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14. Abstract/Notes

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LONG TIME BEHAVIOUR OF THE INTERPLANETARY MAGNETIC FIELD-SECTORIAL STRUCTURE

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ABSTRACT

The behaviour of the Interplanetary Magnetic Field (IMF) polarity was analized from data covering the years 1926 to 1982. The data refer to daily values of the IMF polarity, which is defined as being *away* or *toward*, according to the predominat direction of the magnetic field along the Archimedes Spiral. In order to find possible periodicities, the data were submitted to power spectrum analysis, both in their totallity and also grouped in shorter time intervals. The results show that, although on a large temporal scale the IMF seems to have a structure composed of two approximately equal sectors with opposite polarities, this configuration is not unique. On the contrary, from a subdivision of the data in annual intervals, it is seen that epochs with quasi-symmetric bi-sectorial structures are followed, with recurrences of 1.5 to 3 years by epochs with less defined structures or even with quasi-symmetric four-sectors, thus explaining the apparent controversy concerning the basic features of the IMF-polarity structure.

1- INTRODUCTION

Since the discovery of the sectorial structure of the Interplanetary Magnetic Field (IMF) by Wilcox and Ness (1965) and the later founding of the relationship between the IMF polarity and the kind of perturbation observed in the geomagnetic field at high latitudes (Svalgaard, 1968; Mansurov, 1969; Mansurov and Mansurova, 1970; Friis-Christensen et al., 1971), some effort has been devoted to the study of the possible recurrences in the daily values of this polarity (Wilcox and Gonzalez, 1971; Zerefos et al., 1977 - quoted by Tritakis, 1979). In the present work we show the results for such periodicities on the basis of a power spectrum analysis for a long time interval, namely, from 1926 to 1982.

The data for the polarity of the IMF were taken from different sources. One of them is composed by the values inferred from the horizontal component of the geomagnetic variation field at Godhavn (Geographic 69.2^{o}, 306.5^{o}; Magnetic 77.6^{o}, 41.6^{o}) as presented by Matsushita and Trotter (1980), covering the interval 1926-1970. The main set of data is that given by Svalgaard (1975, 1976), as the result of a compilation from different polar cap geomagnetic observations and spacecraft measurements, for 1947 to 1975. Finally, the interval between 1976 and 1982 was completed with the data given by Scherrer et al. (1977) for 1976 and those published by the Journal of Geophysical Research from 1977 to 1982.

2- PERIODICITIES IN THE IMF POLARITY

The above mentioned series of data for the daily IMF-Polarity were submitted to a power spectrum analysis, in a digital correspondence of +1, -1 or 0 respectively, for positive (away), negative (toward) or indeterminated polarity, in order to have quantitative estimates of the existent periodicities. This technique was implemented with a Hanning-Tukey window (Jenkins and Watts, 1968), with maximum autocorrelation (truncation point) up to 3000 days. The result obtained for a truncation point of 500 days is shown in Figure 1, in a logarithmic scale. In this figure we also show the null spectrum for Markov red noise computed in the way described by Mitchell et al. (1966). Furthermore, the bandwidth, which gives an idea of the maximum detail that can be resolved in the spectrum, and the confidence intervals to 90 and 95% levels of confidence are also presented.

It is evident from Figure 1 the existence of significant periodicities of about 27.5,13.5,9.1 and 6.8 days at a 95% level of confidence, in the complete analyzed temporal series. Due to the fact that the solar photosphere is known to rotate with a period of 27 days, the main peak in the spectrum is associated with this rotation, whereas the other peaks can be interpreted as Fourier harmonics of this fundamental period. Since the relative amplitudes of the harmonics depend on the shape of the periodic function (in this case discrete points at -1, 0 or +1), these were analyzed with the aim of deriving the kind of sectorial structure present within one solar rotation by comparing the results to the theoretical spectra obtained for pure rectangular waves.

As can be seen in Figure 2, it is expected that, in general, rectangular waves with two sectors and a main period of about 27 days, give place to spectra for which the predominant peak correspond to this period. On the other hand, waves with four sectors have spectra in which the predominant peak is that corresponding to the first harmonic (one half of the main period). On this basis, the results of Figure 1 lead to the conclusion that the structure of the IMF polarity is predominantly bi-sectorial. However, on the suspicion that this conclusion is not completely true for shorter intervals of time, the analysis was extended also for one year-long portions of the series. Figure 3 shows the power spectrum for the interval April 1, 1962, March 31, 1963, and Figure 4 for the full year 1964. It can be noticed the great difference in the power spectra of these two quite close intervals. The first one is the typical spectrum corresponding to a two sectors structure, while the second on resembles that of a four-sectors structure. As we show below, this variability in the spectral characteristics in lapses of a few years is more a rule than an exception in the long time behaviour of the IMF polarity.

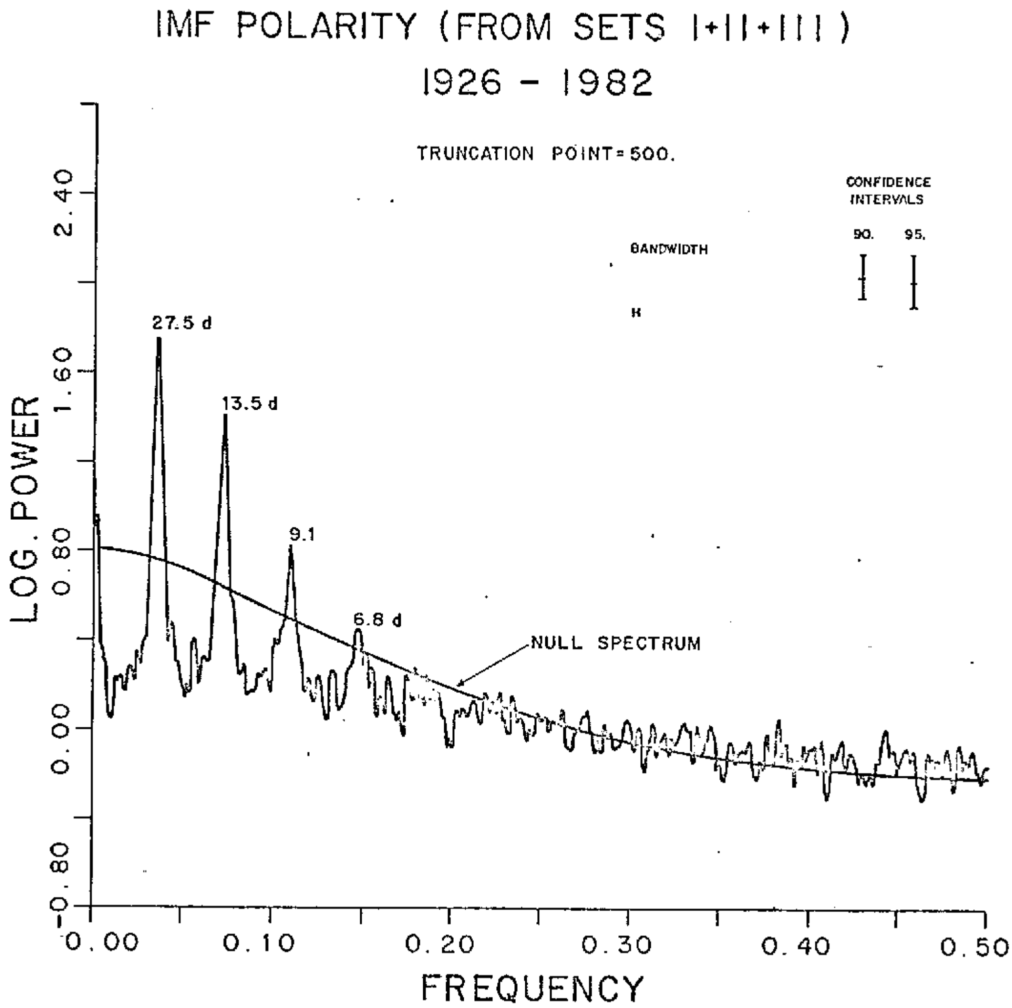

Fig. 1 - Smoothed spectral density estimates (logarithm) for the whole set of data (1926-1982), corresponding to a truncation point of the Tukey-Hanning lag window equal to 500 days.

FOURIER SPECTRA FOR RECTANGULAR WAVES

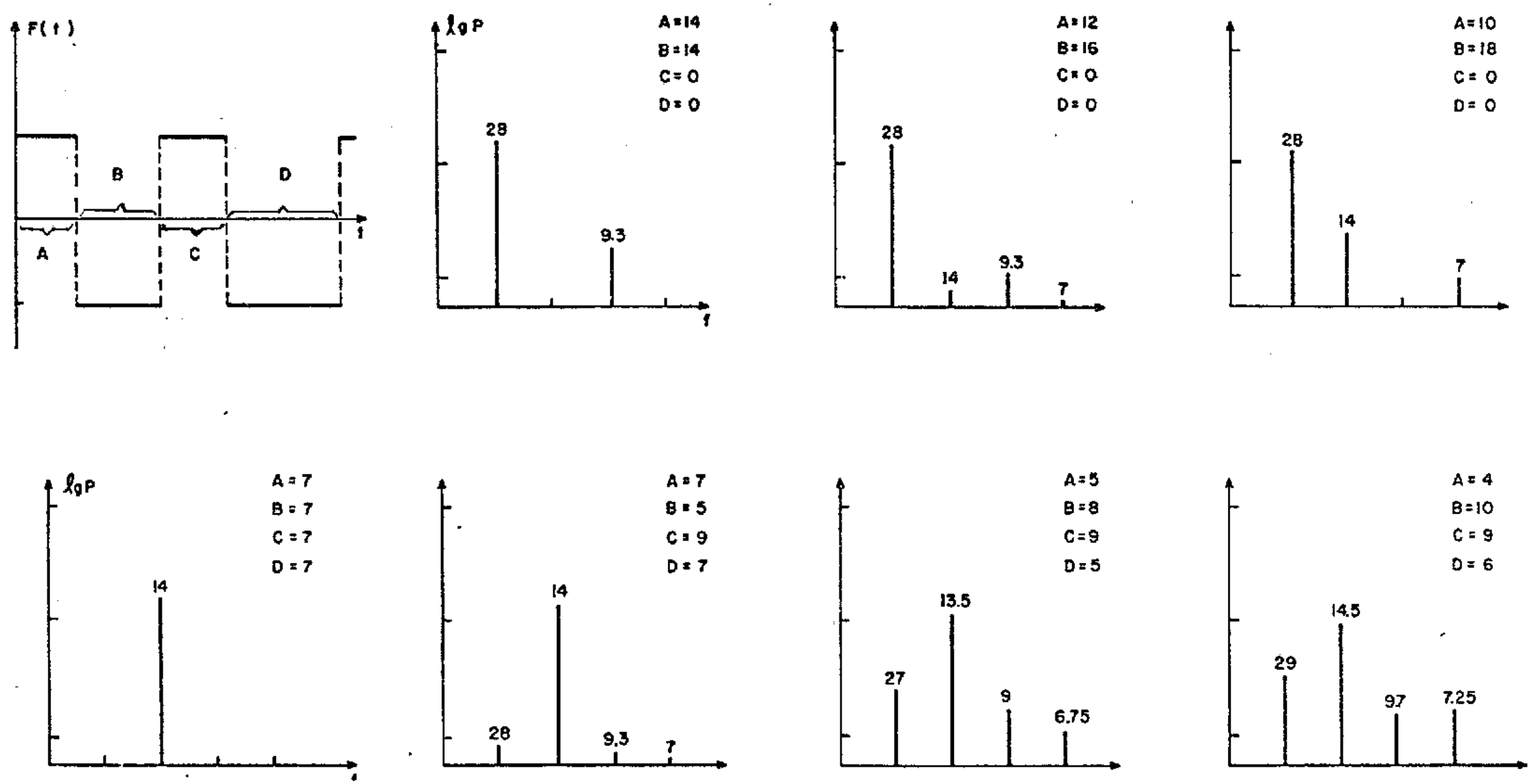

Fig. 2 - Fourier spectra for purely rectangular waves. The examples on the top of the figure correspond to rectangular waves with two sectors and show a predominance of the main period over the harmonics. Those on the bottom correspond to four sectors and show a predominance of the first harmonic over the main peak and the remaining harmonics.

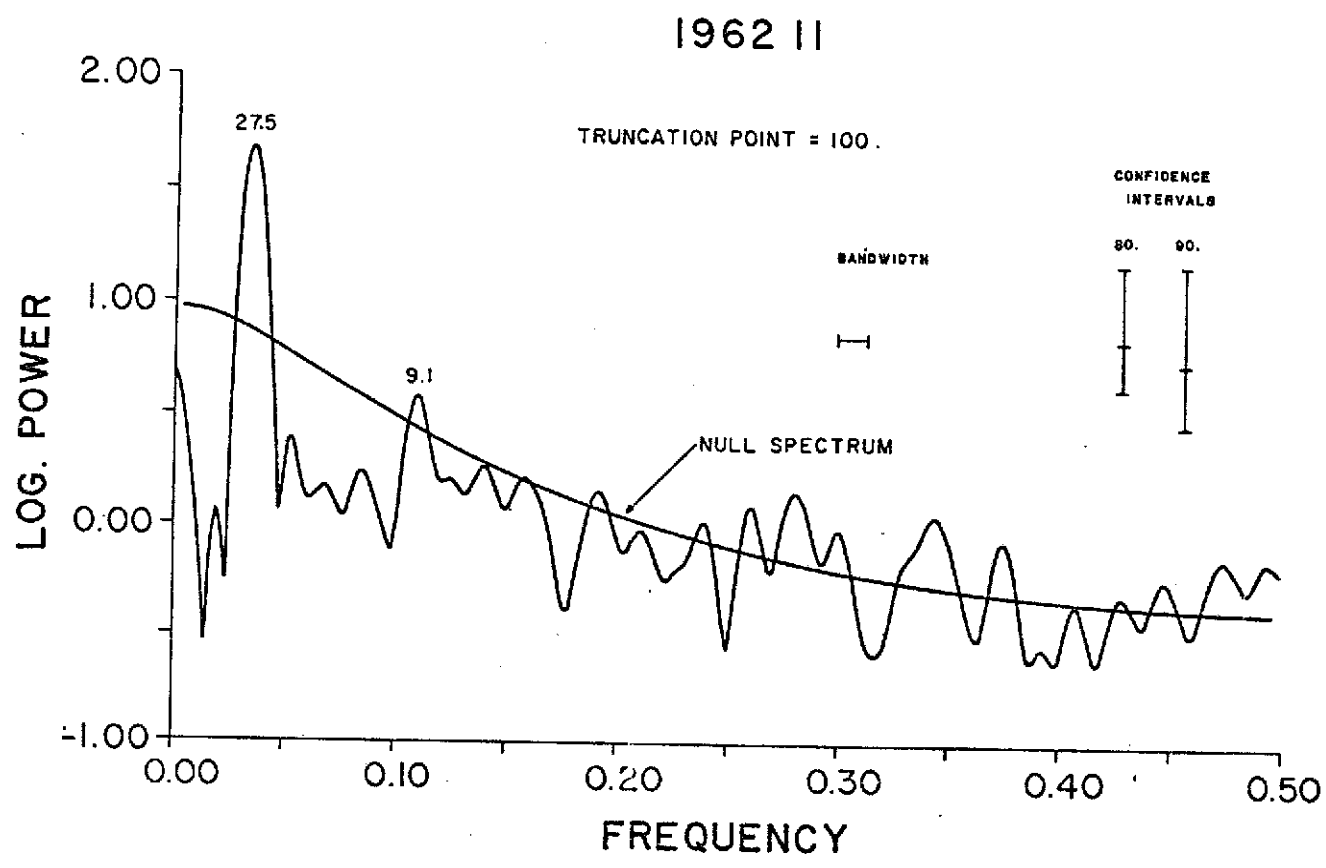

Fig. 3 - Smoothed spectral density estimates (log) for the twelve months interval of April 1, 1962 to March 31, 1963, corresponding to a truncation point equal to 100 days.

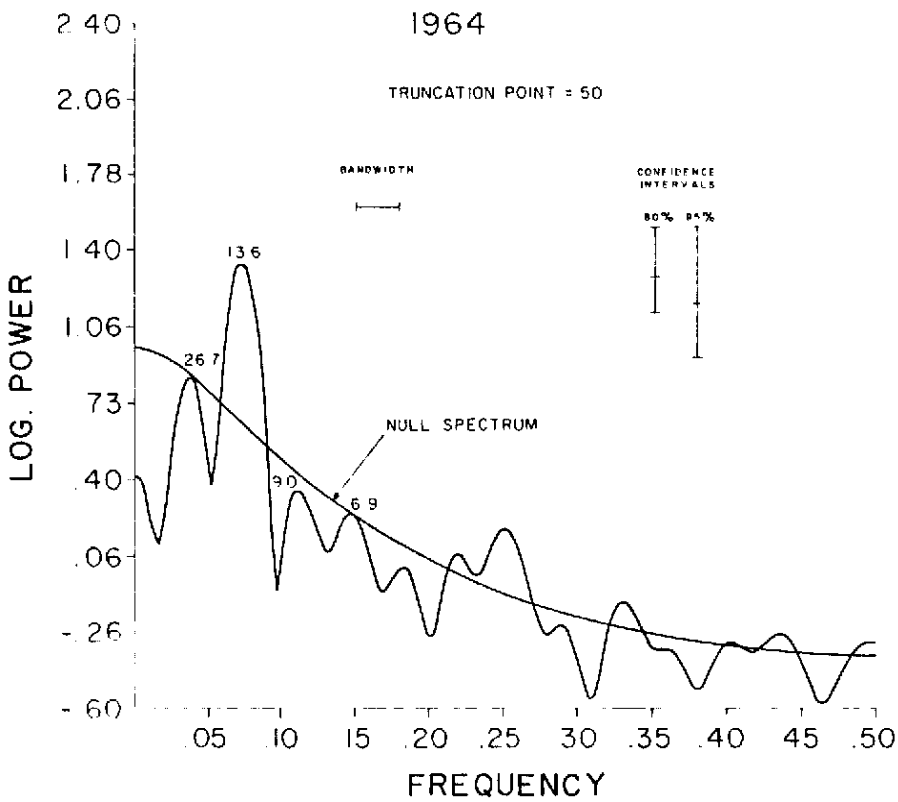

Fig. 4 - As in Figure 2, for the interval January 1 to December 31, 1964.

3- ANNUAL VARIATIONS OF THE SECTORIAL STRUCTURE

Due to the above considerations, a yearly analysis of the sectorial structure was done by taking the power spectrum of the IMF polarity in annual intervals, which were grouped consecutively with a difference of three months between them. The results are shown in Figure 5. In this figure the ratios between the power of the first peak, P_1, and that of the second one, P_2, in a logarithmic scale, are plotted against time for the interval of 1926 to 1982. In the same plot, the variation of the solar activity, given by the Sunspot Number in 12 months running averages, is also shown for comparison.

As mentioned above, bi-sectorial structures are characterized by a predominance of the first peak of the spectrum. This means positive values for $\log P_1/P_2$. Four-sectorial structures, on the other hand, correspond to negative values of $\log P_1/P_2$. Thus, as can be seen in Figure 5, the continuous variations in this index show that the sectorial pattern of the IMF polarity is not unique but constantly suffers variations, so that in the course of a few years it changes from a markedly two-sectors structure to a less defined pattern or even a four-sectors structure. Although on a long time basis the two-sectors seem to be a prevailing feature of IMF polarity, justifying the appearance of Figure 1, the four sectors seem to be characteristic of time intervals particularly present around solar minima.

In order to see qualitatively the existence of recurrence in the type of observed structure, the values of $\log P_1/P_2$ of Figure 5 were themselves subjected to a power spectrum analysis. The results obtained for a truncation point of 50 (i.e., 150 months) are shown in Figure 6. Acoording to this spectrum, besides the periodicity of about 12.6 years probably associated with the solar cycle period, there are peaks at 3.7, 2.2 and 1.5 years. Among them, the last one, of 1.5 years, is significant at a 50% level of confidence and would show the already mentioned variations os the IMF sectorial structure in short time intervals.

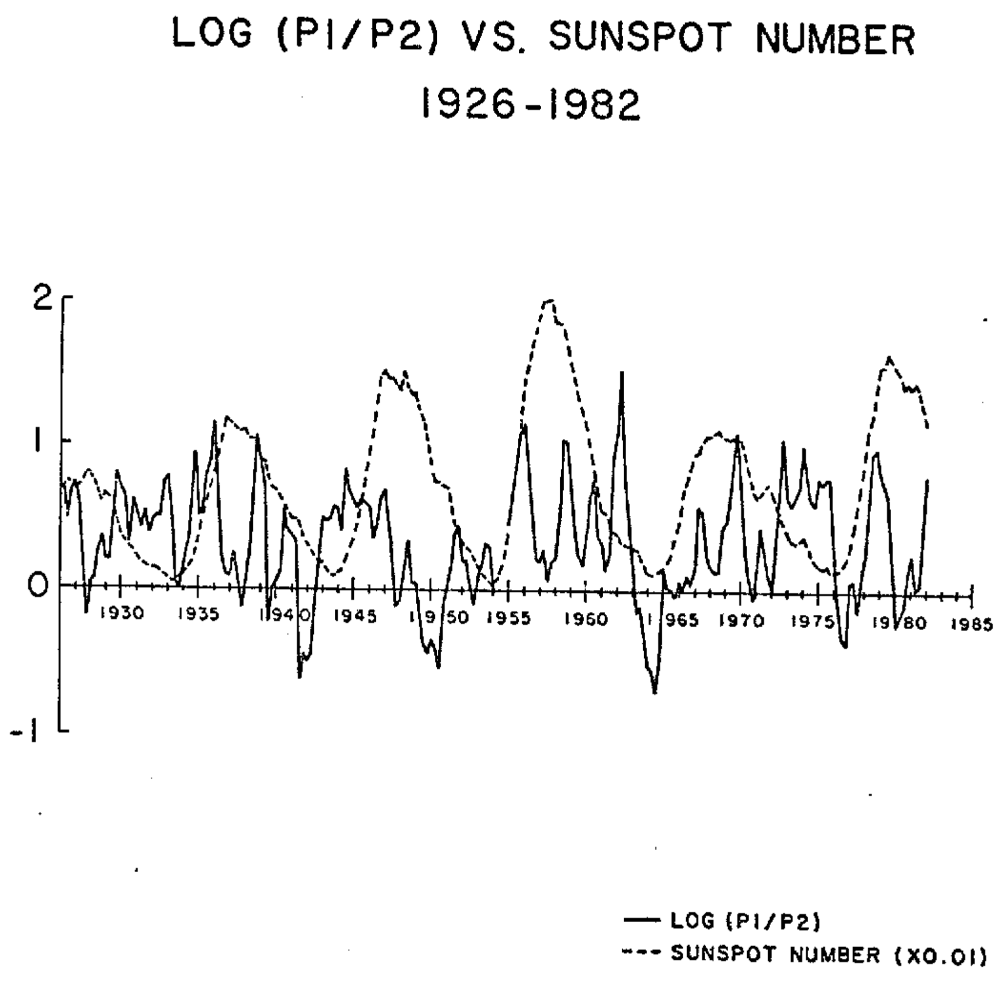

Fig. 5 - Variations of the index log (P_1/P_2) against time. Four points are given for each year, corresponding to 12-months overlapping intervals starting in January, April, July and October, respectively. The running average of the sunspot number of the same annual intervals is given for comparison.

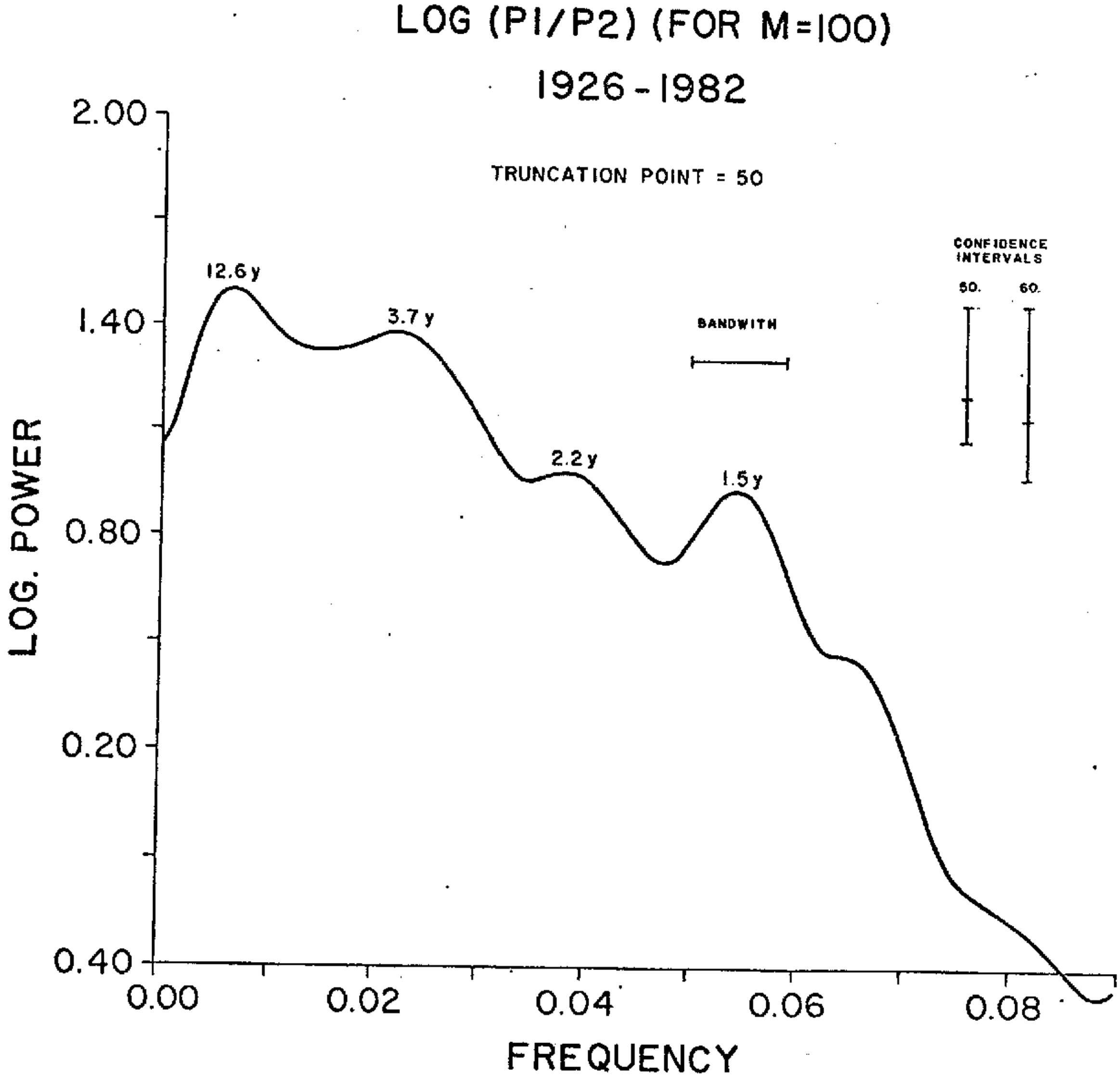

Fig. 6 - Smoothed spectral density estimates (log) for the series log P_1/P_2 (Figure 5), corresponding to a truncation point of 50 interval (150 months).

CONCLUSIONS

It becomes quite evident from the long time analysis presented above, that the sectorial structure of the IMF polarity presents continuous changes varying, with recurrence times of 1.5 to about 3 years, between patterns corresponding to quasi-symmetric bi-sectorial structures and less defined or even quasi-symmetric four-sectorial structures. The conclusion of some authors (e.g. Zerefos et al., 1977) that this structure is mainly bi-sectorial comes from the fact that the two sectors predominante on a long time basis, as seen in Figure 5. On the other hand, the hypothesis of the four sectorial structure presented by Wilcox and Ness (1965) is justified by the fact that such a conclusion was based on the observations for the year 1964 which, as we have seen, is typically a year with this type of structure.

Finally, it is worth to mention that the power spectrum of the Zurich Sunspot Number also has a rich structure in the range of 1.3 to about 5 years (Sugiura, 1980). Furthermore, a periodicity of 1.4 years was found for the auroral occurrence frequency (Silverman and Shapiro, 1983). A comparison between these periodicities with the similar ones found in the present work is expected to lead to a better understanding of the physical processes involved in this range of variability of the solar plasma dynamics.

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