COSMIC RAY SECULAR VARIATIONS IN TERRESTRIAL RECORDS AND AURORAE

M.R.Attolini, Istituto TESRE del CNR, Bologna
G.Cini Castagnoli and G.Bonino, Istituto di Fisica Generale, Università and Istituto di Cosmogeofisica,CNR,Torino, Italy
M.Galli, Dipartimento di Fisica, Università di Bologna
T.Nanni, Istituto FISBAT del CNR, Bologna

1.Introduction. The rediscovery that the Sun and the Solar wind can undergo important changes on historical time scales[1,2,3] has brought into question the stability of the cyclic behaviour of past time series of Solar and Solar-terrestrial origin. In preceding papers we have found[4,5,6] by Vector Fourier analysis that the solar eleven year cycle is present in the series of ^{10}Be, $\delta^{18}O$, in ice cores and of TL (thermoluminescence) in sea sediments during the last Millennia with a frequency modulation, that we could relate to the Sun behaviour, as tested by comparison with the Sunspot number R_z series[7], in recent times. In a companion paper of this Conference (SH 7.1-1) we have shown that the cyclogram of the series of yearly Aurorae from 1721 to 1979 linear-regression-corrected-for-R_z is straight for the periodicity τ=11,1y, indicating that such periodicity is constant in time corresponding to the only line present in the 11y band. The maxima of this component appear at the same time together with the high speed solar wind streams taking place in coronal holes situated at high heliolatitudes. This connection with a regular solar rithm induced us to search for the possibility that this frequency would be dominant also in the long running (2300 years) scanty record of historical Aurorae recorded at mid and low latitudes in European and oriental countries.

2.Historical Aurorae. The record of Aurorae[8,9] from 686BC to 1731AD is here analysed: unfortunately the Sunspot record is not available before 1700 so we cannot undertake the aforementioned procedure adopted for the yearly Aurorae. However similarities can be tested on the total series: the power spectral density (p.s.d.) of the Hystorical Aurorae has been computed for two subseries one from 687 BC to 1000 AD and the other from 1000 AD to 1731 AD; and compared to the p.s.d. of the Aurorae from 1721 to 1979 (see Figure 1). We may notice that all three p.s.d. show in the 11y band two peaks respectively around 11,1y and 10.0y: before 1000 AD at 10.8y and 9.5y whereas after 1000 AD at 11.4y and 10.5y, the recent p.s.d. at 11.1y and 10.0y. The phase cyclogram (see Figure 2) at τ=11y and T=100, infact shows frequency oscillations of duration of about 2 centuries around two main frequencies one of a little less than 11y (right bending) before 1000 AD and the other a little greater than 11y (left bending) after 1000 AD. The values of the periodicities (11.1y and 9.9y) in the recent Aurorae record could represent a transition similar to the one observable in Figure 2 around the XI century (1016 AD) and perhaps to another one which could have occurred around the beginning of the Christian era.

3.Comparison of Solar-terrestrial records. The frequency modulation of the eleven year cycle on a 2 century time scale could be associated with the presence in the series of oscillations of the same period. Therefore we have performed the phase cyclogram of the historical Aurorae (Au) series at τ=200y together with those of three other series of data in which the Solar-Terrestrial relationships could be involved: D/H in a South Pole ice core[10], ^{14}C in tree rings[11], Thermoluminescence (TL) in a sea sediment[12], from 500 A.D. up to the present time. They are shown in Figure 3. All of these cyclograms are fairly stretched, indicating that this recurrency is present during this interval in all the four series. However the phases of the four cyclograms are different. The phase shift between Au and ^{14}C is about 180°. This can be interpreted as a consequence of the known fact that increasing Solar activity corresponds to decreasing C.R. intensity and therefore cosmogenic ^{14}C production.

The cyclograms of Au and TL are approximately in phase, this favours the hypotesis that the TL signal is in direct correlation with the Solar activity.

The cyclograms of Au and D/H are out of phase of about 90°. This corresponds to the fact that the global temperature index D/H has its maximum during the ascending phase of the 200y cycle of the Aurorae. These considerations however are not sufficient to assess that the origin of the 200y cycles is definitely of solar and not of terrestrial origin, in particular because the series which shows the strongest amplitude of 200y wave and its constancy in phase is indeed the series of D/H.

Moreover the phase-cyclogram for ^{14}C over the entire la Jolla series for 8400y (see Figure 4) shows that a regular bisecular wave is not always present: trains appear from time to time, the last one starting at about the third century B.C. For comparison the cyclogram at τ=178y is shown in the same Figure. The long periodicities "Suess wiggles" have been extensively discussed by Sonett[13] and the presence of common long periodicities in ^{14}C and TL were previously pointed out by us[14].

4.Conclusions. This analysis shows that a cyclicity of about 200y is present in terrestrial natural phenomena (^{14}C in tree rings, TL series in marine sediment, D/H global temperature index and Aurorae), which could have a common control processbased on Solar-Terrestrial relationships.

If one assumes that the Aurorae record can be used as proxy data of Solar activity then:

a) its anticorrelation with ^{14}C can be interpreted as a consequence of the well known fact that increasing Solar activity corresponds to decreasing C.R. intensity;

b) its direct correlation with TL favours the hypothesis that Solar activity is responsible for this effect;

c) the global temperature index D/H has its maximum during the ascending phase of the Solar activity.

The analysis of the eleven years cyclicity of the Solar activity through the structure of the Aurorae records seems to suggest that in modern time we are having a transition similar to the one observable in the XI century AD. Moreover there is strong evidence that the eleven year cycle has undergone frequency oscillations on a time scale of two centuries, although it is very difficult to determine the periodicities with high accuracy.

References

1.Eddy J., (1980), In Proc.Conf.Ancient Sun, Geochimica and Cosmochimica Acta suppl.13, p.119

2.Siscoe L., (1980), Rev.of Geophys. and Space Phys. 18, 647

3.Feynman J., (1983), Reviews of Geophys. and Space Phys., 21, 338

4.Cini Castagnoli G., Bonino G., Attolini M.R., Galli M. and Beer J., (1984), Il Nuovo Cimento 7C, 235

5.Attolini M.R., Beer J., Cecchini S., Cini Castagnoli G. and Galli M., (1984), Proc.of Int.Symp. on C.R. modulation in the heliosphere, Morioka, Japan

6.Beer J., Oeschger H., Finkel R.C., Cini Castagnoli G., Bonino G., Attolini M.R. and Galli M., (1984), Proc. 8th Conf. on the Application of Accelerators in Research and Industry, Denton,(Texas), 12-14 nov' 84 in Nuclear Instr.& Methods (In press)

7.Attolini M.R., Galli M., Cini Castagnoli G., (1985), Solar Physics, 95, 391

8.Aurorae records: Stothers, Link, Newton, Dall'Olmo, Keimatsu (kindly provided to us by Dr. F.R.Stephenson)

9.Shove D.J., (1980), Proc.of the SolarTerrestrial Predictions Workshop U.S. Dept.of Comm., Washington DC

10.Benoist J.P., Jouzel J., Lorius C., Merlivat L., Pourchet M., (1982), Annals of Glaciology 3, 17

11.Suess H.E., (1980), Radiocarbon 22, 200

12.Cini Castagnoli G., Bonino G. and Miono S., (1982), Il Nuovo Cimento 5C, 488

13.Sonett C.P., (1984), Reviews of Geophys. and Space Phys., 22, 239

14.Attolini M.R., Bonino G., Cini Castagnoli G. and Galli M., (1983), 18th ICRC, 9, 321

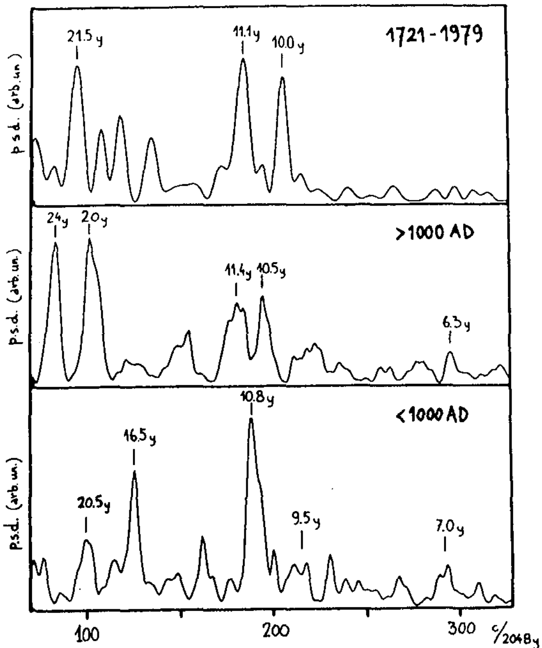

Fig. 1

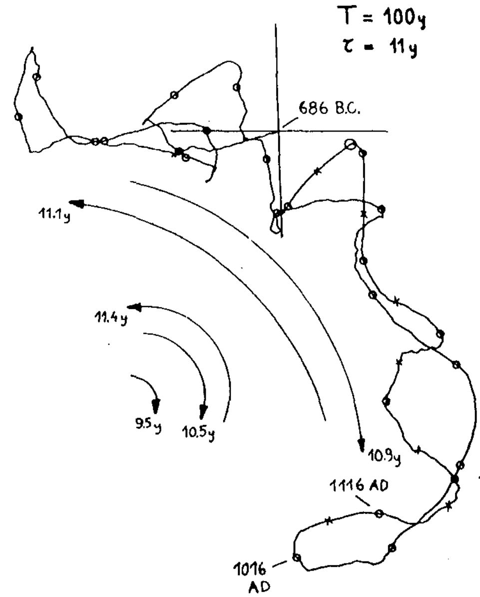

Fig. 2

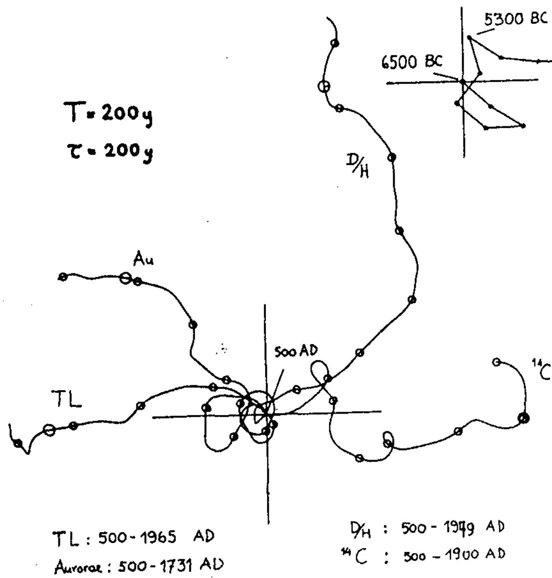

Fig. 3

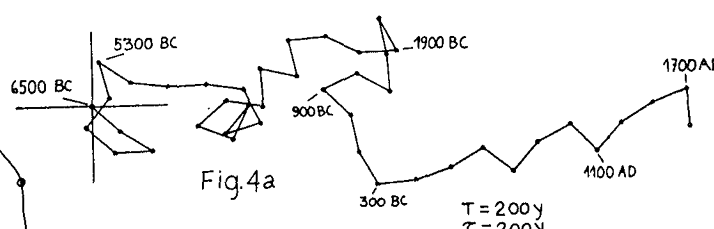

Fig. 4a

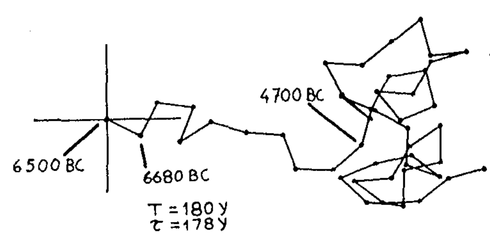

Fig. 4b