THE TWO COMPLEXES OF ACTIVITY OBSERVED IN THE NORTHERN SOLAR HEMISPHERE DURING 1982 AND THE 24-DAY PERIODICITY OF FLARE OCCURRENCE

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Abstract. Daily numbers of solar Hα flares of importance classes ≥ 1 for the northern solar hemisphere in 1982 are studied applying wavelet power spectra (WPS). Special attention is paid to the occurrence of a 24-day period in the WPS. The wavelet power spectra method is combined with synoptic maps of the magnetic fields. Separately, flare indices of two activity complexes mainly contributing to flare occurrence in this period are examined. It is found that the detected 24-day signal in the WPS is mainly a consequence of the presence of the two flare activity complexes separated by about 45° in longitude during several successive Carrington rotations.

Key words: Sun - flare occurrence - activity complexes

1. Introduction

Investigations on periodicities in the flare occurrence rate have been performed by Bai (1987) who found that the occurrence rate for hard X-ray flares during the the time span 1980 - 1985 is higher in active zones which rotate with a period of 26.75 days and that there is a hint of active centres rotating at a period of 23.7 days which was attributed to the possibility that active centres in deep layers rotate with such a period (all periods mentioned in this contribution are synodic). Temmer et al. (2004) using
wavelet power spectra calculated for daily numbers of northern/southern H-alpha flare events for the time span 1955 - 1997 found a 24-day period in certain time intervals in all four studied cycles (nos. 19 - 22). The 24-day period was observed also in the occurrence of subflares but it was more prominent when flares of importance classes \( \geq 1 \) were considered. They suggested that the 24-day period in the solar flare occurrence rate is rather related to a periodical emergence of magnetic flux than to the surface rotation of sunspots.

In this contribution we investigate periodicities in the flare occurrence rate during the year 1982 in the northern solar hemisphere with special regard to the previously reported 24-days period by the wavelet power spectra method combined with synoptic magnetic map data and separately investigating the flare activity of the individual active regions. This time span was chosen, as a rather simple situation was present in the northern hemisphere where two complexes of activity predominantly contributed to the production of flares.

2. Methods

2.1. Wavelet power spectra

Wavelet power spectra (WPS) are an appropriate tool to investigate the time of appearance as well as the temporal evolution of dominant periods in time series (Daubechies, 1990). By varying the value \( \omega \) (for details see Torrence and Compo, 1998) the resolution of the reconstructed wavelet spectrum either in time or in frequency can be varied. This enables to locate periods within exact time ranges. The wavelet analysis is carried out for a period range from 20 to 30 days in order to cover periods related to the solar differential rotation. As significance tests, confidence levels at 90\%, 95\%, and 99\% are calculated using a red noise background spectrum. Regions where edge effects become important due to dealing with finite-length time series, such as the beginning and the end of the wavelet spectrum, are labeled as cone of influence (COI). The computation of the wavelet parameters is performed in the way as described by Torrence and Compo (1998).
2.2. Synoptic magnetic maps

To get an insight into the relation of the detected periods with the magnetic field evolution we shall combine the obtained statistical results from wavelet power spectra with synoptic magnetic maps measured at the National Solar Observatory/Kitt Peak. The maps are derived from daily full-disk photospheric magnetograms of the Sun and each of the maps represents one Carrington rotation (CR), i.e. 27.2753 days (see e.g., Harvey et al., 1980; Gaizauskas et al., 1983; Worden and Harvey, 2000). The maps are used to construct vertical time series (stack plots) of the magnetic fields. The line-of-sight component of the magnetic field is represented with light and dark colors for positive and negative polarity, respectively. Longitude increases from left to right and time increases upward. Note that vertical features observed in successive Carrington Rotations ('||') have rotation rates close to the CR rate, i.e. ~27.3 days, whereas sloped bands inclined to the left ('\') or to the right ('/') reveal periods that are longer or shorter than the CR rate, respectively.

3. Results

3.1. Wavelet power spectra and synoptic maps

The wavelet power spectra calculated for daily numbers of H-alpha flares with importance class ≥ 1 observed during solar cycle 21 from March 1982 to February 1983 covering the Carrington rotation numbers 1720 - 1732 are presented in Figure 1. Here the values \( \omega = 48 \) to obtain a high frequency resolution as well as \( \omega = 6 \) to obtain a high temporal resolution have been chosen. The high frequency resolution WPS in Figure 1 (top left panel) shows a broad range of periods from about 23.5 to 28.7 days. Here, we shall not concentrate on periods related to the solar differential rotation, but only on periods of about 24 days.

As can be seen from the high-time resolution WPS presented in Figure 1 (top right panel) calculated with \( \omega = 6 \) for the same time span a 24-day period appears during CR 1723 to CR 1726.

In the bottom of Figure 1 the stack plots for the northern hemisphere latitude strips between 0° and 40° constructed from the synoptic magnetic maps for the time range March to September 1982 (CR 1720 - 1726)
Figure 1: Top: WPS derived for major flares in the northern hemisphere during CRs 1720 - 1732 with $\omega = 48$ (left) and $\omega = 6$ (right). White contours from thin to thick denote confidence levels at 90%, 95% and 99%. Crosshatched lines mark the COI. The bars indicate the time range when strong power occurs in the WPS. Horizontal solid and dashed lines are drawn for periods of 23.8 ± 0.5 days, respectively. Bottom: Stripes of synoptic maps for CRs 1720 - 1726. White arrows denote the separation between the two flare productive ACs in successive Carrington rotations which correspond to a quasi period of about 24 days.
are presented. One can identify two activity complexes (AC) separated by about 45° in longitude: the first one located at the Carrington longitude of about L 320° present in CRs 1720 to 1726 and the second one located at L of about 280° and present during CRs 1723 to 1725. The main flare activity in the northern hemisphere in the considered time period occured in these two complexes. We can illustrate the outcome of such a situation on the expected signal in the WPS by the example schematically drawn in Figure 2. A period of 27.3 days is obtained if the flare activity feature A is tracked from CR 1723 to CR 1724 at L=280°. However, if the feature A from CR 1723 at L=280° is tracked to the feature B at L=320° in CR 1724, then a much shorter period in the range of 24 days is obtained. Such a situation indeed occurs in the synoptic maps presented in Figure 1 during CRs 1723 to 1726 showing activity complexes which are shifted by 40° - 50° in longitude in two successive CRs giving rise to the signal of about 24 days in the WPS. We have to stress that here we are connecting different flare active features in successive rotations and that the 24-day period is not the rotational period of a single feature (for more examples see also Temmer et al., 2005).

3.2. Flare activity of the two activity complexes

We shall now investigate in more detail the mentioned two complexes of activity observed in the northern hemisphere during 1982. The complex of activity located at the Carrington longitude L of about and 310° in CR 1720 surviving 7 rotations (corresponding to the AC-B in Figure 2) had the properties of a nest of activity according to the definition given
by Becker (1955) who investigated the clustering of sunspot appearance. Becker supposed that that the observed concentration of sunspot activity is connected to a long lived nest of activity (Fleckenerherd) located in the deeper layers from which sunspot groups repeatedly rise to the photosphere. By his definition a nest of activity has a lifetime of at least 6 rotations. He investigated the data from Greenwich Photoheliographic Results for the cycles 12 to 17, i.e. the period 1879 to 1941, and established the existence of 46 nests (on the average 8 nests per cycle). The total area covered by a nest corresponded to the area covered by a medium or large spot group. The nests show no systematic preferred latitudinal or longitudinal ranges in either hemisphere and follow a differential rotational law, however they rotate 2° - 3° faster than sunspots per rotation.

Data on the two complexes of activity observed in the northern hemisphere during 1982 are given in Table I.

**Table I:** Data on the two complexes of activity.

<table>
<thead>
<tr>
<th>CR</th>
<th>Hale number</th>
<th>NOAA number</th>
<th>Distribution of spots</th>
</tr>
</thead>
<tbody>
<tr>
<td>1720</td>
<td>18280</td>
<td>3659</td>
<td>N 8° - 14° L 305° - 315°</td>
</tr>
<tr>
<td>1721</td>
<td>18330/332/319</td>
<td>3703</td>
<td>N 10° - 19° L 310° - 320°</td>
</tr>
<tr>
<td>1722</td>
<td>18382/383</td>
<td>3740</td>
<td>N 13° - 23° L 300° - 315°</td>
</tr>
<tr>
<td>1723</td>
<td>18422</td>
<td>3776</td>
<td>N 10° - 16° L 305° - 320°</td>
</tr>
<tr>
<td>1724</td>
<td>18474</td>
<td>3804/14</td>
<td>N 10° - 21° L 310° - 330°</td>
</tr>
<tr>
<td>1725</td>
<td>18511</td>
<td>3837/39</td>
<td>N 8° - 18° L 320° - 350°</td>
</tr>
<tr>
<td>1726</td>
<td>*</td>
<td>3886</td>
<td>N 10° - 16° L 325° - 345°</td>
</tr>
</tbody>
</table>

* (Hale active region numbers ceased to be published in SGD from September 1982)

During its first, fourth and fifth rotation the AC-B appears in the list of superactive regions which produce five or more flares with HXRBS peak rates above 1000 counts per second studied by Bai (1987).

The average time interval of successive CMP disc passages of this AC was 27.0 days. The same rotation rate was found for large scale magnetic polarity patterns by Bumba and Howard (1969).
The other activity complex (corresponding to AC-A in Figure 2) located at L of about 280° in CR 1723 and present from June to August 1982 was classified by Bai (1987) as superactive region during its first disc passage.

To get further insight in the detected period of 24 days in the WPS from another point of view, we investigated the flare occurrence of the two ACs using the flare index F being the product of the modified flare importance I and the duration D of the respective flare in minutes (Křivský, 1977):

\[ F = I \cdot D \]

(1)

where the modified flare importance I is 0.5 for the Imp classes sf, sn; 1 for sb, 1f, 1n; 1.5 for 1b; 2 for 2f, 2n; 2.5 for 2b; 3 for 3f, 3n; 3.5 for 3b

The histograms of the daily flare indices of the studied ACs in the time interval March to September 1982 embracing Carrington rotations 1720 to 1726 are shown in Figure 3. The CMP times are denoted by broken lines and 24 days time spans are indicated. The nest of activity (AC-B) shows a periodical pattern of flare activity with a period P ≤ 27 days. A similar behaviour is exhibited by the other activity complex A. One can see that the combined flare occurrences in June, July and August of the two complexes of activity can lead to a 24-day signal in the WPS. The flares occuring in the AC-A in June (CR 1723) can give rise to a 24-days signal in the WPS when combined with the flares occuring in AC-B in July (CR 1724). Again
the flares occuring in the AC-A in July combined with the flares occuring in AC-B in August (CR 1725) can give rise to a 24-day period in the WPS. However, we have to stress (see Figure 3) that a significant contribution to the 24-day signal in the WPS is provided by the continuing flare activity of the AC-B in CR 1724 till July 22 when it disappeared behind the west limb. Also we have to note that in constructing the flare index also subflares are included, while in the WPS only flares with importance class ≥ 1 have been considered. Temmer et al. (2004) constructed WPS also for subflares for the activity cycles 19 - 22 and found also simultaneous, but less pronounced 24-days periods as for the major flares.

4. Discussion and Conclusions

From the synoptic maps it is seen that the 24-day period observed in the occurrence of high-energetic Hα flares can be explained by their spatial distribution. Flare productive complexes of activity separated by about +40° to +50° in longitude within successive rotations correspond to periods shorter than the Carrington rotation rate by −3.0 to −3.8 days, i.e. to signals from 23.5 to 24.3 days. This can be interpreted in terms of a rotational period only in cases where such a longitudinal shift between successive rotations is observed for the same feature.

It is known that active regions are not randomly distributed but within clustered regions (Bumba and Howard, 1965). These so called complexes of activity (clusters, nests) typically evolve within one month and can be sustained due to fresh emergence of magnetic flux for about 3 - 6 months (Gaizauskas and Harvey, 1983). Especially, parallel, converging, or diverging nests exhibit enhanced flare productivity (Pojoga and Cudink, 2002). These spatial separations are supposed to be related to typical size scales like giant convective cells (Bumba and Howard, 1965) with typical diameters ≥ 90 000 km (corresponding to \( L \geq 47° \)). Such situations might be present in the other cases with detected 24-days periods in the occurrence of major flares during the activity cycles 19 - 22 (Temmer et al., 2005).

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References

V. RUŽDJAK ET AL.: 24-DAY PERIOD OF FLARE OCCURRENCE

DVA AKTIVNA PODRUČJA OPAŽANA TIJEKOM 1982. NA SJEVERNOJ SUNČEVOJ POLUTCI I 24-DNEVNA PERIODIČNOST POJAVE BLJESKOVA

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Izlaganje sa znanstvenog skupa

Sažetak. Metodom WPS se istražuju dnevni brojevi Sunčevih bljeskova klasa važnosti $\geq 1$ na sjevernoj Sunčevoj polutci tijekom 1982. g. Posebna se pažnja posvećuje pojavi 24-dnevnoj periodi. WPS metoda se nadopunjuje uporabom sipotičkih karti magnetskih polja. Zasebno se istražuju indeksi bljeskova za dva aktivna područja u kojima se opaža najviše bljeskova u navedenom razdoblju. Ustanovljeno je da je detektiran 24-dnevni signal u WPS-u uglavnom posljedica aktivnosti u navedana dva područja koja su međusobno udaljena za oko 45° u longitudi tijekom nekoliko uzastopnih Carringtonovih rotacija.

Ključne riječi: Sunce - učestalost bljeskova - aktivna područja