Solar Activity and its Magnetic Origin
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Basic topology and dynamics of magnetic field leading activity the Sun

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Abstract. Observations of the large scale magnetic field in the photosphere taken at the Wilcox Solar Observatory since 1976 up to 2005 have been analyzed to deduce its latitudinal and longitudinal structures, its differential rotation, and their variability in time. Basic topology of solar magnetic field was reconstructed in coordinate system rotating with different rate.

Keywords. Sun: magnetic fields, photosphere, activity

The main results of the study of the magnetic field topology are the following:

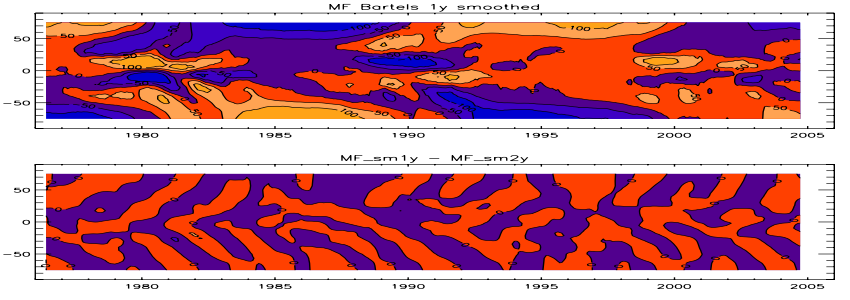

Figure 1. The 1-year mean photospheric field (upper plot) and its short-term variable part (bottom plot) as a function of time and latitudes. Orange and blue (light and dark) colors indicate positive and negative polarities. The contours correspond to the levels of -50, 0, 50 micro Teslas. The contours correspond to the levels of 50, 100, 300 micro Teslas.

- The latitudinal structure of the solar magnetic field (SMF) with a period of polarity change of 22 years consists of four zones: two sub polar and two pre-equatorial with boundaries around +25, 0 and -25 degrees (see upper plot in Fig. 1).

- The presence of the polarity waves running from the equator to the poles with a period of 2-3 years has been clearly demonstrated (see bottom plot in Fig. 1).

- The study of North-South asymmetry of solar magnetic field and its variability in time reveals that the period of the short term running waves in the Southern hemisphere is 25% shorter than in the Northern hemisphere. Due to this they are in phase each 11 years (see bottom plot in Fig. 1). A quasi 9–11-year periodicity is presented in the North-South SMF correlation. The correlation is the lowest one on the zone boundaries of the $4Z-$structure.

- Differential rotational rate of the magnetic field and its temporal dependence has been evidenced at different latitudes through activity cycles. It was found that the rotational rate has a character of torsional waves running to the equator with 11 year periodicity. At high latitudes the rotation is getting slower during minimum of activity when the field measured there is stronger.

- The reconstruction of the latitudinal structure in the coordinate system rotating like the photosphere demonstrates that 22-year periodicity of the SMF is determined by the differential rotation rate of the SMF (see Fig. 3). The polarity in the opposite hemispheres are in phase each 20–22 years in this system.

- The longitudinal distribution of the solar magnetic field in Carrington system has two active longitudes around 10 and 220 degrees. The possibility of the interpretation of the longitudinal distribution of the photospheric magnetic field by the models of fully random perturbations is excluded.

- Longitudinal structure in different coordinate systems rotating differentially like the photosphere does and with different constant rates were reconstructed.

These results are fundamental for the understanding of the magnetic origin of the solar activity, dynamics, the heliospheric structure and for the prediction of the solar wind and magnetospheric perturbations.

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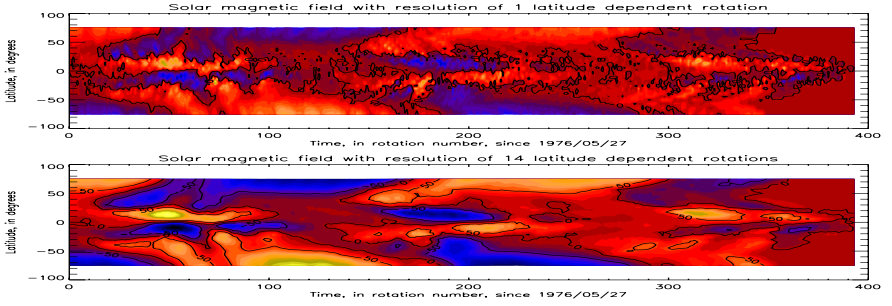

Figure 2. The 1-CR mean (upper plot) and 1-year mean photospheric magnetic field as a function of time and latitudes reconstructed in the system rotating like photosphere does.

- Extremely interesting quasi-stable over 30 years longitudinal structure has been found in the system rotating rigidly with the period revealed experimentally by analysis of the temporal behavior of the photospheric field (Fig. 3). Its relation to the latitudinal topology of the magnetic field was studied.

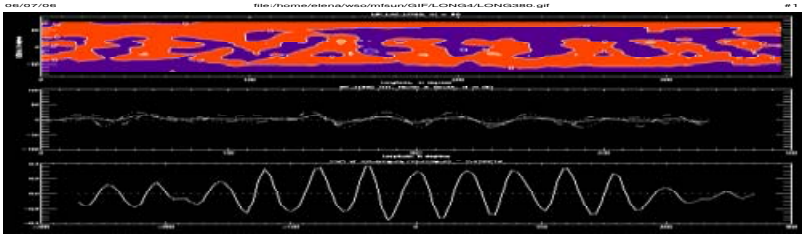

Figure 3. Longitudinal structure mean over 21 and 22 cycles of activity $MFLONG(\phi, \theta)$ reconstructed in a system rotating rigidly with the period revealed from the WSO observational data (upper plot); mean over northern – $MFLONG_N, \phi)$, southern $MFLONG_S(\phi)$ and all the latitudes θ; coefficient of cross-correlation between $MFLONG_N$ and $MFLONG_S$ as a function of a shift in longitude ϕ (bottom plot). Orange and blue (light and dark) colors indicate positive and negative correlation.

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