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Time-latitude prominences distribution (1967-2006)

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Abstract. This paper presents a study of the solar prominences time-latitude distribution for the period 1967-2007. The different patterns of the prominences distribution and its evolution during solar cycle are reported. The evolution of the different prominences patterns is closely related to the time-latitude topology of the large-scale magnetic field.

Key words: Sun: activity – Sun: magnetic fields – Sun: prominences

1. Introduction

Solar prominences are formed in magnetic structures that hold relatively cool, dense gas closed in the surrounding hotter corona and suspended above the surface of the Sun. Prominences observed on the solar disk are darker features known as filaments. Filaments (and prominences) may occur at all latitudes above magnetic neutral lines at boundaries between opposite-polarity magnetic fields. This was presented by Babcock and Babcock (1955) and afterward by Howard (1959). The time-latitude distribution of the prominences has been studied for over several decades (e.g., Waldmeier, 1973; Bumba *et al.*, 1990). Despite decades of study, the mechanism by which prominences are formed and distributed is not well understood yet. Magnetic fields are known as a dominant influence on gas motions within the solar corona, but the exact form of magnetic interaction required to produce, maintain and distribute prominences has yet to be determined. A key point for the understanding of the time-latitude distribution of all prominences is the solar magnetic field. The purpose of this paper is to study the time-latitude distribution of all prominences over the solar surface and time.

2. Data and data processing

The prominences data as the date and time of observation, heliographic latitude, area *(A)* and relative brightness *(RB)* on a three degree scale were derived from a regular photographic observations of prominences around the whole solar limb at the Lomnický Štít observatory since 1967 (Rušin *et al.*, 1988). The data used here covers 4714 observational days during the period 1967-2006. A 'prominence index' PX is defined as the product of the area of a prominence and the prominence relative brightness

$$PX = A \times RB. \quad (1)$$

The PX values were computed for all of the prominences. We consider the PX as an approach of the prominence mass. The latitudes of the prominences were interpolated to 73 equal 5 degree steps in the positional angle range 0°to 360°. For each date of observation in the period 1967-2006 (14510 days) and each positional angle of the prominences the PX values were inserted into prominence matrix of size 73 rows by 14510 columns. For the purpose of visualizing a sparse prominence matrix and in order to reduce the effect of an uneven distribution of the prominences' observations in time, an 81-day running average (roughly 3 solar rotations) along all prominence matrix rows has been performed. A positional angle to the latitude conversion has been applied for each matrix column. The local maximal values for each column of resulting averaged prominence matrix (APX) were used for the study of the prominences time-latitude distribution.

3. Time-latitude distribution of prominences

On a short time scale prominences seem to be distributed around the solar limb randomly. The largest and longest lasting quiescent prominences, visible over several solar rotations, are often located in the polar crown high latitude areas. On the other hand, they may occasionally be found between or near active regions. The active prominences are short lived structures associated with solar flares and other forceful occurrences. Figure 1 shows a time-latitude distribution of all APX values during the period covered by the data set (note a sparse APX distribution in the vicinity of the polar migrating branches). On a long-term basis we find large prominences to be concentrated into belts. The structure of these prominence belts is complicated, especially in mid- and low-latitudes, e.g. Makarov and Sivaraman (1989), Bumba et al. (1990). The APX histogram analysis is used to study the prominences' distribution. For each latitude has been used a histogram of the corresponding APX data to highlight the boundary limits for the APX classes with different time-latitude distributions. The APX data were divided into three classes: one for APX values less than 7, second for APX values from 7 to 17 and third for APX values above 20. This approach is not a formal one; elements of each class have different time-latitude distribution during solar cycles. In a recent paper, Minarovjech et al. (1998) have employed the APX data to produce plots of the time-latitude prominences distribution during period 1967-1997. The updated plot of the time-latitude distribution of the APX classes for the period 1967-2006 covering now almost four solar cycles is shown in Figure 2. Plotted rectangles show the time-latitude distribution for each individual APX class with the values in the range above 20 (upper panel),

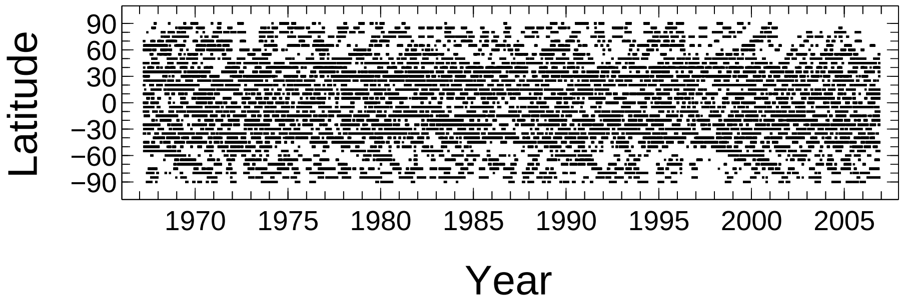

Figure 1. Time-latitude distribution of all *APX* values.

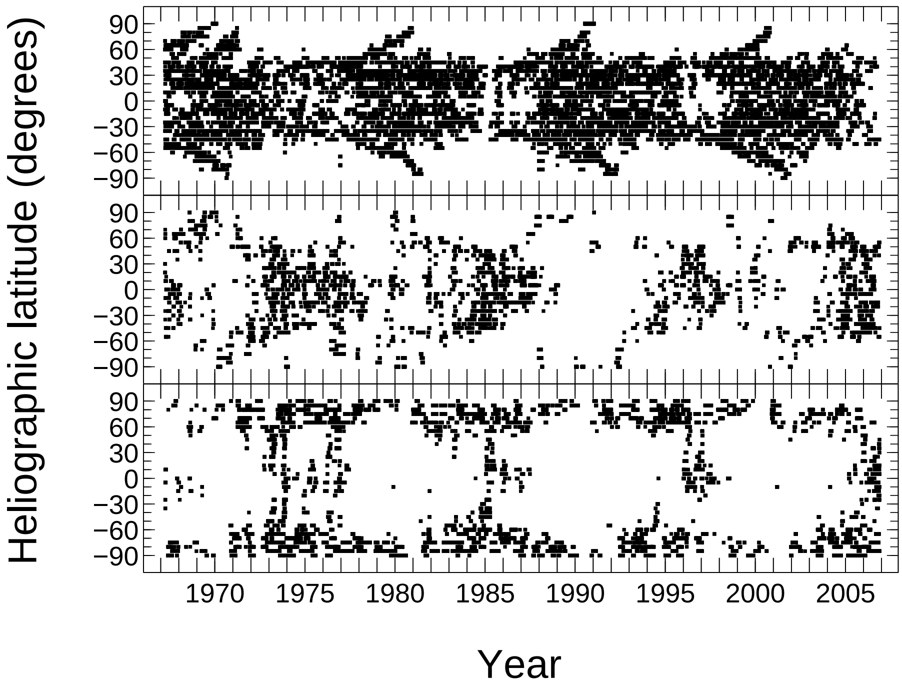

Figure 2. Time-latitude distribution for the *APX* classes with values above 20 (upper panel); values from 7 to 17 (center panel); values smaller than 7 (bottom panel).

from 7 to 17 (middle panel) and smaller than 7 (bottom panel). The size of each rectangle is proportional $\pm$ 2.5°in latitude and 81 days (approximately 3 solar rotations) in time. For example, the distribution of large prominences with time resembles the familiar butterfly diagram of the sunspot cycle (Figure 2, upper panel) but other (Figure 2, middle and bottom panels) not (Rust 2001). There is a little overlap between separate distributions of the *APX* classes. This overlap is probably caused by two main sources. The first source is a sparsity of the prominence matrix (only 32% columns contain measured data), and the second source is the fact that the estimation of prominence brightness has been done visually and thus is somewhat subjective. In order to prevent the overlap, a small gap from 17 to 20 between the second and third *APX* class is applied.

4. Results and conclusions

The solar prominences are usually sorted out according to activity into two main classes: quiescent (long lived, fairly static) and active (short lived, moving). Prominences may be divided, alternatively, according to the distribution in the latitude and different behaviour within solar cycles into three groups: sunspot type prominences, associated with the zone of spots, a stationary prominences, developed from the centers of activity out of the spot zone and a polar zone prominences that lie at latitudes above 45°. In the course of solar cycle the first two groups migrate towards the equator, the last one migrates poleward (see, e.g., Waldmeier 1973).

A sorting of the prominences presented here is based on the *APX* data time-latitude distribution as shown in Figure 2. Three classes of prominences have been proposed. The first one (Fig. 2, top panel) seems to denote latitudes between $\pm$50°and the polar- and high-latitude regions where dominant polar migrating branches of prominences are formed between the merged and dispersed opposite-polarity magnetic fields' remnants of many previous active regions. There is no observable equatorward migration in the time-latitude distribution, however, the density of this class is sparse around the solar cycle minimum. The second one (Fig. 2, middle panel) predominantly appears in the descending phase of solar cycle at latitudes about 60°and in the course of solar cycle is contracting to the equator, where it disappears around the solar cycle minimum. The last one (Fig. 2, bottom panel) denotes two areas. First one is a polar area above 60°in the latitude and between each two consecutive solar cycle maxima in time. Around the solar cycle maximum those polar components disappear. The second one arises only around the solar cycle minimum and take places in the latitude range between $\pm$60°.

Prominences appear above magnetic channels in the chromosphere, trapped by the magnetic fields. Large-scale, long-lived prominences are associated with large-scale, slowly changing magnetic fields; small-scale, short-lived prominences are related to small-scale, rapidly changing magnetic fields (Martin, 1986). The distribution of APX with time resembles the familiar butterfly diagram of the sunspot cycle (Figure 2, top panel). This suggests that the amount of magnetic flux in filaments varies with the magnetic cycle (Rust, 2001).

Martin (1998) already suspected the possible existence of a scaling law which could allow insights into the essential conditions for prominences' formation. The time-latitude distribution of prominences on the solar disk provides us with important hints about the global structure of the solar magnetic fields. Based on almost disjunctive time-latitude distribution of the APX classes, we hope that the present analysis will be a useful step for a deeper understanding of how magnetic energy comes to be stored in prominences.

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References

Babcock, H.W., Babcock, H.D.: 1955, *Astrophys. J.* **121**, 349

Bumba, V., Rušin, V., Rybanský,M.: 1990, *Bull. Astron. Inst. Czechosl.* **41**, 253

Makarov, V.I., Sivaraman, K.R.: 1989, *Sol. Phys.* **119**, 35

Martin, S.F.: 1986, in *Coronal and Prominence Plasmas*, ed.: A.I. Poland, NASA, CP-3224, Washington, 73

Martin, S.F.: 1998, *Sol. Phys.* **182**, 107

Minarovjech, M., Rybanský, M., and Rušin, V.: 1998, in *New Perspectives in Solar Prominences*, eds.: D.F. Webb, D.M. Rust and B. Schmieder, ASP Conf. Ser. 150, San Francisco: ASP, 484

Rust, D.M.: 2001, *J. Geophys. Res.* **106**, A11, 25075

Rušin, V., Rybanský, M., Dermendjiev, V., Stavrev, K.Y.: 1988, *Contrib. Astron. Obs. Skalnaté Pleso* **17**, 63

Waldmeier, M.: 1973, *Sol. Phys.* **28**, 389