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ROTATIONAL MODULATION OF NORTHERN AND SOUTHERN ACTIVITY TRACERS

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Abstract. We study solar activity phenomena, Hα flares and sunspots, with respect to their periodical occurrence related to the solar rotation. The analysis is carried out separately for the northern and the southern hemisphere. Furthermore, flare occurrences are studied with respect to different importance classes, and the results are compared to the predominant periods derived from Sunspot Numbers. Significant asymmetries are obtained between the northern and southern activity for both Sunspot Numbers and flare occurrences. Differences between Sunspot Numbers and flares result particularly when only higher energetic flares are considered. A 24-day period is found for large flare events in both hemispheres which is not detected in Sunspot Numbers.

Key words: solar flares, energy release, solar cycle

1. Introduction

The appearance of sunspots on the solar disk is not uniform with respect to the solar equator resulting in significant north-south (N-S) asymmetries (see, e.g., White and Trotter, 1977; Carbonell, Oliver

Hα importance	no. Hα_{north}	no. Hα_{south}
S, 1, 2, 3, 4	49 024	51 345
1, 2, 3, 4	5 257	5 471
2, 3, 4	646	643

Table I: Definition of groups of Hα flares together with the number of events for the time span 1975–2001, separately for the northern and the southern hemisphere.

and Ballester, 1993; Temmer, Veronig and Hanslmeier, 2002, and references therein). In the same way solar flares reveal a N-S asymmetry (e.g., Bai, 1987; Garcia, 1990; Li, Schmieder and Li, 1998; Temmer et al., 2001, and references therein). Besides the asymmetrical occurrence of these activity phenomena on the solar disk also the rotational periods are subject to a N-S asymmetry. These asymmetrical behaviors have been also observed in the photospheric magnetic field (see Antonucci, Hoeksema and Scherrer, 1990; Henney and Harvey, 2002).

In the present paper we investigate Hα flare occurrences and Sunspot Numbers with respect to dominant periods related to the differential rotation together with their localization in time. The southern and northern hemisphere are considered separately. Furthermore, the dependence of predominant periods on the flare importance is studied.

2. Data and Methods

Time series of daily numbers of Hα flares are constructed using the Hα flare data reported in the Solar Geophysical Data. Daily hemispheric Sunspot Numbers for the time span 1975–2000 are taken from the "Catalogue of hemispheric Sunspot Numbers" online available under: *www.uni-graz.at/igam5www/daily_RnRs/* (for a detailed description see Temmer, Veronig and Hanslmeier, 2002) as well as from the Sunspot Index Data Center for the year 2001. The Hα flares are subdivided into three groups based on their importance class, i.e. all flares, flares of importance ≥ 1, and flares of importance ≥ 2 (see Table **I**). We applied periodograms (Lomb, 1976; Scargle, 1982; Horne

and Baliunas, 1986) for the determination of dominant periods, and wavelet analysis (Torrence and Compo, 1998) in order to study where the periodical occurrences are localized in time.

Both the periodogram and the wavelet analysis are carried out for a period range from 20–40 days[1] in order to cover periods related to the solar differential rotation. The significance of a peak in the periodogram is estimated via a false-alarm probability, FAP (for details see Scargle, 1982; Horne and Baliunas, 1986). For the wavelet power spectra presented in this paper, a confidence level at 99% is applied as significance test. The computation of all the wavelet parameters is performed in the way as described by Torrence and Compo (1998).

3. Results

Fig. 1 shows the periodograms derived from daily Sunspot Numbers and daily Hα flares subdivided into three different groups regarding their importance class, separately for the northern and the southern hemisphere. Considering all flares, i.e. importance $\geq$ S, significant periodical occurrences of $\sim$27 days for the northern hemisphere and of $\sim$28 days for the southern hemisphere are obtained. These results are in very good agreement to those revealed for Sunspot Numbers. By waiving the low-energetic subflares, some different periods are obtained. For the southern hemisphere flares of importance $\geq$ 1 show their most prominent peak at $\sim$24 days which is well defined above the 1% FAP level. Similar, but at a higher FAP level of $\sim$50%, for the northern hemisphere flare events of importance $\geq$ 2 show a $\sim$24-day period, too. However, this period is not found in Sunspot Numbers. The well defined signal of periodical occurrences for the northern/southern hemisphere at $\sim$27/$\sim$28 days is successively attenuated considering only higher energetic flares.

In Fig. 2 the wavelet analysis of the total number of Hα flare events, i.e. importance $\geq$ S, is presented. As it can be seen, the temporal localization of dominant periods given with 99% significance are found to be clearly different for both hemispheres. In general, for the northern

[1]All periods stated in this paper are synodic.

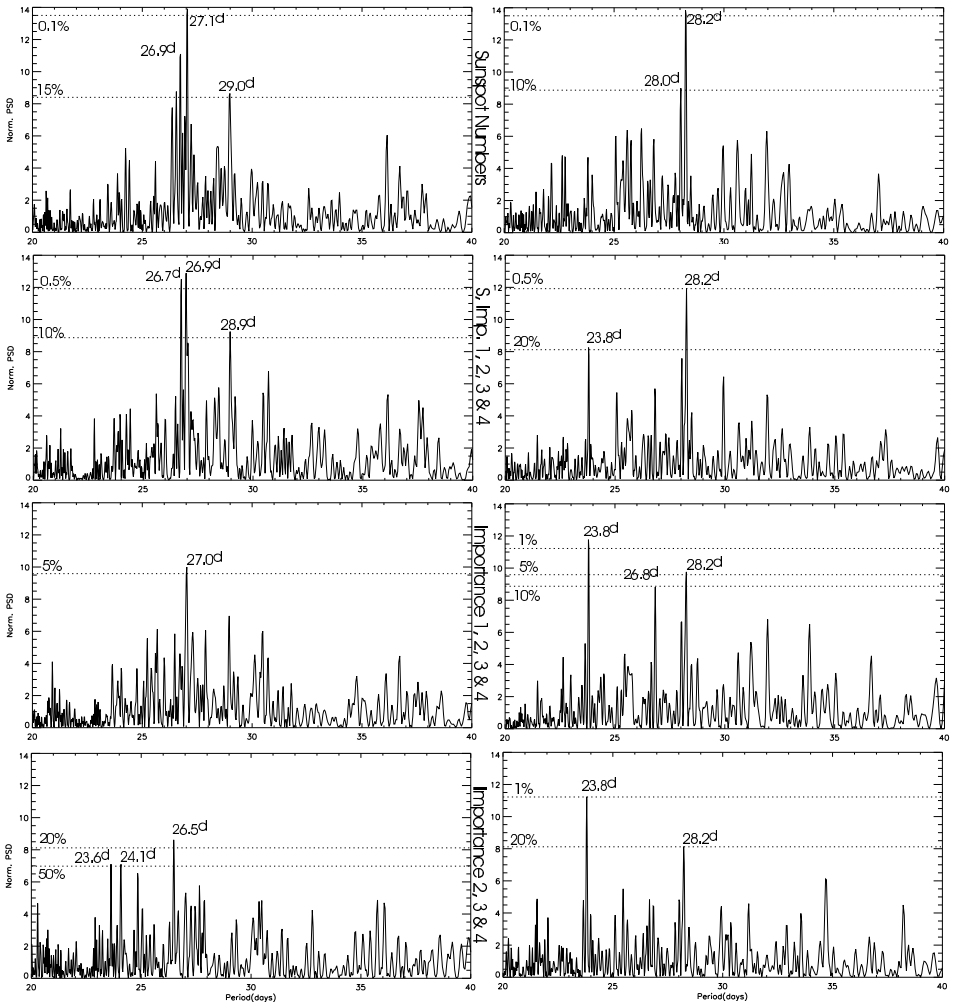

Figure 1: Normalized power spectral density (PSD) for (top to bottom) Sunspot Numbers, total number of Hα flares, Hα flares of importance ≥ 1, and flares of importance ≥ 2. Left panels refer to the northern, right panels to the southern hemisphere. Dashed lines indicate the FAP level of the peaks in the periodograms.

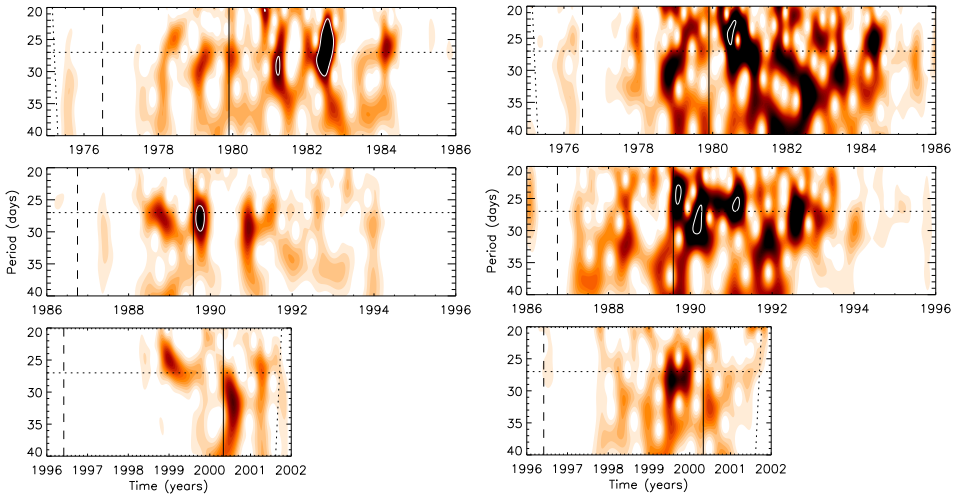

Figure 2: Wavelet power spectra derived from the northern (left panels) and southern (right panels) Hα flare events. Grey-scale coding from white to black represents the square root of power in a linear scale. Dashed and solid vertical lines indicate the solar cycle minima and maxima. White contour lines show the 99% confidence level. *Intercalibration* was not used between the power scales in the plots of the right and the left panel.

hemisphere a higher power is obtained than for the southern (ratio of $\sim$17:10) which is focused around narrow time ranges showing periods near 27 days. For the southern hemisphere a rather diffuse "periodical picture" is shown with broad time ranges of enhanced power enclosing significant periods in the range from $\sim$23–30 days. Significant power in the range of 24 days is revealed for solar cycle 21 about one year after and for cycle 22 shortly after the cycle maximum. A distinct 28-day period for the southern hemisphere is only seen during cycle 22 about one year after the maximum phase. The power localization of major flares (figure not shown), i.e. importance classes ≥ 1, is for both hemispheres increasingly focused on the late declining phase considering cycle 21 and around the maximum phase for cycle 22. In the southern hemisphere, a 24-day period is mainly revealed during the maximum and the declining phase of solar cycle 22. The northern hemisphere shows a broad period range of enhanced power including a 24-day pe-

riod in the declining phase of cycle 21 and during the maximum phase of cycle 22.

4. Discussion and Conclusions

The results of periodical occurrences in the range of ∼27/∼28 days obtained for the northern/southern Hα flares are in good agreement with those of the northern/southern Sunspot Numbers (see also Temmer et al., 2002). The same periods have been found in the photospheric magnetic field, suggesting a strong coupling of these phenomena.

Deviations from these periods are revealed considering only higher-energetic flare events, i.e. waiving subflares, which comprise ∼90% of all flare events (see Table **I**). Out of this, a periodical occurrence rate of ∼24 days is found, with higher significance for the southern than for the northern hemisphere. Thus, major flares seem to be not that strongly related to a N-S asymmetry. In agreement, Bai (1987) found that hard X-ray flares (mainly major flares) for the time span 1980–1985 rotate with ∼23.7 days in both hemispheres. A dominant ∼23.5-day period is also found in irradiance measurements as well as in the areas especially of young and "active" sunspot groups (Pap, Tobiska and Bouwer, 1990). Thus, the 24-day period is supposed to be a real periodical feature, and the anchoring hypothesis of new-borne spots representing deeper and thus faster rotating layers could provide a useful link to the theory of energetic flare events (see, e.g., Balthasar, Schüssler and Wöhl, 1982).

Flares occur preferentially in association with active regions of complex magnetic configuration, such as δ, $\gamma\delta$, and $\beta\gamma\delta$. Sammis, Tang and Zirin (2000) analyzed 8 years of active region observations with respect to solar flare occurrence, and found that most of the major flares occurred in active regions of $\beta\gamma\delta$ structure. It was pointed out that there is a strong tendency of major flares to be associated with large active regions of a complex magnetic configuration. As it can be inferred from Table **I**, major flares (i.e. importance ≥ 1) account only for ∼10% of the total of events. Therefore, we suggest that the fact that a 24-day period is found in the occurrence of major flares but not in Sunspot Numbers is due to a selection effect towards magnetically

complex and large active regions when considering time series of major flare events. In further studies it is planned to test this hypothesis by analyzing time series of occurrences of large and complex active regions, in particular considering $\beta\gamma\delta$ configurations.

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