EPHEMERAL PERIODICITIES IN THE SOLAR AVTIVITY

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ABSTRACT/RESUME

We have carried out a spectral analysis of Ha flares and CMEs during the rising phase of solar cycle 23. The temporal behavior as well as the spatial distribution on the solar disk is examined. We study short-term periodicities of solar activity using Wavelet analysis. The time profiles expressed by an analytical relation as a network of periods of enhanced activity computing their amplitudes and phases using the SA method. A mixture of stable and ephemeral periodicities (present only for limited time intervals) have been found. Many models and speculations have been published especially after the reported 154 days periodicity. A "clock mechanism" and the superposition of a stochastic behavior on the photospheric magnetic field with various sizes and time scales, have been proposed. The existence of north-south and east-west asymmetries of the flares and CMEs is examined.

1. INTRODUCTION

Search for possible periodicity in solar activity data is essential since any detection of periodicity in it would have fundamental significance for the understanding of solar activity. Short-term periodicities in different manifestations of solar activity have been pointed out, such as of 14, 21-23, 27-28, 51, 74, 86, 90, 104, 129, 152-158, 300-360 and 540 days [1, 2, 3, 4 and references therein]. The existence of these periods depends strongly on the data time span. There is no acceptable explanation for the physical origin of the most of them [5, 6, 7, 8].

The connection between the spatial distribution of active regions and the structure of large-scale fields has a long history. North-south (N-S) and east-west (E-W) asymmetries are shown by several statistical studies for most of the solar activity phenomena [9, 10, 11, 12, 13 and ref. therein]. Although the N-S asymmetry is not so well understood, the E-W asymmetry has been more controversial. The N-S asymmetry reverses its sign with the reversal of the Sun's magnetic dipole [11 and ref. therein]. Preference for the north hemisphere (N) during the rising phase of the current solar cycle 23 is reported for solar flare index and for the yearly rate of Ha flares during 1975-1999, as well as, a small but significant E-W asymmetry in Ha flares [13 and ref. therein]. Almost all authors find a low but prolonged dominance of the east (E) hemisphere.

In this paper a temporal behavior and a spatial distribution of the Ha flares and CMEs on the solar disk during the rising phase of the current solar cycle 23 is examined. The daily values of Ha flares for the period 1994-2000 have been downloaded from NOAA, USA (http://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_FLARES/). Criteria were set in order to eliminate dublicate reports of the observed flares. The daily values of CMEs observed by the SOHO/LASCO coronagraph during the time interval 1996-2001 obtained from http://cdaw.gsfc.nasa.gov/CME_list/UNIVERSAL/ . The apparent central position angle (PA) measured counterlockwise from the projection of the Sun's north pole is linked with the apparent location of CMEs [14].

2. SPECTRAL ANALYSIS

The Wavelet analysis enables us to find short-term

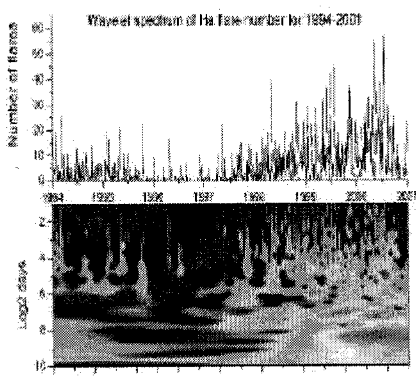

Fig. 1. Wavelet power spectrum of the record of Ha flares during the rising phase of the current solar cycle 23. Daily distribution of them is shown in the upper panel. The noticeable periodicities of 27, 59, 137 and 330 days are presented.

ephemeral periodicities in the rate of occurrence of CMEs and Ha flares. Wavelet-based analysis techniques have been applied to a variety of astronomical problems. We use the continuous wavelet transform which is particularly suited for time-frequency studies of non-stationary signals such as records of solar activity [15]. The periodicities of 27, 59, 137 and 330 days for the flares and the ones of 37, 97, 182 and 365 days for the CMEs have been found (fig. 1 and fig. 2).

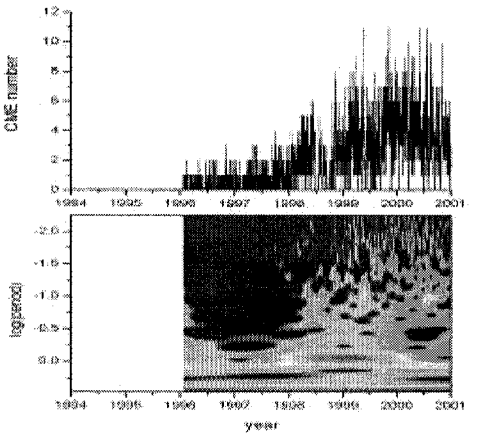

Fig. 2. Wavelet power spectrum of the record of CMEs during the rising phase of the current solar cycle 23. Daily distribution of them is shown in the upper panel. The noticeable periodicities of 27, 59, 137 and 330 days are presented.

A reconstruction of Ha and CMEs time series was obtained using a sum of sine waves derived from spectral analysis of their data. The method named 'Successive Approximations' (SA) has been introduced by Xanthakis and collaborators [16 and ref. therein] in order to study various time series. Reference [17] have developed for the first time software for the SA method. The basic idea of the method is that a quasi-stationaty and quasi-periodical time series can be represented by a sum of sine functions of n periods. Therefore, the number of events per time interval (A^{cal}) is given by the following relation:

$$A^{cal} = a_0 + \sum_{i=1}^{n} a_i \sin[(2\eth/T_i)(T-Ts)] \quad (1)$$

Where : Ts<T<Te, Ts and Te are start and end time-terms of each calculated quasi-period
a_0 is the constant shift of the curve
a_i is the amplitude of the i-sinusoidal curve
T_i is the i^{th} periodicity

The best fit of the time series is made in order to find long, medium or short-term quasi-periods. The accuracy, the standard deviation and the degrees of freedom are checked step by step.

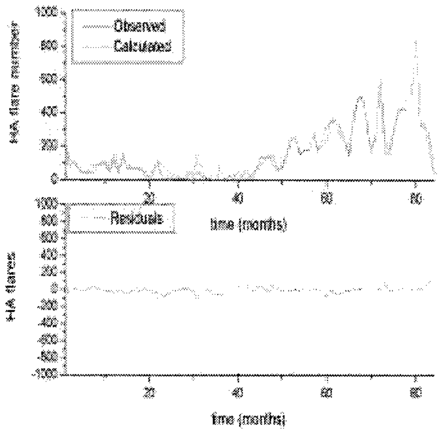

Fig. 3. The results of SA (Successive Approximation) method on the time series of the occurrence rate of Ha flares during the time interval 1994-2000. In the upper panel is presented the reconstructed time series obtained from the analytical relation (Eq. 1) of the computed short-term quasi-periods (see fig. 5) compared with the observed time series. In the bottom panel the corresponding residuals are shown. The accuracy of the results is 78% (standard deviation=36.288).

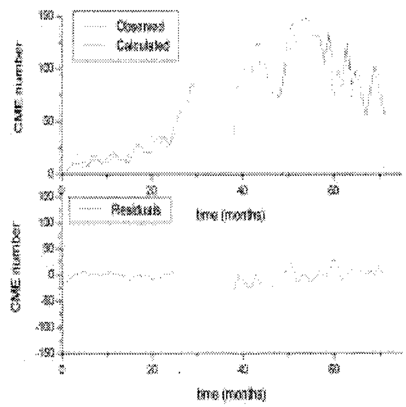

Fig. 4. Same as fig. 3 for the time series of the occurrence rate of CMEs during the time interval 1996-2001. There is a data gap between July 1998 until January 1999. The accuracy of the results is 79% (standard deviation=5.891) and 86% (standard deviation=14.038) for the first and second part of the curve respectively.

We have to compute the monthly values of flares and CMEs, as a sum of sine waves. The reconstructed time series are shown in fig. 3 and fig. 4. The residuals between observed and computed values are presented to check the accuracy (80%). The obtained periods vs time for the Ha flares and CMEs are presented in fig. 5. Short-time variations of 2-3 months have temporally appeared for both time series. The well –known period of about 5 month (154 days) is more pronounced in Ha flares than in CMEs. The same result is also obtained from the wavelet analysis. The periods of 12 and 6-7 months appeared in both data set but in different time intervals.

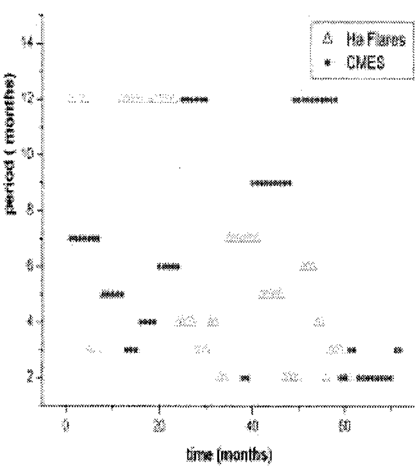

Fig. 5. The obtained periods vs time for the Ha flares and CMEs are presented.

Recently, the periodicities of 1.6, 1.8, 2.3, 3.51, 5.13 and 16.8 months for the monthly vaues of grouped flares during 1996-2000 [18] and 127 days (4.2 months) for flare occurrence during months) for flare occurrence during 1999-2000 [19] are reported.

3. DISTRIBUTION AND ASYMMETRY OF FLARES AND CMEs

The heliographic distribution of the monthly values of Ha flares and CMEs with respect to the NW, NE, SW and SE quarter of the solar disk during the rising phase of the solar cycle 23 (fig. 6) is examined. There is an increase of flares and CMEs following the rising phase of solar cycle. The NW quarter is more active either for flares or for CMEs, especially during the solar maximum.

We have determined the CME and Ha flare monthly numbers N-S and E-W asymmetry. We introduced the asymmetry coefficients,

Ans=(Nn-Ns)/(Nn+Ns) and Aew=(Ne-Nw)/(Ne+Nw), where Nn, Ns, Ne, Nw are the number of Ha flares or CMEs in each henisphere (fig. 7). During the current solar maximum, the preference for N hemisphere either for flares or CMEs as also an excess of them in the E hemisphere is presented. The N-S and E-W asymmetry coefficients are more pronounced in flares than in CMEs.

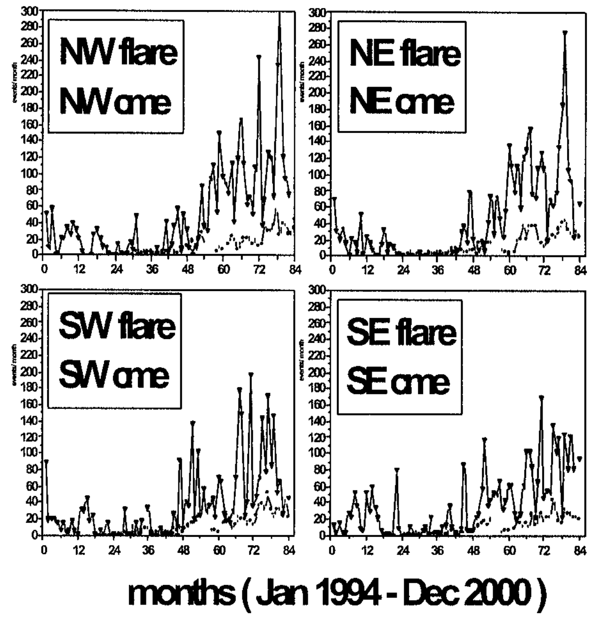

Fig. 6. The heliographic distribution of the monthly values of Ha flares and CMEs with respect to the NW, NE, SW and SE quarter of the solar disk during the rising phase of the solar cycle 23.

4. CONCLUSIONS

The temporal evolution of the Ha flares and CMEs periodicities were analysed by the continuous wavelet transform in the period range between 25 and 365 days using daily measurements. The wavelet analysis indicate that there are some ephemeral periodicities in the above data sets. The periods of 27, 59, 137 and 330 days for flares and 37, 97, 182 and 365 days for CMEs are seen most clearly in the integral spectrum.

A reconstructed Ha flare and CME time series were obtained by applying spectral analysis to the data. The calculated values of flare and CMEs, being a sum of sine waves, found by using the SA method of analysis. They were obtained by applying the periods of about 2-3, 4-5, 6-7 and 12 months to the Eq. 1. The SA results are comparable with the ones of wavelet analysis. Ephemeral periodicities of 12 and 2-3 and 6-7 months occurred in both, flares and CMEs, but in different time intervals. The periodicity of 4-5 months is more pronounced in the flares time series than the CMEs.

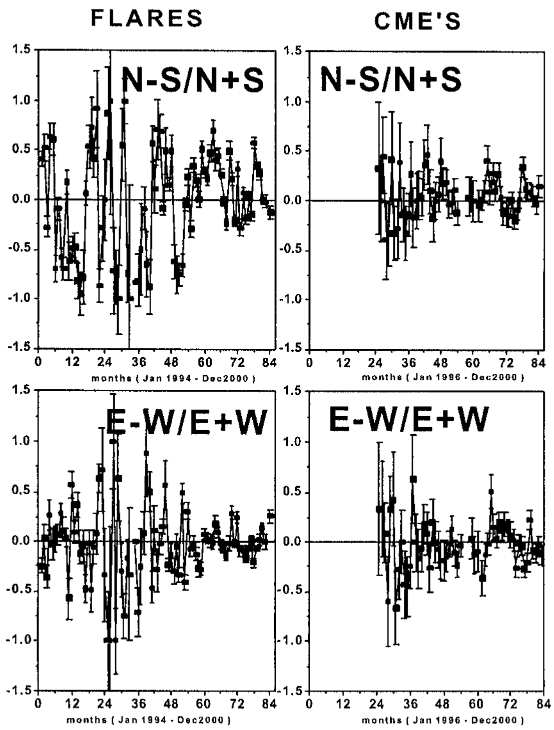

Fig. 7. The N-S and E-W asymmetry coefficients of the CME and Ha flare monthly numbers.

We examine distributions of the Ha flares and CMEs with respect to the NW, NE, SW and SE quarter of the solar disk. The NW appears the more active, especially during the current solar maximum either for flares or for CMEs.

The analysis of the N-S and E-W asymmetry curves leads to the following conclutions. The observed asymmetry is not in phase with the solar cycle. During the current solar maximum, the preference for N hemisphere either for flares or CMEs as also an excess of them in the E hemisphere is presented. The N-S and E-W asymmetry coefficients are more pronounced in flares than in CMEs.

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