starting from 55, 60, 65, 70, 75, 80 and 85 degrees of northern and southern latitude, and found then time points when the total magnetic flux changed its sign. We considered the time points as the time of polarity reversal in the corresponding zones.

## 3. Results

Fig. 1 illustrates evolution of international monthly sunspot number from the SIDC and polar magnetic field measured by the WSO near the maximum of solar cycle 24, in 2012-2015. Smoothed data are plotted by solid lines. It should be noticed that polar fields measured at the WSO are mean fields over the  $|\pm 55|^\circ$  of solar latitude. In the top panel, times of polar field reversal in northern and southern hemispheres (according to the WSO data, bottom panel) are shown by solid and dashed vertical lines respectively.

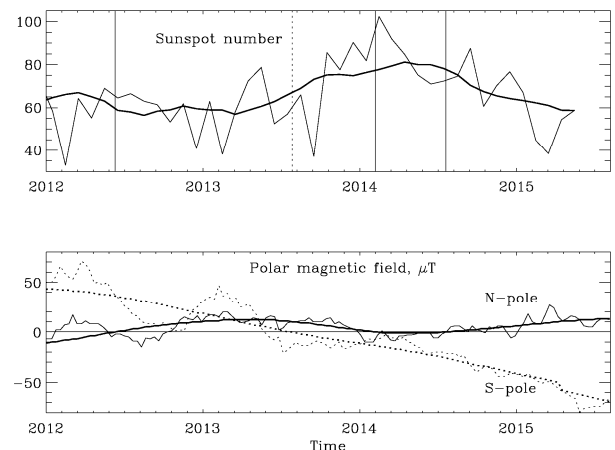


Figure 1: Monthly sunspot number from the SIDC (top) and polar magnetic field measured by the WSO (bottom) since 2012. Smoothed data are plotted by solid lines

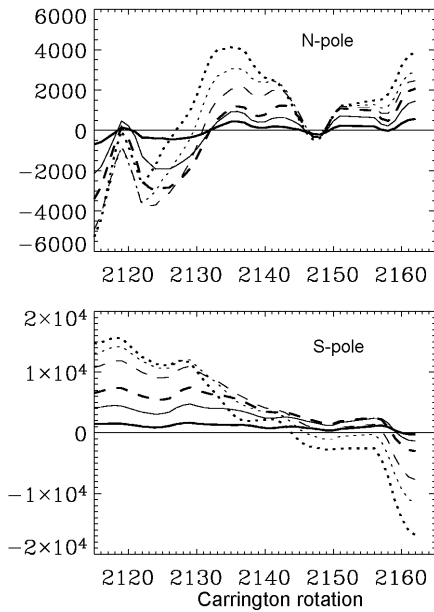


Figure 2a: Evolution of total near-polar magnetic flux in different near-polar zones (SOLIS data, see, the text).

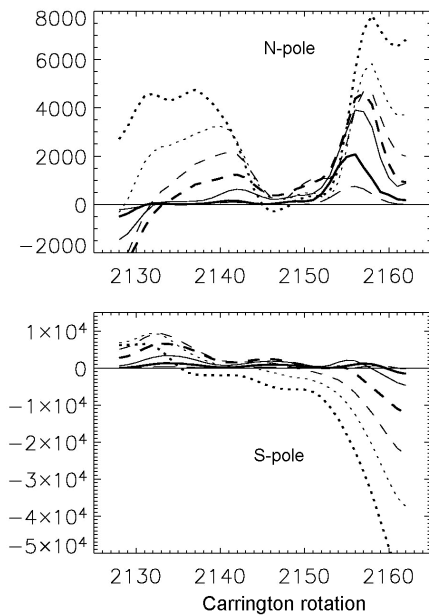


Figure 2b: the same as in fig. 2a for HMI data.

One can see that the polarity reversal in the northern hemisphere was three-fold and it came to the end in the middle of 2014, a year after completion of the polarity reversal in the southern hemisphere in the middle of 2013.

Evolution of total magnetic flux in different near-polar zones is shown in Fig. 2a (SOLIS) and 2b (HMI) by thin and thick solid ( $75^\circ$  and  $\geq 80^\circ$ ), dashed ( $\geq 65^\circ$  and  $\geq 70^\circ$ ) and dotted ( $\geq 60^\circ$  and  $\geq 55^\circ$ ) lines. Line with long dashes in fig. 2b represents near polar zone of  $\geq 85^\circ$ . Note: Fig. 2 was plotted after triple 3-points smoothing.

The current solar cycle began in December, 2008 after a prolonged and weak solar minimum. Polar magnetic fields in minimum of solar cycle 24, measured by the WSO, were almost twice weakened as compared with three previous cycles. Before the cycle maximum, total magnetic flux in near-polar zones was positive in the S-hemisphere and nega-

tive in the N-hemisphere. Near the cycle maximum total magnetic flux changed its sign from negative to positive in the N-hemisphere and from positive to negative in the S-hemisphere. These changes occurred first at low latitudes. It seems that polarity reversal was single in the S-hemisphere and three-fold in the N-hemisphere. The process of polarity reversal in the S-hemisphere and first reversal in the N-hemisphere are gradual when it “moves” from zones of  $\geq 55^\circ$  to poles during 7 rotations to 2 years. Second and third polarity reversals in the N-hemisphere are fleeting and cover all the zones nearly simultaneously. Polarity reversal in the S-hemisphere finished in the first half of 2015, about one year later than in the N-hemisphere. Time of polarity reversals against lower limits of near-polar zones are plotted in fig. 3.

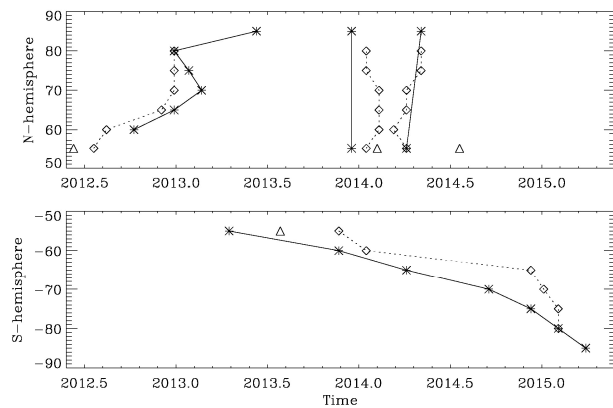


Figure 3: Time of polarity reversal in different near-polar zones in the northern (top) and southern (bottom) hemispheres obtained using data from SOLIS (rhombuses) HMI SDO (asterisks) and WSO (triangles). Note: points of  $\pm 55$  along y-axis correspond to zones from  $\pm 55^\circ$  to poles, and so on.

### Conclusions

In solar cycle 24, polar field reversals occur near the cycle maximum, at different time in N- and S-hemisphere according to the hemisphere activity.

There were three-fold polar magnetic field reversal in the N-hemisphere and single reversal in the S-hemisphere.

The magnetic field reversal in N-hemisphere was completed one year earlier than in the S-hemisphere.

The whole reversal process, from  $\pm 55^\circ$  to poles, lasted about two years in both hemispheres.

### References

Babcock H.D.: 1959, *Astrophys. J.*, **130**, 364.  
 Babcock H.D.: 1961, *Astrophys. J.*, **133**, 572.  
 Leighton R.B.: 1969, *Astrophys. J.*, **156**, 1.  
 Makarov V.I., Sivaraman K.R.: 1986, *Bull. Astr. Soc. India*, **14**, 163.  
 Makarov V.I., Sivaraman K.R.: 1989, *Solar Phys.*, **119**, 35.  
 Petrie G.J.D. et al.: 2014, *Space Sci. Rev.*, 2014, **186**, 325.  
 Pishkalo M.I. et al.: 2005, *Vestnik Kiev Univ. Astronomy*, **41–42**, 98.  
 Sun X. et al.: 2015, *Astrophys. J.*, **798**, article id. 114.  
 Svalgaard L., Kamide Y.: 2013, *Astrophys. J.*, 2013, **763**, article id. 23.  
 Wang Y.-M. et al.: 1989, *Science*, **245**, 712.