The sunspot cycle recorded in the thermoluminescence profile of the GT89/3 Ionian sea core (*)

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(ricevuto l'8 Gennaio 1996; approvato il 15 Gennaio 1996)

Summary. — We measured the thermoluminescence (TL) depth profile of the GT89/3 shallow-water Ionian sea core. This profile has been transformed into a time series using the accurate sedimentation rate previously determined by radiometric and tephroanalysis methods. The TL measurements were performed in samples of equal thickness of 2 mm, corresponding to a time interval of 3.096 y. The TL time series spans ~ 1800 y. The DFT power spectral densities in the decadal periodicity range of this TL series show significant periodicities at 10.7, 11.3 and 12 y closely similar to the periodicities present in the sunspot number series. These results confirm that the TL signal in recent sea sediments faithfully records the solar variability, as we previously proposed.

PACS 96.60.Qc – Sunspots, faculae, plages.
PACS 91.50 – Marine geology and geophysics.
PACS 78.68.Kn – Thermoluminescence.
PACS 01.30.Cc – Conference proceedings.

1. – Introduction

In the last decade, we have introduced in our laboratory a new method for the investigation of the solar-terrestrial relationships in the past millennia by measuring the variations of the thermoluminescence (TL) level accumulated in the fine polymineral material of shallow water marine cores [1-4]. At the same time, we have achieved a very high precision in the technique of the core dating. The TL depths profiles of recent Ionian sea sediments were transformed into accurate time series using the sedimentation rate $s = (0.0065 \pm 0.0007)$ cm/y, determined by radiometric and tephroanalysis methods [5, 6]. Similarities among the TL profile of the GT14 Ionian core, the radiocarbon record in tree rings and the variations of the mean annual sunspot number record R_Z suggest a solar control of the TL signal [7, 8]. The spectral

(*) Paper presented at the VII Cosmic Physics National Conference, Rimini, October 26-28, 1994.

analysis of the detrended TL time series of the GT14 core showed, in particular, the presence in the record of the periodicities 10.8, 12.06, 22.03 y [4, 8], corresponding to the well-known period of ~ 11 y, the Schwabe cycle of the sunspot number R_Z, and to the periodicity of the magnetic ~ 22 y Hale cycle. Recently, we measured the TL profile in the GT89/3 Ionian sea core collected in the same area as the previously analyzed GT14 core [9]. The periodicity of 10.8 y was confirmed in the TL profile and was found also in the carbonate profile [9].

We present here a further study of the TL profile of the GT89/3 core in the Schwabe cycle region.

2. – Thermoluminescence measurements and analysis

The TL signal comes from the bulk TL intensity of the mixture of the polymineralic crystals forming the mud of the core, and derives from an equilibrium TL level attained under two processes in competition: the TL signal induced by the environmental ionizing radiation and the bleaching effect due to the light exposure of the grains. The TL measurements in the GT89/3 core were performed in 584 samples, of equal thickness $\Delta d = 2$ mm, corresponding to a time interval $\Delta t = 3.096$ y. The TL time series spans therefore ~ 1800 y. We recall that in the GT14 core we adopted $\Delta d = 2.5$ mm, which corresponds to $\Delta t = 3.87$ y and the 467 samples analysed in that case span the same time interval. The different sampling interval allows to obtain from the analysis of the two time series results free from aliasing effects.

The preparation of the samples was done in red light, in order to preserve the original TL level; the still wet material of the core was treated as previously by successive washing in NaOH, H_2O_2, H_2O and acetone. After drying in oven at 40 °C overnight, the powder was gently sieved and the fraction < 44 μm was used. For the GT14 measurements, we prepared samples of 15 mg of powder, while for the GT89/3 we use samples of only 2.5 mg. This powder is dispersed in acetone by ultrasound apparatus; the uniform suspension is introduced in a vial and during acetone evaporation it deposits uniformly on an aluminum disk of 1 cm in diameter. Glow curve measurements are made by the TL analyzer, described by Miono and Otha [10]. Each aluminum disk is heated from room temperature up to 420 °C at a heating rate of 5 °C/s, in an atmosphere of pure nitrogen gas. The TL signal from the photomultiplier is registered by a *X-Y* recorder as a function of temperature. The uniformity of the deposition on the disks and the good heating contact give highly reliable and reproducible TL signals.

For the present analysis we read the TL intensity from the glow curves at five different temperatures, namely at 250, 280, 320, 340, 360 °C. Even if the TL signals measured at different temperatures are not independent, the use of different reading temperatures hopefully allows for a reduction of the random noise errors and represent the bulk contribution of the different components of the polymineralic crystals in the sediment to the TL signal.

3. – Results and conclusions

The TL depth profile of the core GT89/3 is obtained by averaging the signals from 3 disks for each layer (readings at the five temperatures as mentioned above). In this paper we discuss only the decadal periodicities. We consider the raw data of the two TL

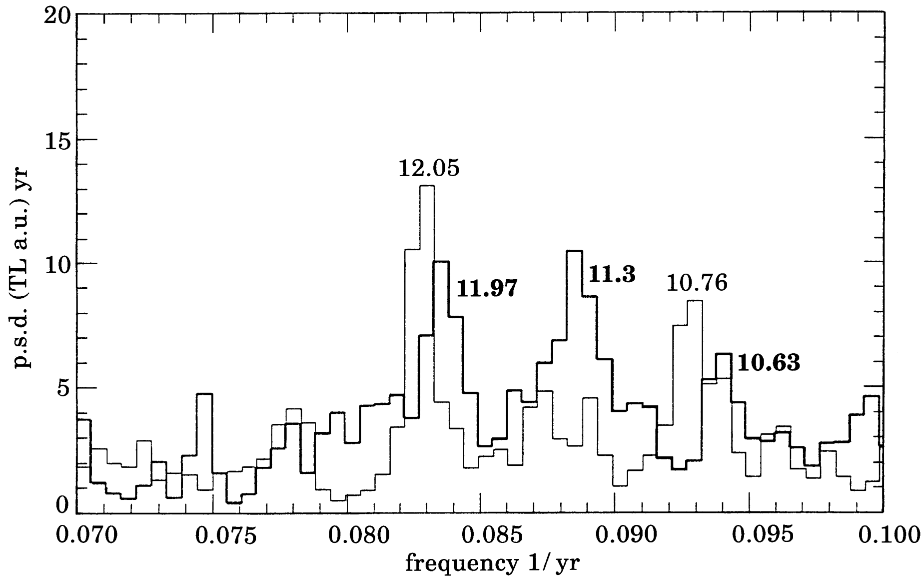

Fig. 1. – DFT power spectral densities in the decadal periodicity range of the TL time series of the GT89/3 core (heavy line) and of the GT14 core.

time series obtained for the cores GT89/3 and GT14. Figure 1 reports the DFT power spectral densities (smoothed by Hanning procedure) in the decadal periodicity range of the TL time series of the GT89/3 core (heavy line) and of the previously analyzed GT14 core. Common periodicities are present in both cores at ~ 10.7 y and 12 y. A peak at 11.3 y is evident in the TL series of GT89/3 core. We notice that the same results may be obtained by using the residuals from the 160 running average of the original time series, as previously done for the GT14 core. The higher time resolution obtained in the GT89/3 series allows for both a better quality of the TL signal and for an increased Nyquist frequency.

As is well known, the sunspot number time series (available with continuity since 1700) presents an average periodicity ~ 11 y (Schwabe cycle). Recently Rozelot [11] has shown that in the sunspot number series the following periodicities in the decadal range are present: 10.01, 10.58, 11.1, 12.05 y. The close similarity between these periodicities and those present in fig. 1 is evident.

In conclusion, these results indicate that a) the TL signal is reproduced in different cores of the shallow-water Ionian sea sediments, b) the Schwabe cycle is present in both the TL time series of the GT14 and GT89/3 cores, obtained at different sampling intervals, c) a close similarity between the periodicities in the decadal range of the TL time series of the GT89/3 core and the sunspot number series exists. These results confirm that the TL signal in recent sea sediments faithfully records the solar variability, as we previously proposed.

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We thank Prof. C. Castagnoli for useful discussions and support. Mr. A. Romero is gratefully acknowledged for the technical assistance.

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