THE INTERMITTENCY OF THE SOLAR INTERMEDIATE–TERM PERIODICITY (1969 – 1998)

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ABSTRACT

Wavelet transform has been used for the time–frequency decomposition of solar data series through the last three solar cycles (the 20-th, the 21-st and the 22-nd), on daily basis, for the following parameters: the non-flare full-disk soft X–ray background (XBG), the daily solar LDE–type flare index (LDE) and the daily impulsive–type flare index (IMP). From the wavelet analysis we can distinguish the existence of discrete impulses of the intermediate–term periodicities (IP) during the 1969–1998 year interval. The impulses were determined in the following years: 1981.0, 1982.7, 1990.0, 1991.6 . It is very likely, that obtained impulsive episodes indicate those time intervals, in which the continuing eruption of the new solar magnetic flux existed.

1. INTRODUCTION

The structure of the 11–year cycle depends on intermediate–term variations of the Sun. Our knowledge of intermediate–term periodicities (IPs) is mainly based on the analysis of sunspot data (see references reported by Antalová, 1999). The existence of the continuous IPs were theoretically predicted from the oscillation–convection model of the Sun (Wolff, 1974, 1983, 1992). From the IPs, two of them are dominant: the 155– and 323–days (Lean and Brueckner, 1989; Cane, Richardson and von Rosenvinge, 1998). SOHO/MDI and GONG helioseismic data (Komm, Howe and Hill, 2000) reveals other very important period around 1.3 year (about 474 days), which they located at the bottom of the convective zone of the Sun. Going to intermittency, we note, that Ballester, Oliver and Baudin (1999) stated the disappearance of 150–day sunspot periodicity during the minima of all modern 11–year solar cycles (No.1 – No.22). During the maxima of the 21–st and the 22–nd solar cycles, Antalová (1999), from Fourier analysis, displayed the different amplitudes in the occurrence of IPs in the solar soft X–ray data. The intermittent character of 150–day periodicity during the maximum of the 21–st cycle was presented in cosmic rays by Bazilevskaya et al. (1998), Kudela et al. (1999). Bouwer (1992) for full–disk soft X–ray background (XBG), from the analysis of August 1975 – October 1986 interval found that 150–day periodicity had two maxima: the 1–st in August 1980 and the 2–nd in September 1982.

The aim of this paper is to investigate the intermittency of the intermediate–term periodicities during 1969–1998 years, on the basis of the solar soft X–ray data. From prior papers we know, that IPs are related to the solar cycle maximum. Data sets available allow us to study *in detail* temporal variations of the occurrence IPs during solar cycle maximum. The question arises if IPs are preferred in certain part of solar cycle maximum. The data sets are given in Section 2. Wavelet transform used for the time–frequency decomposition of the studied solar SXR data series is given in Section 3. Main results are summarized in Section 4.

2. THE DATA SETS

The temporal profiles of our data are shown in Figure 1. The analysis was performed on the following SXR parameters:
(a) the non-flare full-disk soft X–ray background – **XBG**, from the 1–8 Å GOES measurements, as published in *Solar Geophysical Data*. XBG here analyzed is given in units of $10^{-8} W m^{-2}$. The detailed description of construction of homogeneous XBG data sequence is given in Jakimiec, Antalová and Storini (2000) and references therein.
(b) the LDE–type flare index – **LDE**, computed from the 5-minute averages of GOES–flux, from all long lasting (LDE–type) GOES soft X–ray flares, with duration exceeding 2 hours above the quiet SXR GOES level by weighting the SXR flare-classes (in units of 10^{-6} W/m^2). The daily flare indices (FI–LDE) were investigated by Landi and Storini (1997) as well as Landi et al. (1998) in connection with the occurrence of non-recurrent geomagnetic storms, as proxy data of the coronal activity of the Sun, in years 1969–1974.
(c) the impulsive flare index – **IMP**, which is computed by us, in the same way as LDE index, for the flares which duration in SXR is shorter than 2 hours.

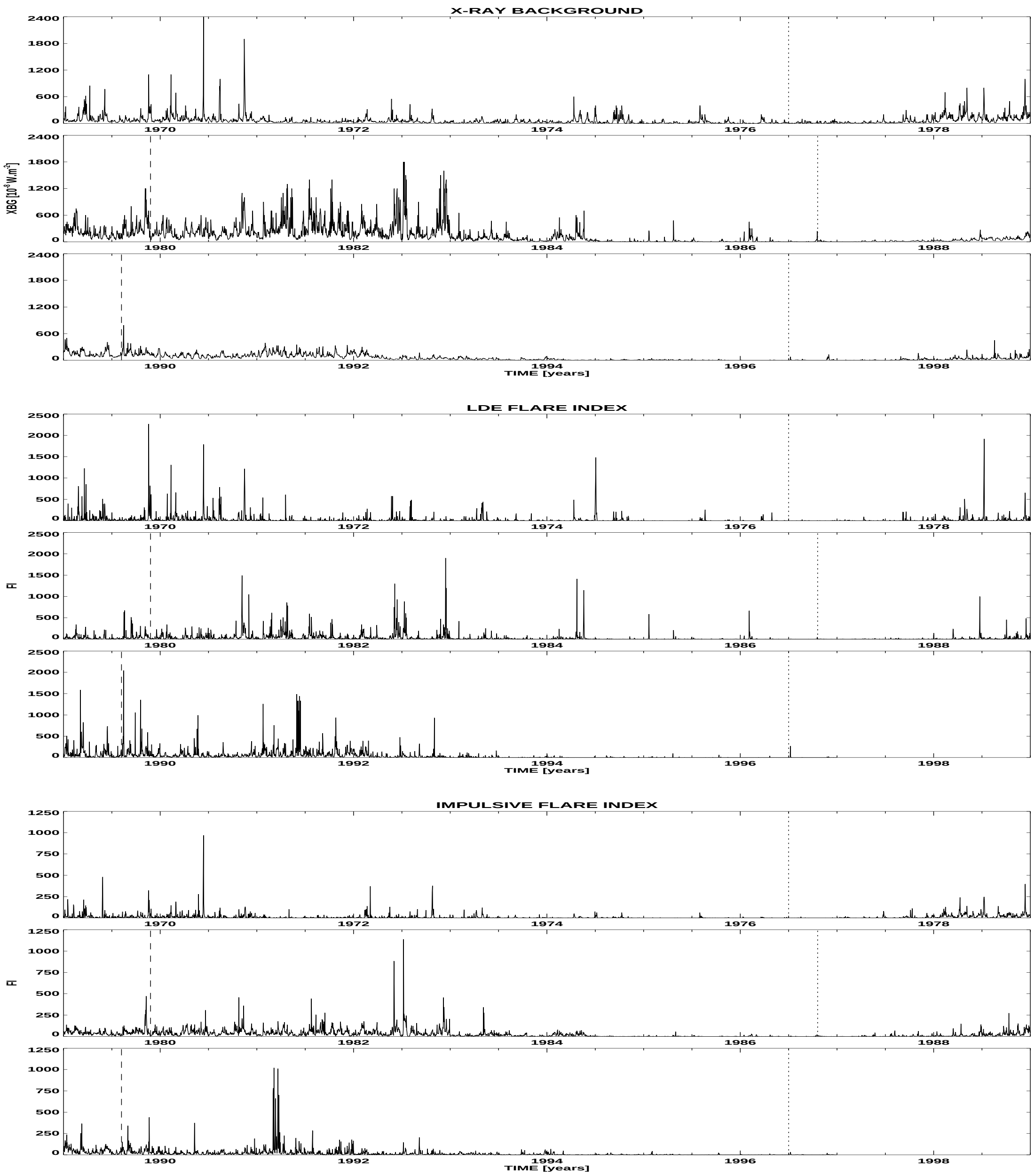

Figure 1. Time series of the daily values of XBG (the upper panel), LDE–type flare index (the middle panel) and IMP flare index of impulsive flares (the bottom panel). The solar activity cycle maxima and minima are signed by dashed and dotted vertical lines respectively.

3. METHOD OF PROCESSING

The wavelet transform (WT) – suitable tool for the analysis of the non-stationary time series (e.g., Daubechies, 1990, Kumar and Foufoula-Georgiou, 1997) was used in this study. The Morlet wavelet – a plane sine wave of amplitude windowed in time by a Gaussian function – has been selected to search for power at different frequencies over the whole length of the series.

The WT computational algorithm of Torrence and Compo (1998) with a convenient set of scales in the period range 16 – 1024 days and the scale resolution 48 scales per octave was used for calculation of the WT power spectra (WPS). The global wavelet spectrum (Torrence and Compo, 1998) has estimated the background mean power spectrum against which the significance of the local wavelet power spectrum features has been tested.

4. RESULTS AND CONCLUSIONS

Intermediate–term periods found in the wavelet global power spectrum analysis are given in Table 1. The WPS of XBG, LDE and IMP flare indices are illustrated in Figure 2. The carried out wavelet power spectrum analysis has shown the following results and conclusions:

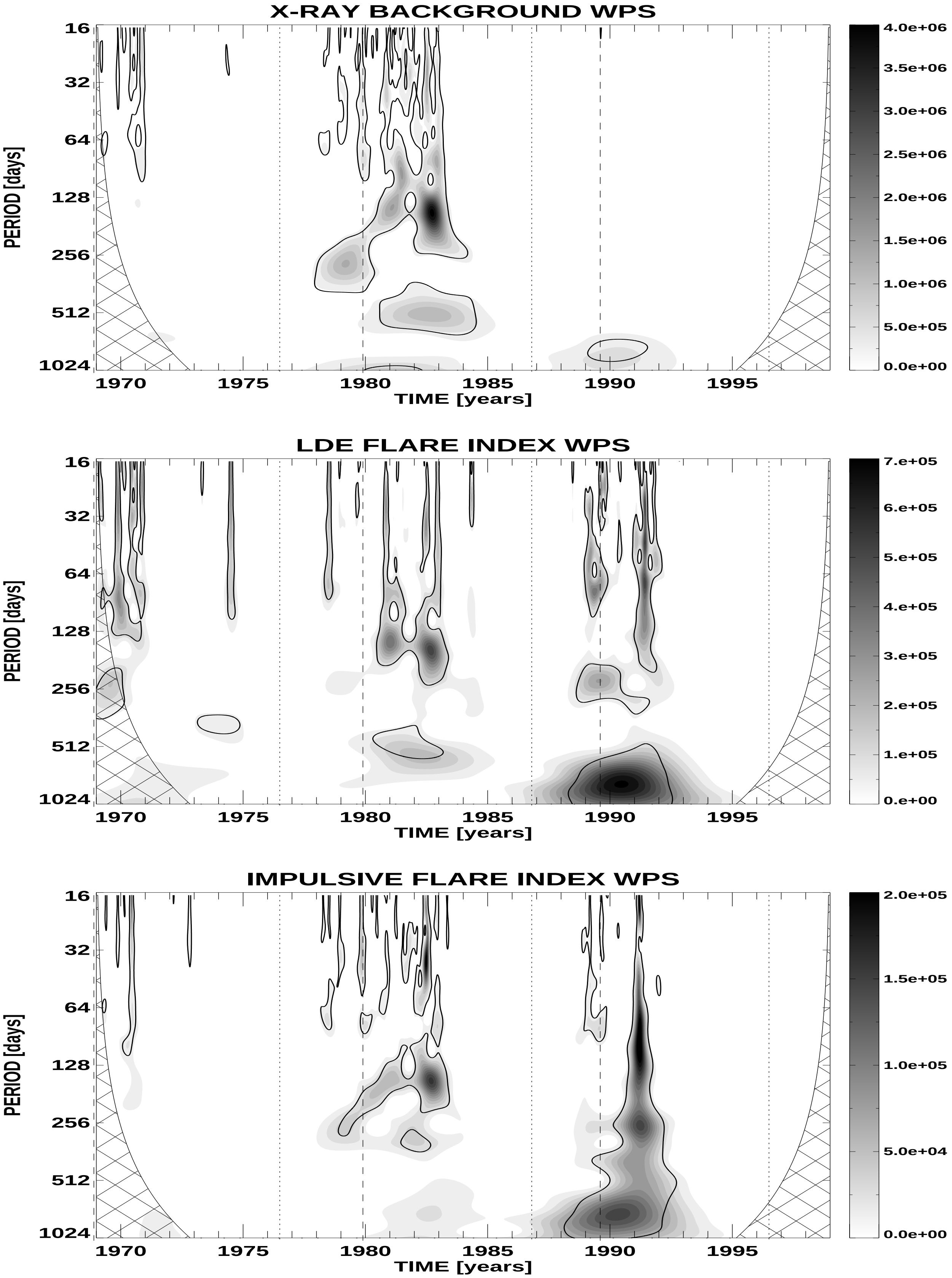

Figure 2. The wavelet power spectra (WPS) of the XGB, LDE and IMP flare index data series. The time spacing parameter of the series is 1 day, the scale resolution is 48 scales per octave. The thick solid curve stem for the 95% confidence level of the spectrum. The coin of incidence is marked by the cross-hatched regions. The solar activity cycle maxima and minima are signed by dashed and dotted vertical lines respectively according to the Wolf's sunspot index.

Table 1. The wavelet global power spectrum analysis of soft X-ray parameters. Periods are given in days. In head–line are given expected periods, from the 27–day synodic recurrence as well as from Wolff's g–beats (Wolff, 1974). Our results from wavelet global power spectrum are given in the three soft X–ray parameter rows. LT–stay for Long Term periods.

IP(days)	27-	80-	155-	270-	323-	LT-
SXR :						
XBG	28	83	155		301	568
LDE	31	80	146	223		850
IMP	38	83	157	268		810

The gap in WPS during the maximum epoch of the last two cycles: The wavelet power spectra of all three SXR parameters display the gaps in the occurrence of IPs during the maximum epoch of the last two solar cycles. We obtained dual peaks, the first peak in the pre-maximum and the second peak in the post-maximum years. As is shown in WPS, the second peak is much stronger, comparing to the first one of the same cycle. This result is consistent with Bazilevskaya et al. (1998) and Kudela et al. (1999) statements.
The dual–peak in the 22-nd solar cycle: In the WPS of solar soft X-ray parameters there is a valley during the maximum of the 22–nd solar cycle, which is similar to structures presented by Feminella and Storini (1997) as well as Massetti and Storini (1998). The valley is called **the Gnevyshev gap** by the Rome Cosmic Ray Group (e.g. Storini and Pase, 1995). The dual–peak maximum of the 11-year solar activity cycle (Gnevyshev, 1977 and references therein) is well indicated, when intense coronal and/or long-lasting activity events are considered.
Relationship between solar activity and the heliomagnetic field: As was shown by Ataç and Özgüç (1998) the first 1989 peak was higher than the second one (1991) for all solar parameters, which they analyzed. One of the most remarkable differences is, that total magnetic flux had the stronger 1991 peak than 1989 one (Mendoza et al., 1999 and Storini et al., 1999). Bao and Zhang (1998) obtained in the magnetic helicity the same temporal profiles (the first peak in 1989 is smaller than the second peak in 1991 year). Our WPS result of the stronger occurrence of IP periodicities in 1991 comparing to 1989 year coincides very well with the magnetic field behaviour. This similarity in temporal evolution gives a promising chain to understand the origin of the Gnevyshev gap and its role in the solar activity cycle.

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