A STUDY OF PERIODICITIES AND RECURRENCES IN SOLAR ACTIVITY AND COSMIC RAY MODULATION

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1. Introduction. Time variability on a wide range of time scales is the main characteristic of cosmic rays observed inside the solar cavity. As the intensity of galactic cosmic rays is assumed to be essentially constant outside the heliosphere, the temporal changes observed must be due to the interaction of CR particles with the IMF which is carried by the solar wind.

The question is then to find out the pattern of the IMF and its flow, to determine the time and spatial evolution of their configurations and to relate them to CR variations.

Unfortunately the direct measurements of the IMF and of the solar wind plasma are insufficient because they are limited to a region close to the ecliptic plane as compared to the vast 3-dimensional extension of the heliosphere. On the other hand CR particles provide an indirect measurement of the global structure of IMF since they sample a large volume of the solar cavity in their travel from its boundary to the Earth.

Yet one can tentatively try to derive important parameters of the interplanetary medium by means of the observations of the source itself, the Sun.

Solar output during the 11yr activity cycle has many different aspects such as the sunspot area and number, the development of polar coronal holes, the solar flares and the solar wind.

Furthermore among the cyclic variations of the various kinds of solar activity one has to distinguish the ones having same period but differing in phase, amplitude and pattern.

It is common practice to use the sunspot number variation as the standard of the solar cycle and to compare to it all the other relevant parameters, even though this approach has not a good physical ground. The same is true for CR intensity since Forbush (1954) discovered an inverse correlation between this latter and the sunspot number. On the other hand the changes in the solar wind characteristics are related to the temperature variations of the corona, which in turn depend on different solar features such as sunspots, flares, polar coronal holes, plages etc. It is then extremely interesting to investigate the possible relationship between these phenomena and the CR intensity.

The spectral and cross-spectral power analysis is the tool that can be used to consider over a wide range of frequencies in a global way correlations on the same time scale between two time series.

We have already analyzed CR variation of ergodic nature (Attolini et al., 1984) but we cannot exclude variations corresponding to spectral lines.

From the operational point of view the best way to study line spectrum is to obtain estimates of the power trough the periodograms and average them on a band as narrow as possible.

This has been done by averaging each periodogram to its consecutive and then repeating this operation six time. in that way we obtain a binomial smoothing which preserve the frequency information over 7 periodograms corresponding to the average of 4.43 independent data equivalent. Since before performing the FFT operation the number of data has been increased to 1024 via zero padding, each coherency value corresponds to 2.13 independent data equivalent. The coherency figure (Y12) is the one defined by Jenkins and Watts (1968). The 95% significance level has been found using simulations on random data series with the same number of data.

In our analysis we have used the monthly data series of the following relevant parameters: *sunspot number* (Rz) from 1944 to 1984 (Solar Geophys. Data); *CR intensity* (RC) from 1944 to 1984 (Huancayo-Climax pressure crrected counting rates); *aa indexes* (aa) from 1944 to 1984 (Mayaud,1973,1975); *major flares* from 1955 to 1979 (Dodson et al.,report UAG N.14,19,52,80).

2. Computations and Results.

a) RC vs Rz

The first thing to note in the comparison of the coherency spectra in Figure 1a-c computed for three different time intervals, is that we can identify two regions,the first one with frequencies higher than 1c/yr, the other one with frequencies lower than 1c/yr. The first one contains few peaks that exceed the 95% confidence level, which do not shift in frequency when increasing the length of the series and whose amplitudes remain the or at least increase with the increase of the number of data. In the other range the peaks slightly wander in frequency and in amplitude; the long wave of 22yr appears only in the longer data set and with low significant level. All the peaks in this region correspond to nearly all possible harmonics up to 10th order of the 11yr cycle in all the series as it can be better seen in the computation with zero padding of the data up to 2048. The other significant peaks of the second region are at periodicities 10.4m, 156.5d, 70.9d.
The correlation is negative (⊖) in the first two and positive (⊕) in the last case. The 156.5 days may be related to the flare occurrence.

b) RC vs aa

Since solar wind plasma drives geomagnetic activity the aa index has been used to investigate CR intensity variations caused by solar wind changes. Following the study by Feynman(1982) we have considered the aa and the aa_I (i.e. aa corrected for Rz) monthly indexes. The results are shown in Figure 2. One can see that the coherencies between CR and either aa or aa_I do not differ very much. The only difference between the two is the 11yr cycle periodicity. The significant peaks are, however, different from the RC vs Rz and the correlation is always negative. More meaningful is to compare the CR intensity deduced after the subtraction of the sunspot correlation computed according to Nagashima and Morishita (1980). In that case the coherency (Figure 3) is significant in a greater number of frequencies. These periodicities are linked to the polarity of the IMF and possibly some of them represent the aliased peaks of more fundamental periodicities such as 28.2,27.15 and 26.85 days typical either of sector structure as described by Svalgaard and Wilcox (1975) or of the recurrent decreases in CR intensity in correspondence to aa_I increases. This last fact can be consistent with the description of high speed stream effects on CR (Iucci et al.,1979). In fact the analysis by Feynman (1982) has put in evidence that the property

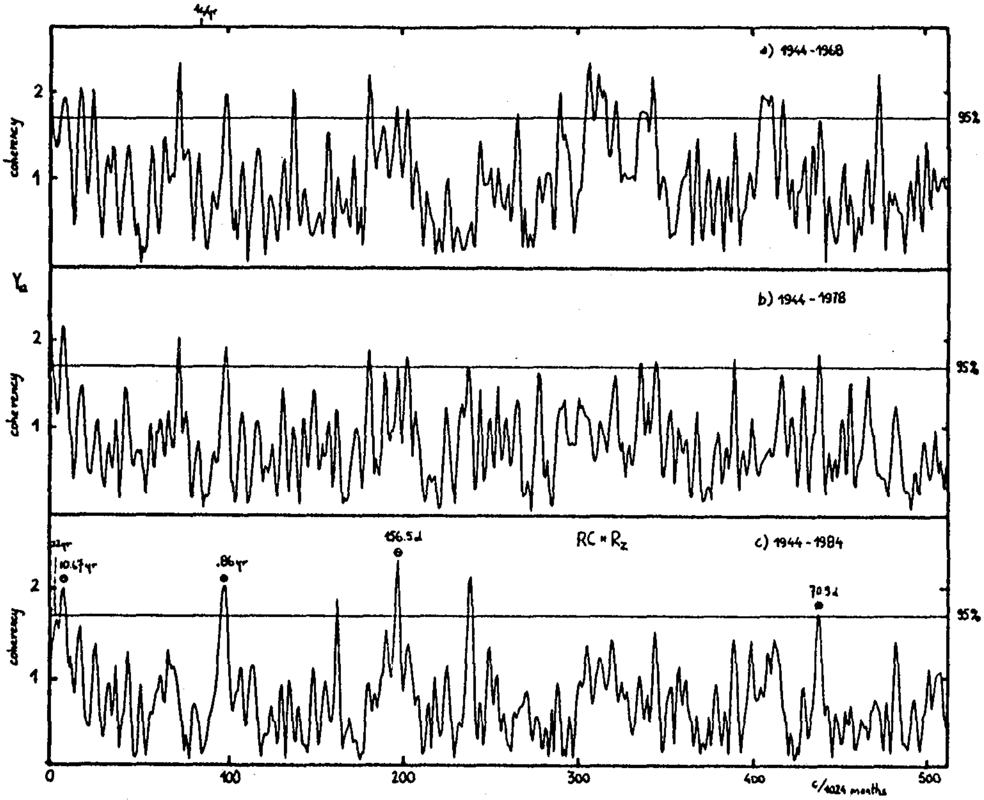

Fig.1

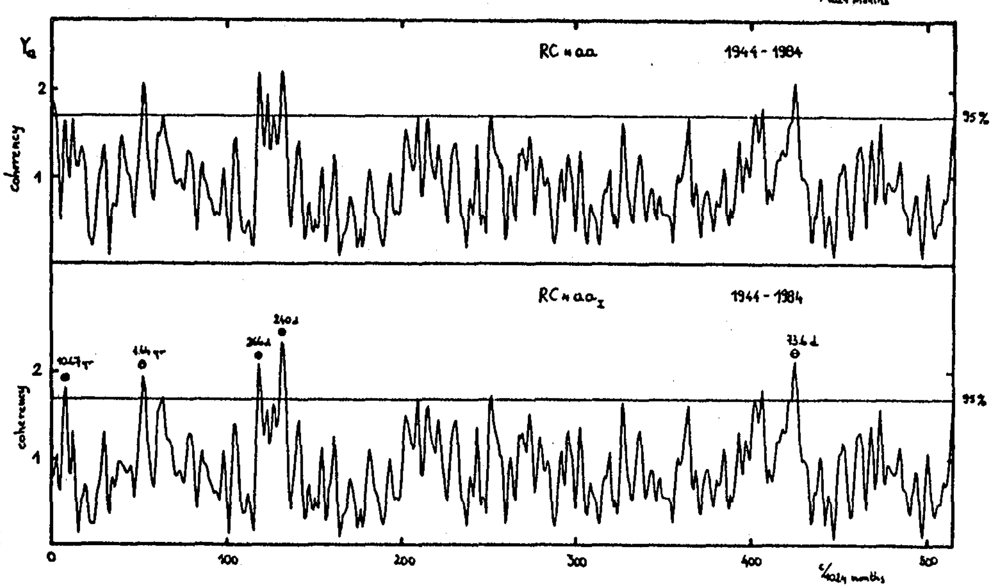

Fig.2

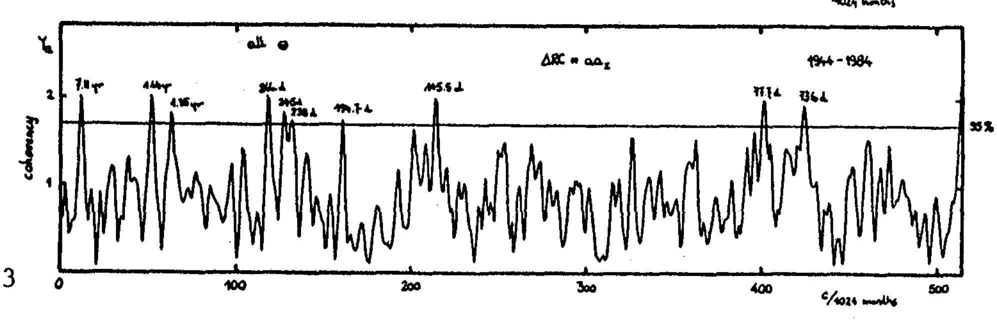

Fig.3

of the aa_I is the high recurrence probability.

It should be remarked that a plasma stream that do not engulf the Earth can nevertheless affect CR that reach us by inducing changes in the 3-dimensional IMF configuration.

c) RC vs Flares

Here the most outstanding periodicity is the one at 66.2 d and the most interesting is the one at 153.4d which is similar to the one found in hard solar flares (Rieger at al.,1984) and near to the 156.4d of RC vs Rz (Figure 4). However the Rz vs Flare coherency does not show such a correlation.

3. Conclusion. We want to stress that our work is aimed to find the correlation of two data series in narrow frequency bands. The fact that does not exist a correlation on a 2 periodogram band does not imply that a very high correlation does not exist on a much wider frequency band (e.g. CR vs Flares,Rz,aa as a whole). The existence of a narrow band correlation, on the other hand, means only that a particular type of variation in a series corresponds, with a very high probability, to a variations on the same time scale in the other series.

Among the results here reported we have found the 154d periodicity in the RC vs Flares, and some other peaks of coherency in the RC vs aa_I that when interpreted as aliased values might correspond to recurring IMF structures and solar wind streams. We cannot exclude however that some of the correspondence with aa are of terrestrial origin.

This study cannot be considered exhaustive due to the fact that other solar variables, such as polar hole size, are possibly correlated to CR intensities,however the number of observations is small so that the interpretation of the results is very difficult.

4. References. Attolini,M.R.,et al.,Nuovo Cim.,7C,413,1984// Dodson,H.W. et al.,Report UAG Nos.14,19,52,80// Feynman,J.,J.Geophys.Res.,87,6153,1982// Forbush,S.E.,J.Geophys.Res.,59,525,1954// Iucci,N. et al.,Nuovo Cim.,26,421, 1979// Jenkins,G.M. and Watts,D.G.,Spectral Analysis and Its Applications, Holden-Day,1968// Mayaud,P.N., IAGA Bulletin Nos.33,39// Nagashima,K.,and Morishita,L.,Planet.Space Sci.,28,177,1980//Rieger,E.,et al.,Nature,312, 623,1984.

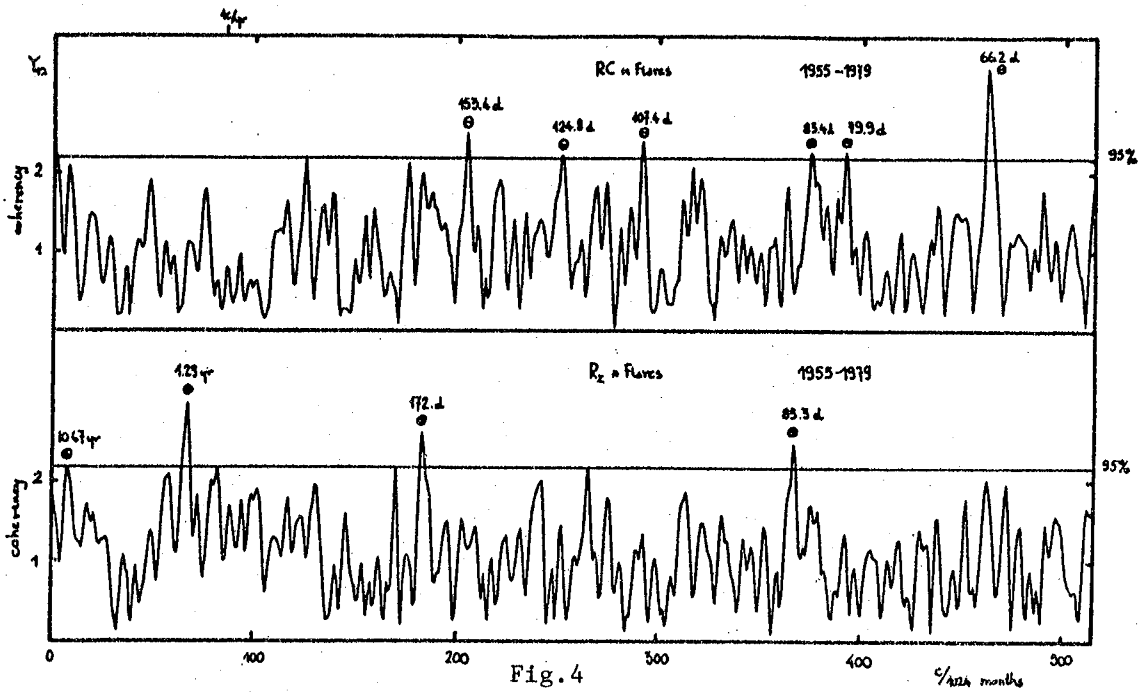

Fig.4