COSMIC RAY ^{10}Be BIENNIAL DATA AND THEIR RELATIONSHIP TO AURORAE AND SUNSPOTS.

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1.Introduction. Studies of Galactic Cosmic Ray (C.R.) variations should give information on three dimensional aspects of the heliospheric magnetic fields and on the Solar wind, which modulate their influx into the Solar System. But in order to decode the information from the C.R. series it is necessary to know the mechanisms through which the modulation is produced; and this problem is not yet solved[1], although it is clear that a balance of effects with sources at different heliospheric latitudes results in the modulated C.R. intensity.

The investigation of the structure of various time series of data, characterized by the imprint of the Solar variability and its comparison with the structure of the C.R. time series may contribute to the phenomenological individuation of the different sources of modulation.

The C.R. data are of two types: a)the direct measurements of the C.R. intensity at ground since their discovery in the last four decades or b)the record of earlier C.R. flux that has been left as cosmogenic isotopes in different reservoirs. In this paper we examine the ^{10}Be series in polar ice from 1900 to 1976 A.D. measured by J.-Beer[2] et al.(1983) in core Dye3, Greenland.

The other time series that we take into consideration are those of the Sunspot (S.S.) number (R_z)[3] of the global geomagnetic activity <aa>[4] and of the Aurorae[5].

The R_z time series is related to the contribution to the C.R. modulation resulting from the solar conditions in the equatorial region; its anticorrelation to the C.R. series is well known (see Figure 1). The Auroral activity is the result of energy transfer from the solar wind to the magnetosphere, when interplanetary shocks and recurrent wind streams with origin at different heliospheric latitudes pass by the Earth. The comparison of the <aa> index and of the aurorae series with the ^{10}Be series may lead us to the determination of a contribution to the ^{10}Be production due to effects with origin at the higher heliospheric latitudes: the effects of the stable polar high speed wind recurrent streams occuring much more frequently during the declining and minimum phases of solar activity and associated with coronal holes. The size of the polar coronal holes and the C.R. intensity from 1965 to 1976 were already found positively correlated by Hundhausen et al.[6] from 1965 to 1976. This correlation is an evidence for the importance of the drift effects or of the large-scale structure of the magnetic field effects on the C.R. modulation[7]. Therefore we expect an increased C.R. flux associated to an auroral activity independent from R_z. The identification of two types of geomagnetic activity (the transient or Sunspot shaped activity and the stable wind stream activity) has been pointed out by Legrand and Simon[8].

2.The series of Aurorae, <aa> index and Sunspot number R_z. One of the most important historical series belonging to the study of the Solar-Terrestrial relationships is the millennial series of the Aurorae. It is therefore very important to compare the behaviour and structure of this series during recent times with that of the geomagnetic activity <aa> series available from 1868 and with the R_z series available from 1701. The annual average of <aa> is in fact a terrestrial parameter objectively measured, related[9] to the annual average solar wind parameter $|B_z| V^2$. In Figure 2 the time series are shown. The Aurorae from 1721 to 1780 are those collected by Rubenson and reported by Feynman and Silverman[10] (note that they may be not homogenous to those starting in 1780[5]). On the whole the Aurorae appear in phase with R_z except for the intervals before the most important maxima of R_z in which they appear to be also abundant a little before the R_z minima.

In Figure 3 the phase cyclograms of the three series are reported at τ =10y. We notice how similar the topology (i.e. loops, bendings and stretchings) of the three series looks like. Moreover a phase shift between the cyclograms of the Aurorae (or of <aa>) and R_z can be observed. This phase shift is confirmed by the cross-cyclogram performed on the Aurorae and R_z series in the band around τ =11y (Figure 4), which is not stretched along the real axis. The two facts leed to the conclusion that there is a part of the Auroral activity which is not related to R_z and although with similar periodicity is substantially phase shifted. We have therefore computed the series of Aurorae linear-regression-corrected-for R_z, after the second order detrending. The phase cyclogram for τ =11,1y of these residual aurorae, obviously independent from R_z, is given in Figure 5, where we have also given how to find the time of maxima of the series. This cyclogram is very straight, showing that the periodicity is constant in time and equal to 11,1y. This is confirmed by the power spectral density (p.s.d.) analysis of the residual Aurorae, given in Figure 6 (lower graph) in which we give also for comparison the p.s.d. of the series of the total Aurorae (upper graph). Two interesting points must be noticed: a)the psd of total Aurorae shows two lines one at 10.0y and one at 11.1y; after correcting for the equatorial activity the residual Aurorae show only the second line; b)the psd of the residuals shows the peak at 21.6y with its third harmonic at 7y reinforced.The maxima starting from 1877 of the residual aurorae (see Figure 5) happen at about the same time of the recurrent geomagnetic activity, which has been shown by Legrand and Simon (1981) in Fig.1 of their paper to be mostly due to the polar high speed wind streams.

3.The series of ^{10}Be. The biennial experimental ^{10}Be data were smoothed by the running mean of two data, giving a series of 39 data starting from 1900-1901. The global geomagnetic activity (or the Aurorae see Figure 7a) has been splitted into the two aforementioned series: the stable-wind-stream and the transient-R_z-related activity (Figure 7b) covering the same interval and with the same averaging time of ^{10}Be shifted by 3 years according to the cross cyclogram of ^{10}Be and R_z. The ^{10}Be series has been correlated in a threefold correlation, according to the statistical model: $^{10}Be=k\langle aa\rangle_{trans} + h\langle aa\rangle_{stab}$ The threefold correlation shows a negative coefficient $k=-0.0047$ ^{10}Be units/$\langle aa\rangle$ units, $ave[\langle aa\rangle_{trans}]=32.06$ and a positive coefficient $h=0.0057$, $ave[\langle aa\rangle_{stab}]=14.79$. With these coefficients the curve of the expected values of ^{10}Be was calculated and it is shown in Figure 7c together with the experimental data. The two curves agree rather well if one takes into account the measurement experimental errors. The errors account for about 20% of the total variance of the series so that only 80% of the variance should be explained from the correlation with $\langle aa\rangle_{trans}$ and $\langle aa\rangle_{stab}$. In our case the total correlation is 62%, covering almost the entire possibility.

4.Conclusions. We have found by statistical analysis that the modulation of ^{10}Be in polar ice may be due to at least two main contributions: one is negative and in phase with the Solar flare activity modulating the cosmic ray flux in Forbush-type decreases and one is positive in phase with the appearence of large wind streams situated at both polar coronal holes. Furthermore from the analysis of Aurorae we have found that the high heliolatitude activity is related to a stable periodicity of 11.1y whereas the low heliolatitude activity contributes to the wondering of the solar cycles.

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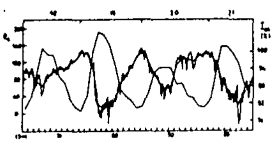
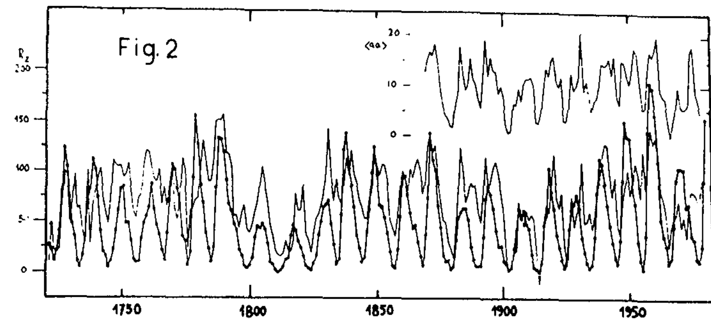


Fig. 1



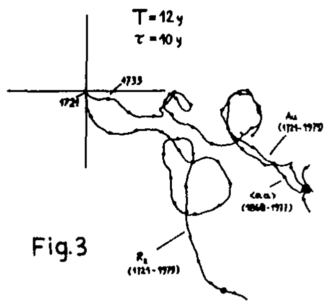


Fig. 3

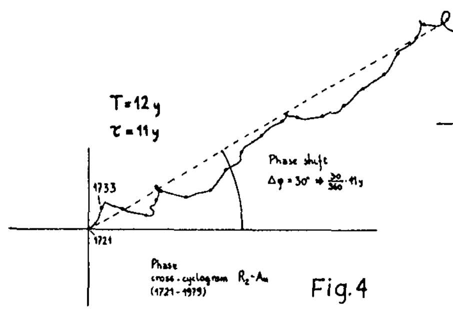


Fig. 4

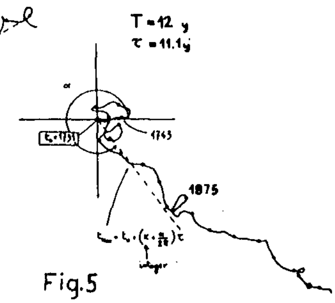
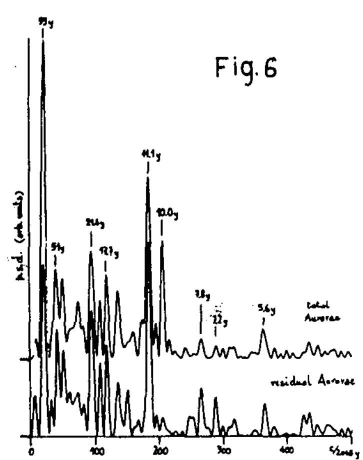


Fig. 5



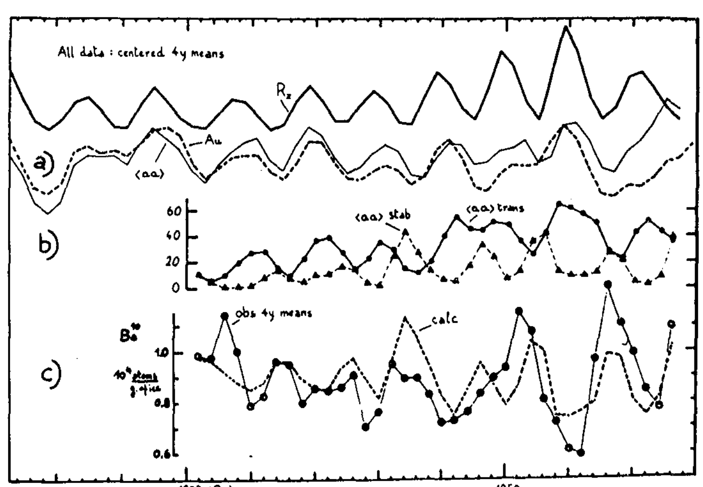


Fig. 7