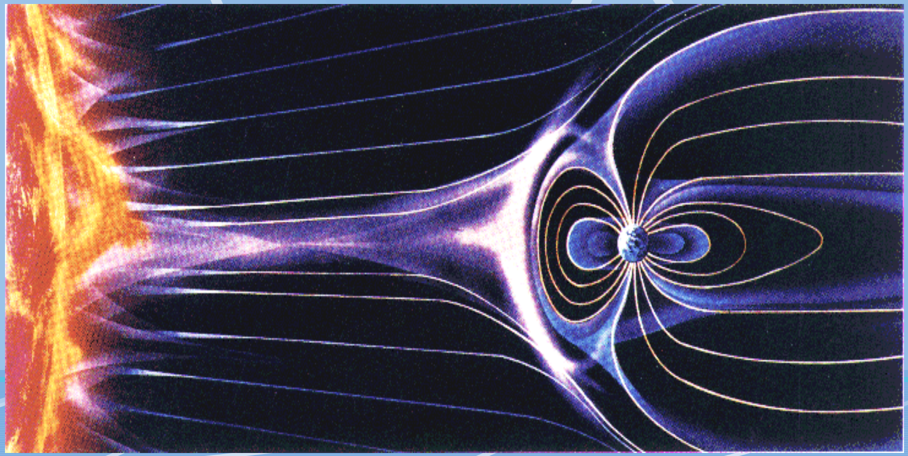
SPECTRAL ANALYSIS OF THE HIGH-SPEED STREAMS IN THE SOLAR WIND



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OUTLINE

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- DATA AND METHOD
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INTRODUCTION

- The detailed analysis of the solar wind properties reveals its basic structure, made up of two components: **low-speed streams (LSS) and high-speed streams (HSS).**

- The best-established sources of the HSSs are ***the coronal holes*** ⇒ the **recurrent (27 days)**, **co-rotating HSS**;
  - The **coronal holes** also are **the sources of the LSS**, which might come from the bordering divergent regions of the hole.

- There also are **non-recurrent HSS** produced by some high-energy solar phenomena such as **the flares, coronal mass ejections, and the sudden disappearing filaments** that appear in active regions with closed magnetic fields.

⇒ The HSSs can be divided, according to their origin, in two classes:

- ***co-rotating*** ones – produced by coronal holes (**CH_HSS**) – and,
- those ***produced by solar flares*** **(FG_HSS).**

- There are different definitions of the HSSs, using different limits of *the increase in the wind velocity*, *the duration of this increase*, *combined or not with* *some increases in the density or the temperature* *of the wind.*
- Corresponding catalogues of the HSSs have been established: Lindblad and Lundstedt, 1981; 1983; Lindblad et al., 1989; Mavromichalaki et al., 1988; Mavromichalaki and Vassilaki, 1998.
- We consider **the importance parameters** for the HSS analysis, all the more as the HSSs in the solar wind have a great impact on the geomagnetic environment:
  - **the mean speed value (V_0)** in km/s**,**
  - **the maximum daily mean speed (V_{max})** in km/s **and**
  - **the duration (*d*) of the streams**, in days,
  - ***the stream importance***, I defined as:

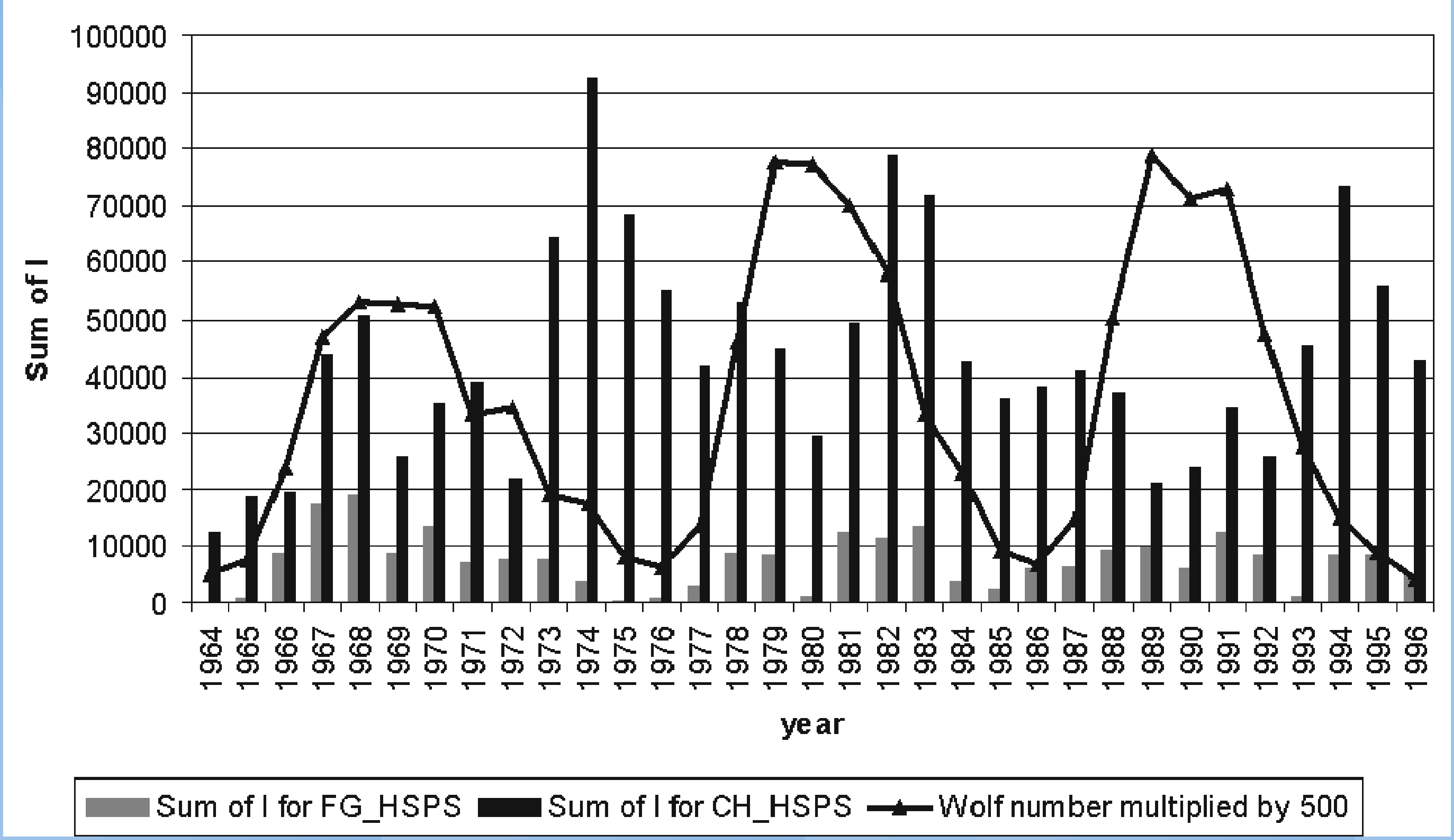
$$I = \Delta V_{\mathbf{max}} \times d$$

where:

$$\Delta V_{\mathbf{max}} = V_{\mathbf{max}} - V_0$$

is the velocity gradient of the stream.

- In our previous papers a cyclic variation of the FG_HSSs and CH_HSSs in keeping with the solar activity was noticed:
  - The time variation of the HSS parameters and their occurrence rate show **an 11-year periodicity** with differences between the two HSS classes;
  - The **FG_HSSs and CH_HSSs present an antiphase variation during the 11-year solar cycle**, only with a few exceptions, for all parameters calculated;
  - A large number of **FG_HSSs appeared during solar cycle maxima** (1969, 1979, 1989 for SCs 20, 21 and 22, respectively) just as it was expected, whereas **the large coronal holes in the solar minima gave a lot of CH_HSSs**


Sum of I
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996
year
Sum of I for FG_HSPS
Sum of I for CH_HSPS
Wolf number multiplied by 500

DATA AND METHOD

- The chosen interval, 1964–1996, includes four minimum and three maximum phases of the 11-year SC, meaning three complete SCs (nos. 20–22);
- ***The stream importance*** was calculated per Bartels rotations as *SI* (taking into account all the streams during a BR) individually, for:
  - the co-rotational HSSs;
  - the flare generated HSSs.
- The basic index of the solar activity – **the daily Wolf number** – was used to compare the cyclic variations → ***SW*** the values for each Bartels rotation (in order to organize thus all three data series in the same way).
- The data have been extracted as samples on Bartels solar rotations ⇒ 446 samples (BR nos. 1785 to 2230) for the three solar cycles studied (a reasonable number for a significant spectral analysis);
- **the Fast Fourier Transform function of the LabVIEW graphic programming environment has been used because of its exceptional presentation capacity of the results under a graphic form.**

⇒ ***the temporal variations and spectral components*** as : the ***amplitude and phase values***

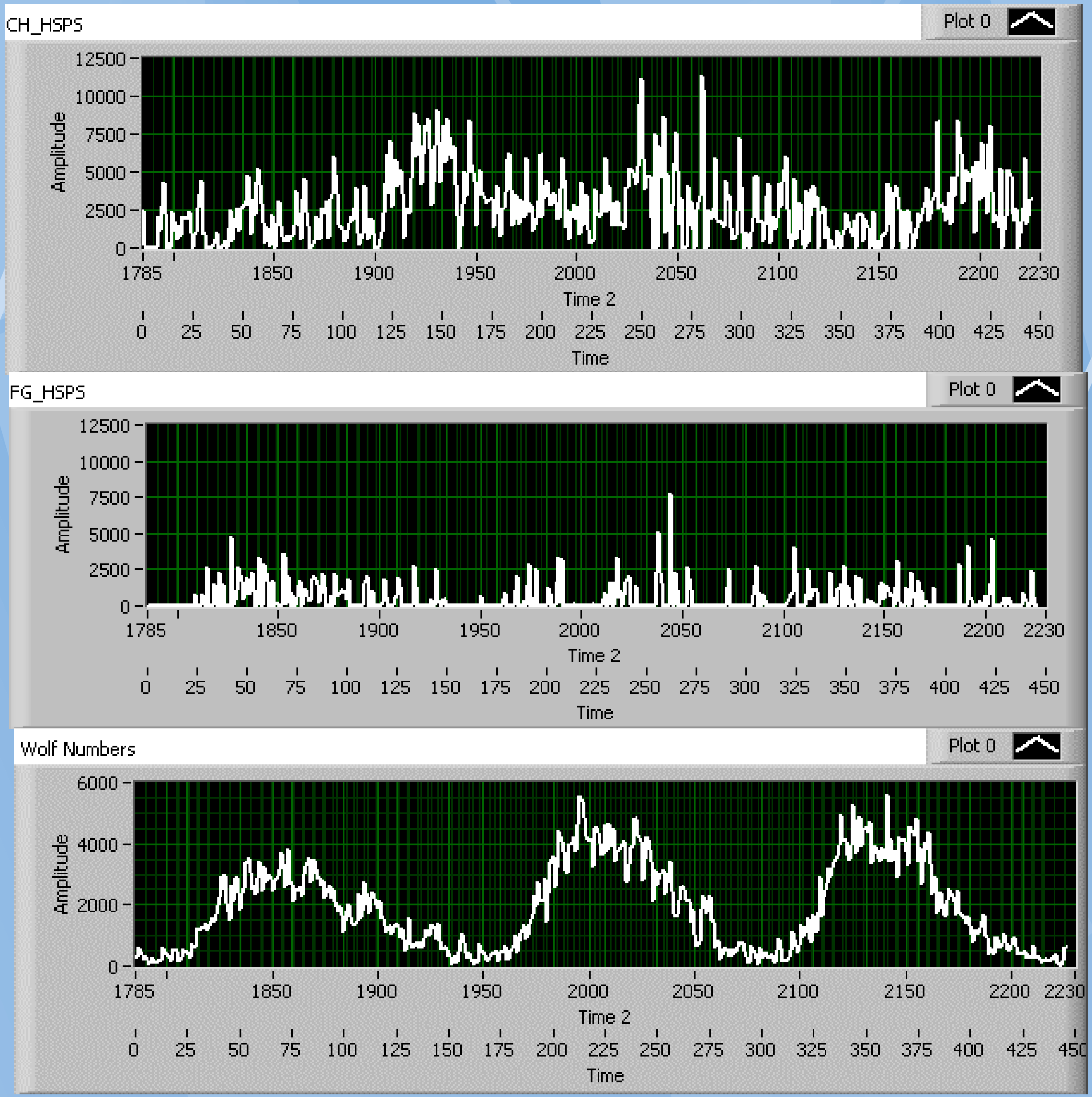


Fig. 1 – Temporal variation of the ΣI and ΣW

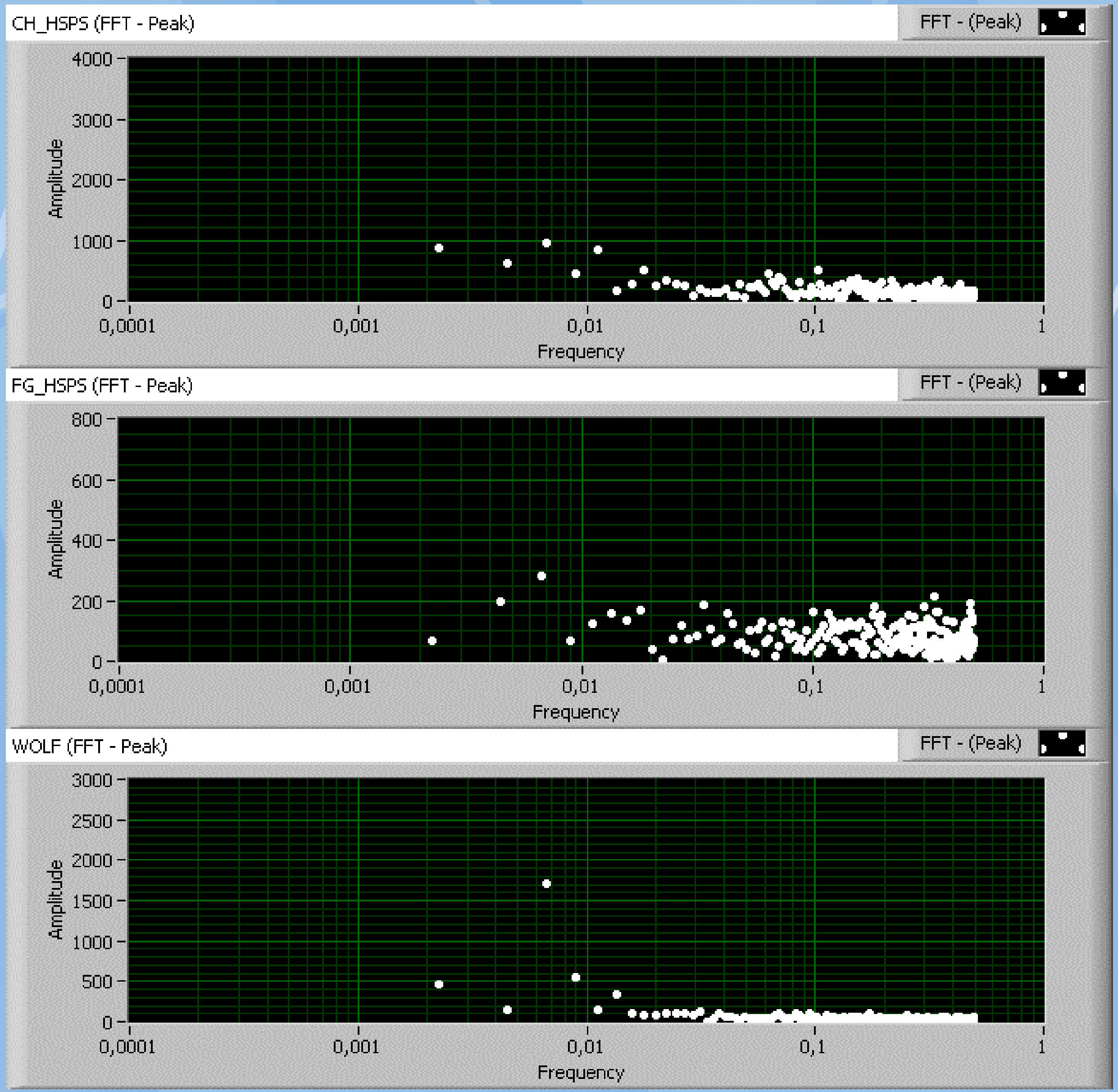


Fig. 2 – The amplitudes of the spectral components for the three data series

ANALYSIS OF THE RESULTS

- In Fig. 2 a predominant component of the spectrum in all data series, situated at the same frequency, can be distinguished, namely at the value:

$$F = 3\Delta f$$

where:

$$\Delta f = \frac{1}{N}$$

with: *N = 446* – the number of values introduced in the analysis.

- We can calculate the main period of the series (in years) according to the formula:

$$T = \frac{1}{F} \times \frac{n_B}{n_y} = \frac{446}{3} \times \frac{27}{365} = 10.99\,years$$

where: n_B is the number of days for a Bartels period (27 days); n_y is the number of days during the year (365 days).

⇒ the classic period of 11 years has been obtained both for the Wolf numbers and for the two types of HSSs.

The values given by the program for the phases of the three spectral components are:

$$\Phi_{FG\_HSS} = +177.416^{\circ};$$

$$\Phi_{CH\_HSS} = +44.1699^{\circ};$$

$$\Phi_{W} = -174.305^{\circ}$$

We translate the origin point of the three phases by +174,305°, in order to bring the curve of the Wolf numbers to the phase point zero $\Rightarrow$ the phases for the three spectral components:

$$\Phi_{W} = 0^{\circ}$$

$$\Phi_{FG\_HSS} = +177.416^{\circ} + 174.305^{\circ} - 360^{\circ} = -8.279^{\circ};$$

$$\Phi_{CH\_HSS} = +44.1699^{\circ} + 174.305^{\circ} - 360^{\circ} = -138.5251^{\circ}$$

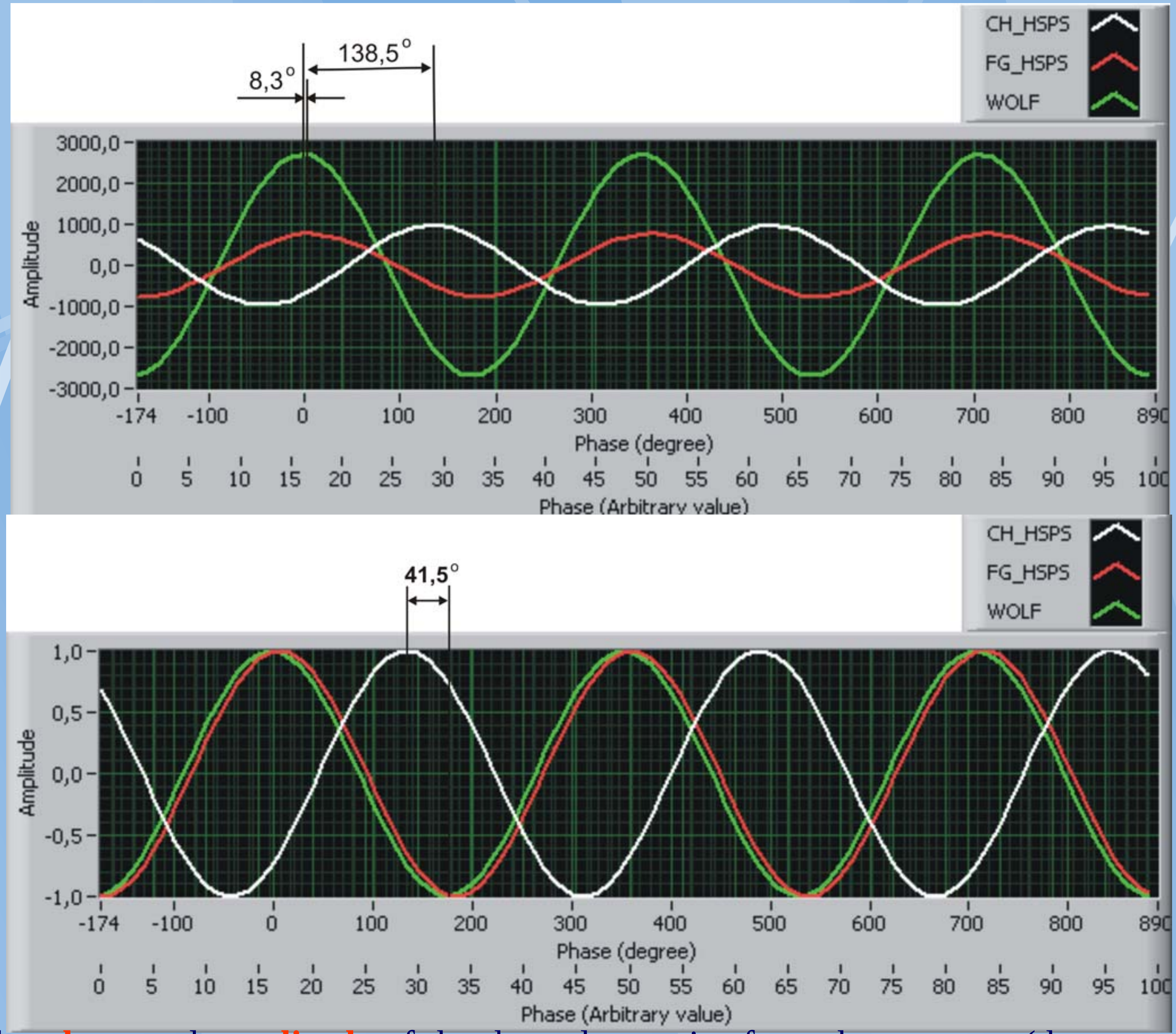


Fig. 3 – The **phase** and **amplitude** of the three data series from the program (the upper panel) and with the amplitudes of the three curves normalized to the value 1 (the bottom panel).

- The phase differences between the extreme epochs of the solar parameters considered, expressed in degrees show that:

  - **the fundamental frequency maximum for the FG_HSS series is lagging behind the maximum of the Wolf numbers curve by approximately 8.3°;**

  - **the maximum of the fundamental frequency of the CH_HSS series is lagging behind the maximum of the Wolf number curve by approximately 138.5°. We might also say that it is lagging before the minimum of the Wolf numbers by 180°– 138.5° = 41.5°.**

- We transformed the phase differences, expressed in degrees, in time differences between the extreme epochs of the solar parameters considered and obtained:

  - **the maximum activity of the FG_HSSs expressed by *ΣI* per Bartels rotation, appears 0.25 years after the maximum of the Wolf number evaluated through *ΣW* per Bartels Rotation;**

  - **the maximum activity of the CH_HSSs, expressed through the same *ΣI* per BR, is attained 4.23 years after the Wolf numbers maximum (*ΣW* per BR) or, 1.27 years before the Wolf number minimum.**

CONCLUSIONS

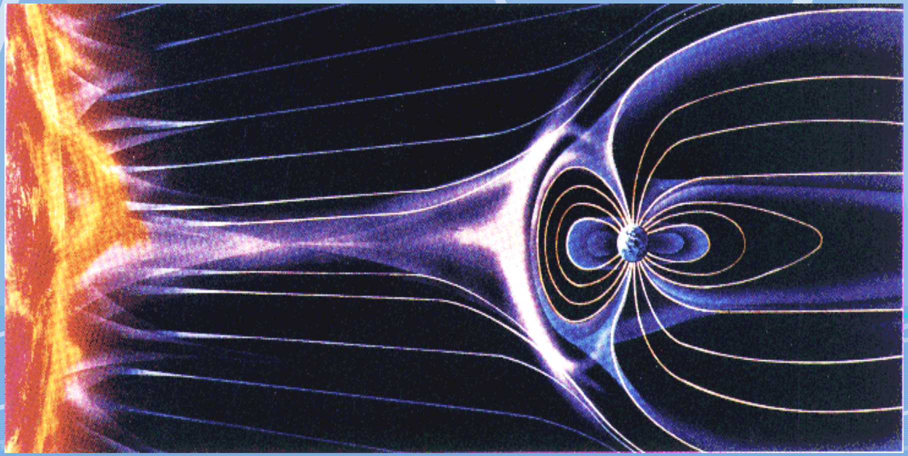
- We underline that our results have been obtained by means of a digital processing for only three cycles of solar activity (nos. 20–22), with the length of 10.99 years.
- It is known that not all cycles have the same length so, we could conclude that the values of phase differences are only approximate but their physical significance is of a real importance.
- The appearance of the ΣI maximum of the FG_HSSs after the ΣW maximum at 0.25 years coincides with the beginning of the polar magnetic reversal.
- The ΣI maximum of the CH_HSSs is attained 4.23 years after the ΣW maximum when the CH are very extended to the low latitudes or 1.27 years before the Wolf number minimum, which coincides with the epoch when the active regions of the new cycles become significant (their appearance disturbs the topology of the magnetic field in the solar atmosphere up to the corona where coronal holes are forced to reduce their extension).

The establishment of the phase differences between the curves analysed and the time differences between the extreme epochs of the solar cycles corresponding to the phenomena analysed, will be useful for long term forecasts of the solar activity and space weather.

FUTURE WORK

- HSS Catalogue for SC 23 (1996-2007);
- The analysis of the HSS parameters during SCs 20 – 23 per years and BRs
  - 22-year magnetic cycle (Hale cycle)
- Spectral analysis of the HSS parameters during four SCs (1964 – 2007)
  - secondary components

THANK YOU



FOR ATTENTION !