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Connection of sunspot's distribution with the torsional wave

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Abstract
The torsional oscillation is a well-known observational fact, but its cause is unidentified yet. There were some theoretical assumptions for its reason, but no final solution has been accepted. Our work focuses on the study of correspondence between torsional waves and the distribution of several sunspot features which were based on the DPD (Debrecen Photoheliographic Data). Two of studied features show some spatial correlation with the shearing zones.
Keywords: *Sun, Torsional wave, Sunspot features*

1 Introduction

The torsional oscillation was discovered by Howard & LaBonte in 1980. They have recognized that the deviation (about 7 m/sec) from the differential rotation profile gives the so-called torsional oscillation pattern. Two waves exist on both hemispheres of the Sun which start from the poles and tend to the equator. These prograde (faster) and retrograde (slower) zones transit toward to the equator during about 22 years together with the magnetic activity. This was the reason that several authors expected some relation between the magnetic fields and the torsional oscillation.

There are no convincing evidences about the origin of torsional oscillation but there are several assumptions. Firstly, Howard & LaBonte (1982) investigated whether the torsional wave generates the magnetic activity or conversely, the torsional wave is only an effect of the magnetic field of the activity cycle. In a recent model the presence of sunspots modify the turbulent viscosity in the convective zone which leads the modulation of the differential rotation (Petrovay & Forgács-Dajka 2002).

A question arises as to what is the depth of the torsional wave. It was determined from Doppler-measurements on the surface and from helioseismic observations (measurements of MDI and GONG) in the subsurface region (Howe et al., 2000, Zhao and Kosovichev, 2004). As a result it has been shown that the flows are detectable down to about 0.92 $R_\odot$.

We would like to find any spatial correlation between the torsional belts and any sunspot features. The solar latitudes have been divided into 1 degree stripes and the chosen parameters have been determined in each belt. The choice of the sunspot parameters to be studied is a matter of intuitive decision. Two choices may seem to be obvious: the total number and the area of the sunspots. The third parameter is somewhat more sophisticated, it also seems to be plausible that the complexity of the sunspot groups can also play a role in the interaction of the magnetic and velocity fields. This complexity was characterized by the third parameter: the mean number of spots within the groups of the given belt (number of all spots divided by the number of groups in the belt).

2 The method

2.1 The data

The data were taken from the Debrecen Photoheliographic Data (DPD) which is the most detailed sunspot catalogue. It contains data (area and position) for each sunspot group and for all observable (including even the smallest) sunspots on a daily basis. At the time of the present analysis the catalogue covered 10 years from 1986 until 1998 except of the years 1990-1992 (Győri et al. 1996 & Győri et al. 2004).

The sunspot features like the total and averaged number of sunspots as well as the total area of sunspots were added up for all stripes by three month periods. The total amount of considered sunspots is 8190 for the years 1986-1989 and 6443 for the period 1993-1998 as can be seen in the following table.

Table 1: *Sunspot's number*

year	total number of sunspots	consumed number of sunspots
1986	3060	398
1987	8592	1150
1988	26453	2840
1989	43012	3802
1993	16500	1823
1994	9057	1049
1995	6399	802
1996	2188	335
1997	5294	615
1998	17927	1819

To compare the obtained distribution with the torsional pattern one has to determine the latitudinal location of the torsional wave. For this purpose the most suitable data of the torsional wave were published by Ulrich (2001), see his Fig. 1, where the slow and fast belts as well as the shearing zones are well recognizable in this period.

2.2 Sunspot features

The first investigated candidate is the number of sunspots. All of the observed spots have been added up for three months in each 1° wide stripe. All groups were taken into account at the time of their largest extension. In this approach only the number of sunspots was considered with no regard to their size. All of the resulting distributions were plotted onto the simplified plot of the migrating zones, where grey/white stripes indicate the prograde/retrograde belts respectively.

The second targeted feature of the sunspots is their size. The method is the same as previously, the total area of sunspots has been added up for three month periods in all 1° wide latitudinal stripes and the obtained values were plotted onto the plot of migrating zones. The groups were considered at the moment when they had the largest extension during their passage through the solar disc.

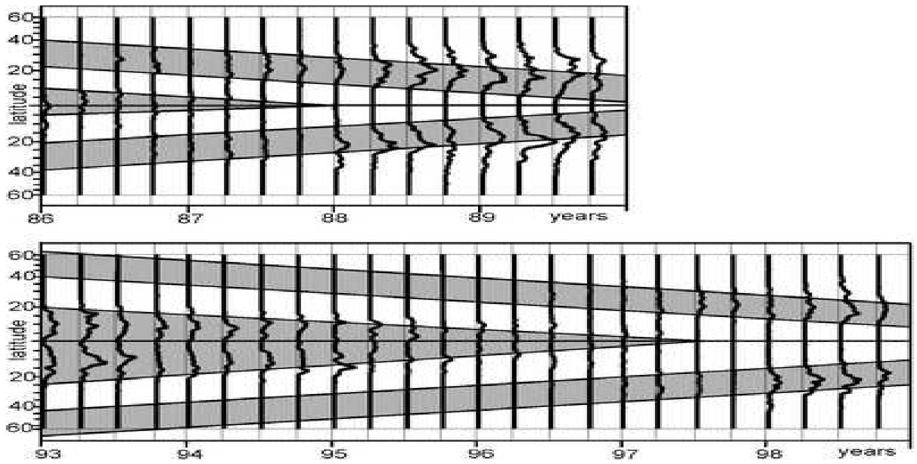

Figure 1: *Latitudinal distributions of the number of sunspots in comparison with the torsional belts.*

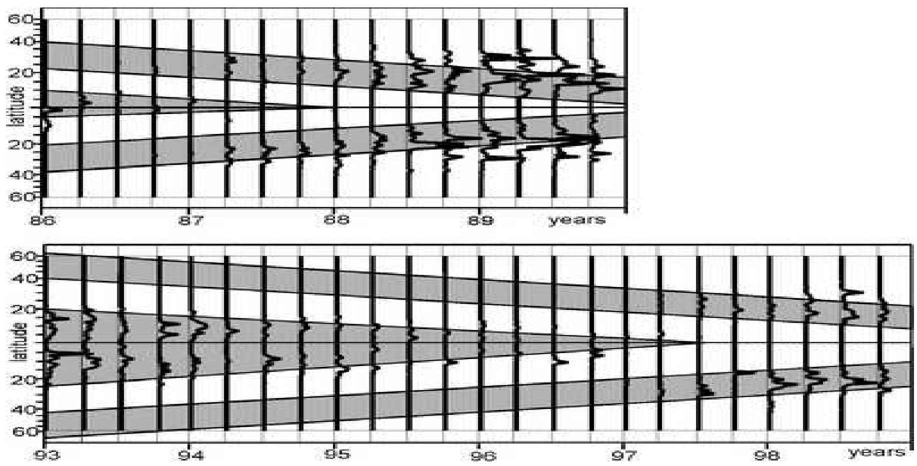

Figure 2: *Latitudinal distributions of the total area of sunspots in comparison with the torsional belts.*

The mean number of sunspots in the groups has also been studied. The procedure was the same as in the above cases but the total number of sunspots in a stripe was averaged by the number of sunspot groups belonging to the same stripe. This parameter may be a measure of the sunspot group complexity.

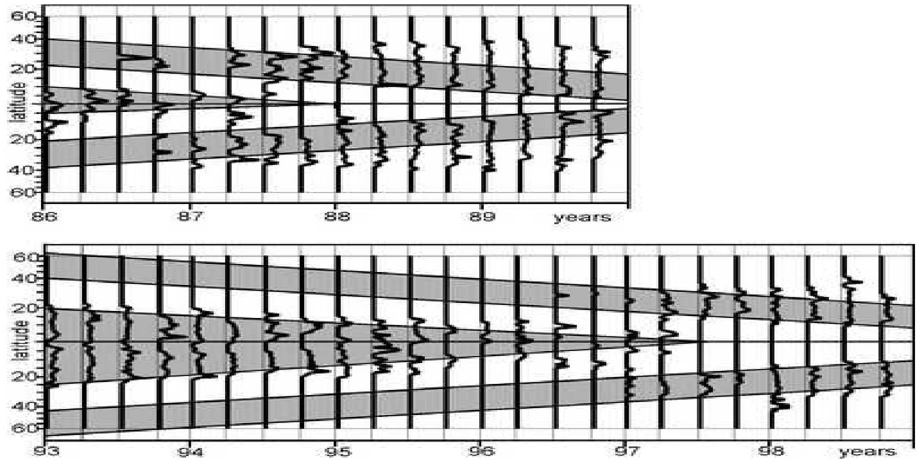

Figure 3: *Latitudinal distributions of the averaged number of sunspots in comparison with the torsional belts.*

3 Discussion

As can be seen in the above figures the total number and area of sunspots by stripes exhibit some spatial correlation with the torsional belts. It seems, that the bulges of the distributions coincide with the faster zones and their peaks are close to the poleward sides of the lower latitude borders of the faster zones. The complexity of the groups is apparently not remarkable from this view point, no trend can be recognized in the Figure 3 but the values of this parameter are also mostly situated in the faster belts.

These are preliminary results of this study, further details will be published elsewhere.

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