SINGULARITIES OF THE DIFFERENTIAL ROTATION VELOCITY OF FILAMENTS WITHIN THE SOLAR CYCLE

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Abstract. The active longitude intervals of filaments along the interval 1957–1989 are determined. The filaments with pivot-points are computed as singularities of the differential rotation velocity. A comparative study of the rigid rotation of the filaments with pivot-point and the active longitude intervals of all filaments is done. If the pivot-point filaments reveal singularities of the differential rotation velocity, the active longitude still rests an enigmatic behavior of the solar activity.

Key words: Sun – differential rotation – prominences – pivot-point – active longitudes.

1. INTRODUCTION

The problem of active longitudes has been studied for different features of the solar activity: sunspot groups, solar flares or radio emission bursts (Losh 1938; Vitinskij 1960). Vitinskij (1969) has shown that the active longitudes of active regions point out a rigid differential rotation during one year.

The pivot-points of filaments were detected by Mouradian et al. (1987) as a very special feature of solar activity: sites of flare production. Dumitrache et al. (1994) computed the evolutionary sequences of filaments by applying a cluster analysis method and suggested a classification with three types of sequences, one of them consisting of filaments with pivot-point. The pivot-points of filaments are defined as rotating with the Carrington velocity (Dumitrache, 1997), so they also reveal a rigid rotation. The question is: what relationship could exist between filaments with pivot-point and active longitudes? Do the active longitude filaments display a rigid rotation, representing by this reason singularities of the differential rotation of the Sun?

In this paper we have used the mean coordinates of 19 060 filaments, along three cycles of solar activity (1957–1989); they are available from *Solar Geophysical Data.*

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2. ACTIVE LONGITUDES OF FILAMENTS

Fig. 1 displays the nests of activity of the filaments on the solar disk, during the above mentioned period. In this figure, the cells are dimensioned at 10° latitude (*y*-axis) and 40° longitude each one, counting the number of events recorded (*z*-axis); on the *x*-axis we represent the time in years. The butterfly diagram appears very clearly. The concentration of activity in different cells is dependent on both latitude and longitude location, and a North-South asymmetry is obvious.

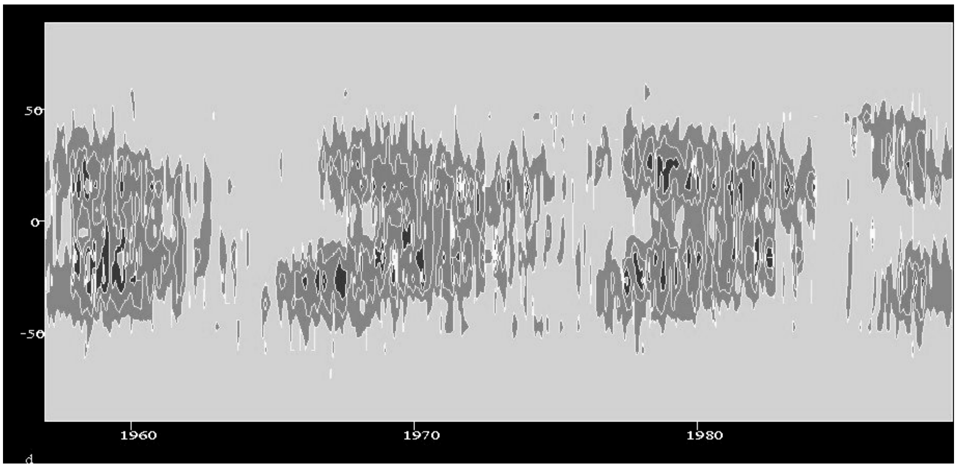


Fig. 1 – The filaments distribution during 1957–1989.

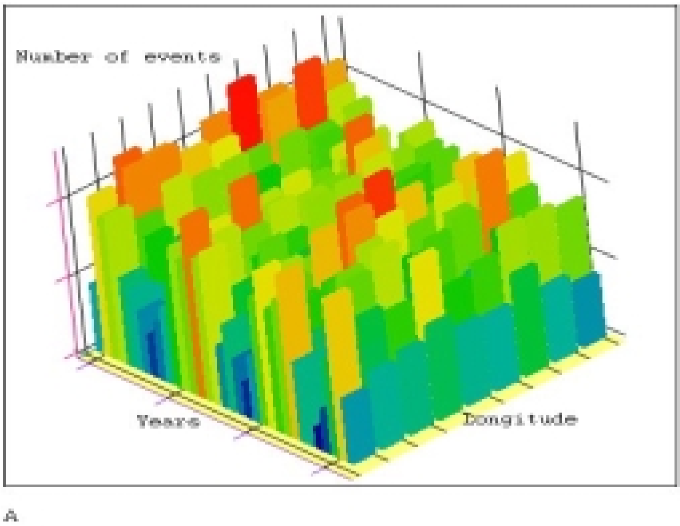


Fig. 2 – The active longitudes of filaments between three solar maxima (1957–1989).

The 40° longitude intervals of the filaments activity during 1957–1989 are plotted in Fig. 2. The active longitude intervals for each year, i.e. the intervals with maximum number of events recorded, are presented in Table 1.

Table 1

The active longitude intervals

Year	Interval (°)	Year	Interval (°)	Year	Interval (°)
1957	160–200	1968	160–200	1979	120–160
1958	200–240	1969	240–280	1980	120–160
1959	280–320	1970	000–040	1981	160–200
1960	080–120	1971	240–280	1982	160–200
1961	280–320	1972	000–040	1983	120–160
1962	280–320	1973	120–160	1984	280–320
1963	000–040	1974	160–200	1985	120–160
1964	120–160	1975	000–040	1986	080–120
1965	200–240	1976	120–160	1987	320–360
1966	120–160	1977	160–200	1988	040–080
1967	240–280	1978	040–080	1989	140–180

It can be seen that the active longitude intervals migrate during the solar cycle. Only very seldom they are stable two consecutive years, and this happens on the descending phase of the cycle.

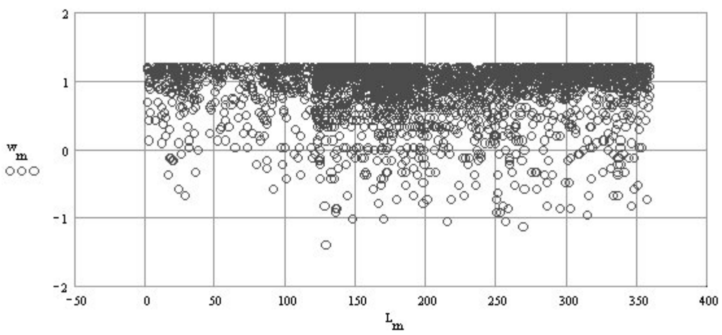


Fig. 3 –The differential rotation velocities for the filaments observed inside the active longitude intervals.

We have computed the values of the differential rotation velocities for the filaments recorded inside the active longitude intervals, using the law of d'Azambuja:

$$\omega(\phi) = 1.22 - 1.4\sin^2\phi - 1.33\sin^4\phi\,. \tag{1}$$

Are these values ranged in the proximity of zero or not? The plot of these values (Fig. 3) reveals that the active longitude filaments have a random distribution. Moreover, these filaments have no preference to appear at certain latitude, so they have no reason to have a rigid rotation. Therefore we think that the active longitude filaments do not belong to the category of objects representing singularities of the differential rotation velocity of the Sun.

3. THE FILAMENTS WITH PIVOT-POINTS

The existence of the pivot-point filaments is due to their rigid differential rotation velocity. They appear in the neighborhood of the latitude of $\pm 49^\circ$ in the case of d'Azambuja's law (Dumitrache 1997). Generally

$$\phi_{\mathrm{pivot-points}} \in V\{\,\phi \mid \omega(\phi) = 0\}\,, \tag{2}$$

where $V\{\,\phi \mid \omega(\phi) = 0\}$ represents the latitude intervals in the neighbourhood of the zeros of the ω law used in the computation (here $(\pm 49^\circ) \pm \varepsilon$).

Usually, only few filaments with pivot-point are recorded along a year. By applying the definition (2), we have detected all the filaments with a rotation velocity value of d'Azambuja's law obeying the condition $|\,\omega\,| < 0.02$.

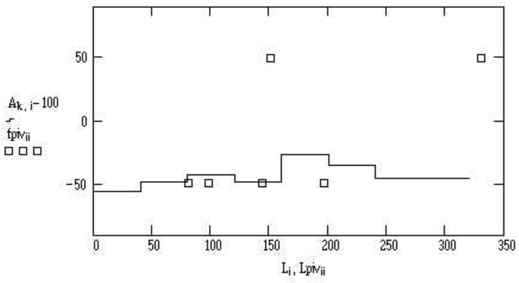
The distribution of these filaments was compared with the active longitude intervals detected in the previous section, for each year during the mentioned period. The question was whether the pivot-point filaments appear inside the active longitude intervals. We present in Fig. 4 some plots for different years in different phases of the solar cycle.

In the figure the boxes represent the pivot-point filaments location on the solar disk, whereas the continuous lines (steps) are the number of all filaments recorded inside each 40° interval.

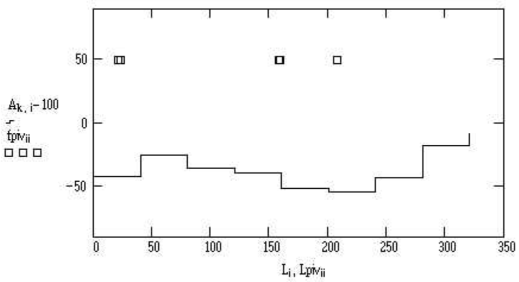
The notation we used in the figure is: T_k = year; $A_{k,i}$ = the active longitude intervals during the year T_k; $f_{piv,ii}$ = latitude of the pivot-point filaments observed in the year T_k; $L_{piv,ii}$ = Carrington longitude of the pivot-point filaments observed in the year T_k; L_i = the 40° Carrington longitude intervals.

The examination of the distribution of filaments with pivot-point on the solar disk reveals no preference for the active longitude intervals. In many cases we could observe that the filaments with rigid rotation have the tendency to appear in the longitude intervals with minimum activity, much more in zones with minimum clustering activity (considering the coordinates of the cells in latitude and longitude).

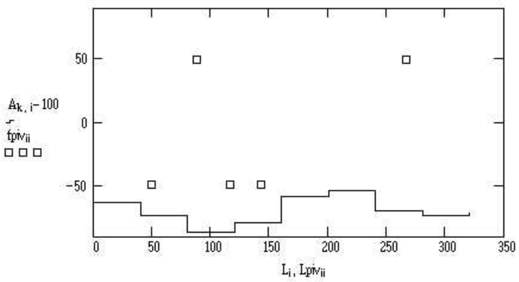
$T_k = 1.957 \times 10^3$



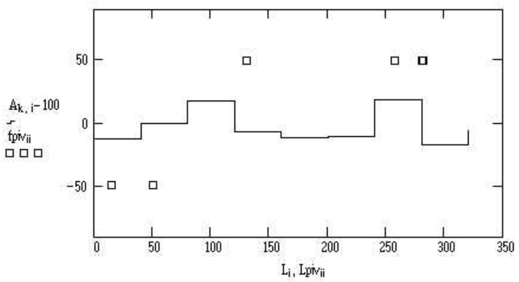
$T_k = 1.961 \times 10^3$



$T_k = 1.965 \times 10^3$



$T_k = 1.969 \times 10^3$



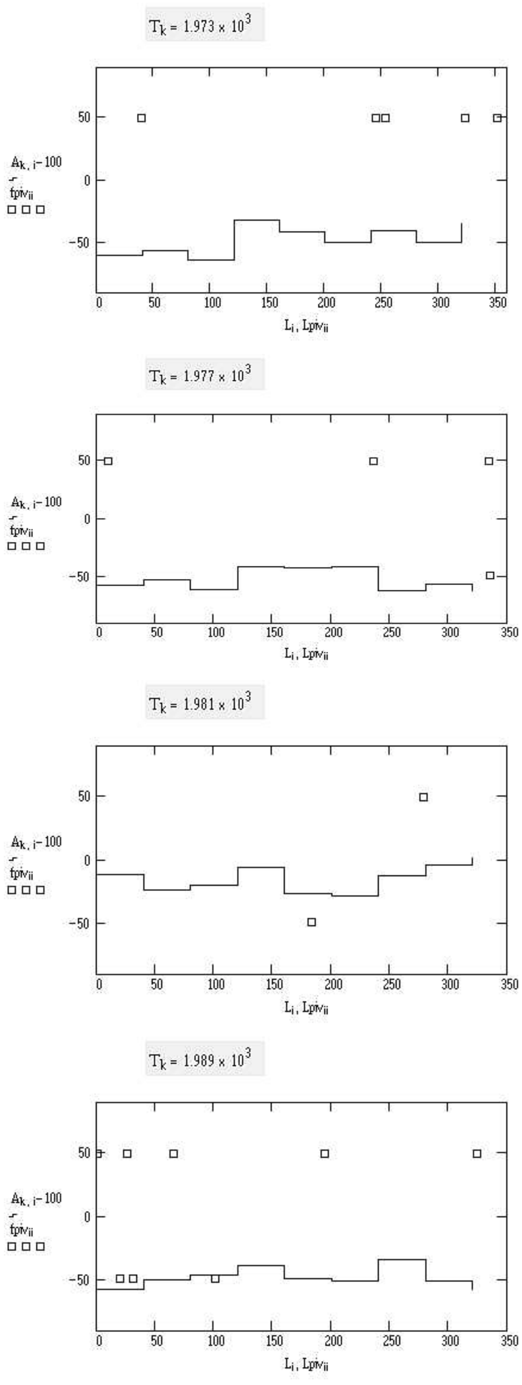


Fig. 4 – Active longitudes compared with the distribution of the pivot-point filaments.

4. DISCUSSION

We have analyzed the connection between the active longitude and pivot-points of filaments; we have detected the pivot-point filaments defined in Dumitrache's (1997) sense. In this sense we conclude that the singularities of the differential rotation of filaments are found very seldom in the region where the neutral line of magnetic field piles up.

Martres et al. (1986) have shown that the emergence of the magnetic flux in the form of parasitic polarity and flares appears in zones rotating with the Carrington velocity, whatever the latitude is. These regions are always signaled in the preceding rotation by a filament pointing in.

Any differential rotation law has certain latitude (symmetrically in North and South) where it takes values near the Carrington rotation velocity values. Dumitrache (2002), using the same sample of data as in the present study, has fitted the differential rotation laws of filaments for each year. The results reveal very well the torsional oscillations as in Fig. 5, where the curves of the fitted laws are oscillating around the curve of d'Azambuja's law, considered as standard.

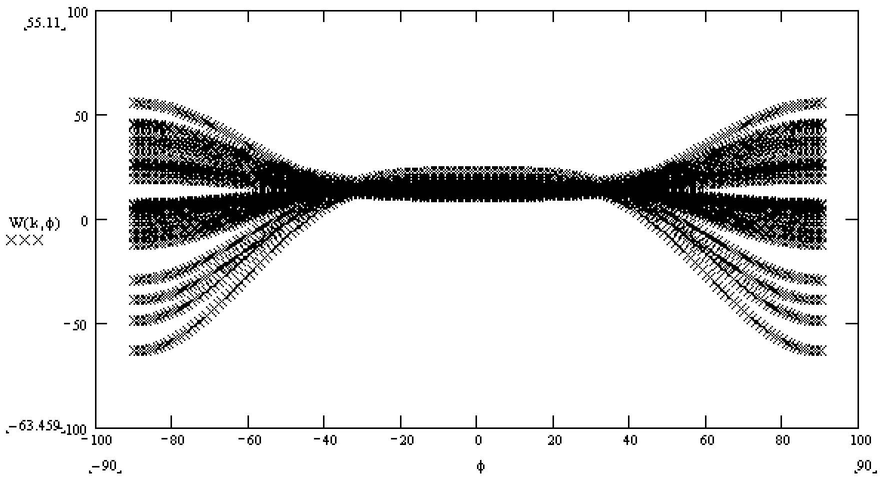


Fig. 5 – The differential rotation velocity oscillation during three solar cycles.

These kinds of laws have different zeros each other, so we could find filaments with pivot-points at different latitudes in different years. Using these laws, we have analyzed the distributions of the pivot-point filaments and the result has been the same: these filaments do not have preference for active longitude intervals, but ,contrarily, for zones with minimum clustering activity.

The active longitude intervals represent clusters of different events, on longitude, but the clusters are defined by both latitude and longitude. These clusters often contain the apparition of the same long-lived filament. The differential rotation law is dependent on latitude, but meridional flows superimpose on the proper motion of the region, too. Sheeley et al. (1987) and Wang et al. (1989) showed that a meridional component of the magnetic flux transport offsets the shearing effect of the differential rotation and gives rigidly rotating patterns of large scale magnetic field.

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