AN ACTIVE REGION QUASI-BIENNIAL OSCILLATION

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ABSTRACT

A quasi-biennial fluctuation has been detected in the time-series of the sunspot umbra/penumbra (U/P) area ratio on the basis of the Debrecen Photoheliographic Data. The study is based on an intermittent period of nearly eight years; the material comprises more than 18,000 individual sunspots. The present contribution reports preliminary pieces of information about the temporal behaviour of the U/P ratio and period analyses. The physical background of the phenomenon is as yet unclear but it seems to belong to the growing family of mid-term fluctuations.

1. INTRODUCTION, MID-PERIOD PHENOMENA

There exist several different reports on solar mid-term periodicities. In the remainder of the paper, mid-term and mid-period are used to designate phenomena fluctuating quasi-periodically within time scales longer than a year, but substantially shorter than the sunspot cycle.

Mid-term periodicities have appeared in a broad variety of contexts in the fields of solar and geomagnetic physics, often completely unexpectedly. In some cases, a mid-period is the main feature of a fluctuation. Different examples are the shear oscillation of the solar tachocline region [1], the mid-term variations in solar wind speed data [2] and the fluctuations of geomagnetic activity [3]. These vary quasi-periodically, with non-constant cycle lengths in the interval 1.2-1.8 years. Some studies show that the cycle lengths of solar wind speed and geomagnetic activity are systematically different during even and odd solar cycles [4] and that the strengths of the fluctuations depend on the level of solar activity [5]. Other mid-period phenomena appear as superposed oscillations on main trends correlated to the solar cycle. Sunspot numbers themselves [6] as well as, e.g., green corona activity [7] and the solar radio flux at 10.7 cm [8], contain quasi-biennial oscillations. The time-scales of these variations are somewhat longer than the previously mentioned ones. The cycle lengths vary in the interval of about 1.6-2.4 years, with an average of around two years. The links between different solar phenomena with mid-period characteristics are enigmatic. There have up to now not been any reports of mid-period variations of solar active regions.

2. THE OBSERVATIONAL DATA

There are several sunspot databases produced by single or networks of observatories around the world, all with their own flavour. Examples of sunspot catalogues are the Greenwich Photoheliographic Results, the Solar Optical Observing Network (SOON) and the Mount Wilson Data [9].

2.1 The Debrecen Photoheliographic Data

The Debrecen Photoheliographic Data (DPD) is a sunspot catalogue conducted at the Debrecen Heliophysical Observatory, Hungary. To date, the DPD consists of three published and five unpublished years. The published years are 1986 to 1988 ([10],[11],[12]) and the set of unpublished years contains the almost complete year of 1989 together with 1993 to 1996. The available catalogue consists therefore of nearly eight years in total, separated into two intervals, in the ascending and descending phases of the solar cycle number 22.

The photoheliograms used to compile the DPD have a resolution of about one arcsecond when the weather conditions are good, but the resolution is lower during for example winter.

3. FLUCTUATION OF THE UMBRA-PENUMBRA AREA RATIO

The DPD contains, among other parameters, sunspot, and umbra area measurements. The penumbra areas are calculated from these two parameters. Analyses of the DPD show that the umbra-penumbra area (U/P) ratio varies in a quasi-biennial manner. We have treated the case of several sunspots sharing a common umbra or penumbra, by adding the umbra area values shared between spots. Sunspots consisting of an umbra or penumbra only, are neglected. Umbra and penumbra fragments not associated with another are neglected in the analyses.

The number of sunspots during the years used in the analyses is summarized in Table 1. The number of sunspots during the year 1986 is much lower than during years closer to the solar cycle maximum.

Table 1. Number of sunspots observed during the available years of the DPD. The year of 1989 is not complete. The months available at the time of analyses were January to July.

Year	No of Spots	No of Spots* with U, P, U+P > 0
1986	3060	602
1987	8592	1583
1988	26740	4865
1989 (I-VII)	24580	5171
1993	15181	3384
1994	7923	1170
1995	5910	1100
1996	2179	511
Σ	**93165**	**18386**

*After having added the umbra values for spots with common penumbrae.

Fig. 1 shows the monthly mean values of the U/P ratio for sunspots with both a distinguishable umbra and penumbra. A period of about two years can be seen. The 1986 and the first half of 1987 data are more spread than the rest of the values. These years of the catalogue are produced with an older method than the following years. The monthly mean of October 1996 with large error-bars consists of only three sunspots.

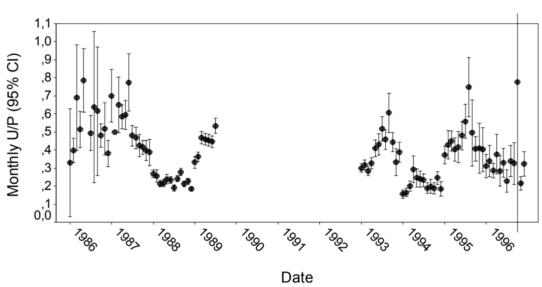

Fig. 1. Monthly mean of the U/P ratio for sunspots, plotted with 95% confidence interval (CI).

Analyses of the periodic behaviour of the U/P ratio fluctuations found in the DPD have been conducted by estimating its power spectral density (PSD) using a periodogram. The two different time intervals, 1986 to 1989 and 1993 to 1996, have been treated separately. Fig. 2 shows the PSD estimate for the 1986 to 1989 time interval, and Fig. 3 shows the estimate for 1993 to 1996. The mean U/P ratio of the intervals have been subtracted from the two sets of monthly values, respectively, to centre the data around zero and only reveal their periodic behaviour. The spectral peaks are broad due to the shortness of the data sets, but we are able to make rough estimations of their frequency contents.

The 1986 to 1989 data set has its highest spectral peak at a frequency corresponding to a period of almost 43 months. The peak is broadened in the sense of shorter periods and has a bump at a frequency corresponding to a period of about 20 months.

The 1993-1996 spectral analysis in Fig. 3 has its highest spectral peak at a frequency corresponding to approximately 21 months. This peak has a lower absolute value than the highest peak of Fig. 2 and is broadened in the sense of longer periods.

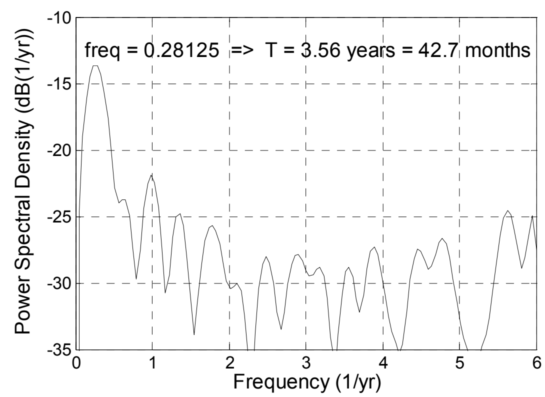

Fig. 2. Periodogram of the 1986-1989 monthly data.

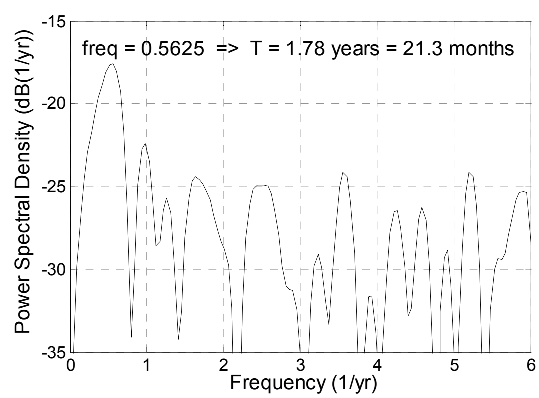

Fig. 3. Periodogram of the 1993-1996 monthly data.

4. CONCLUSIONS, MID-PERIOD PHENOMENA

A quasi-biennial fluctuation of active region characteristics has been found in the DPD. This fluctuation, revealing itself as a cyclic variation of the sunspot U/P ratio, was not an expected feature. No previous investigations known to the authors of this parameter have either contained as many sunspots, or shown temporal behaviour of this kind. No physical mechanism explaining the phenomenon can be suggested at this moment; the feature is a complete novelty, but seems to be a new member of the growing family of solar mid-period phenomena.

This paper is a preliminary report. More details about the behaviour of the U/P ratio and phase relations with other fluctuations will be investigated and published elsewhere.

5. ACKNOWLEDGEMENTS

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