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Reconstruction of solar activity variations in the past by measurement of cosmogenic radioisotopes in meteorites

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Abstract. Many reconstructions of solar activity variations in the past are based on the measurement of cosmogenic isotopes (such as ^{14}C and ^{10}Be) stored in terrestrial archives. The concentration of these isotopes is however influenced by terrestrial phenomena. In order to avoid this problem our group is studying cosmogenic radioisotopes in meteorites at the underground laboratory of Monte dei Cappuccini in Torino (Italy). Measurement of ^{44}Ti decay activity in 21 meteorites has revealed a centennial oscillation superimposed on a decreasing trend of the cosmic ray flux in the last 235 years. The decreasing trend is consistent with some models based on solar open magnetic field variations. We show some preliminary results obtained using a new acquisition system we have recently developed and set up in order to enhance selectivity of ^{44}Ti detection.

Key words. Sun: activity – Meteoroids – Cosmic rays – Sun: magnetic fields – Techniques: gamma spectroscopy – Sunspots – Interplanetary medium – Solar-terrestrial relations

1. Introduction

Galactic cosmic ray (GCR) flux in the interplanetary space is modulated by the solar magnetic field and therefore an approach to study solar activity in the past is to measure cosmogenic isotope records. For many years extensive studies on cosmogenic ^{10}Be and ^{14}C radioisotopes produced in Earth's atmosphere and subsequently stored in terrestrial archives, such as ice cores and tree rings, have been carried out in order to deduce information about solar activity in the past. The measured records are however affected by terrestrial processes such as geomagnetic field variations, climate-variable deposition rates and exchange between various reservoirs; on the contrary the radioactivity produced in meteorites is free of these interferences. In space, meteoroids are exposed to both solar and galactic cosmic rays, but the isotope production is dominated by GCR particles, as solar particle effects are limited to the outermost layer ($\lesssim$ 5 cm), which seldom survives during the atmospheric transit.

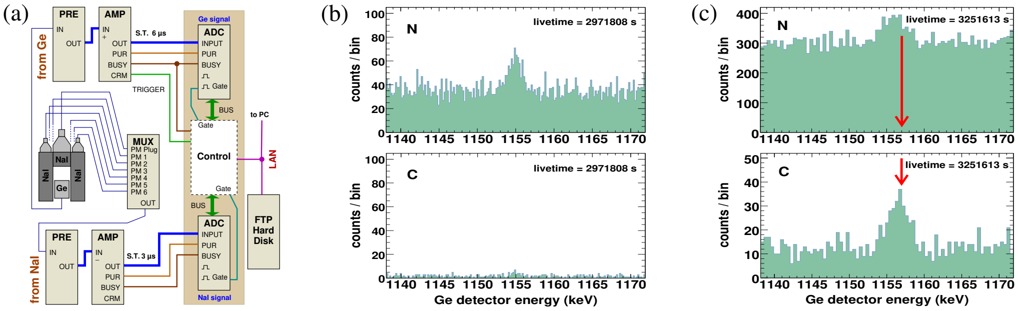

Fig. 1. a) Block diagram of the detector assembly. b) Detail of detector background for (N)ormally acquired Ge signal and after filtering the data with Ge-NaI (C)oincidence energy windows. c) N and C spectra for Dhajala meteorite (fall 1976, India), showing 1157.03 keV ^{44}Sc(^{44}Ti) prominent γ peak after data filtering.

By measuring radioisotopes having different half lives it is possible to study GCR variations on different time scales. In particular ^{44}Ti ($t_{1/2}$ = 59.2 years) in meteorites is suitable for studying solar activity variations on centennial scale. This radioisotope is mainly produced in spallation reactions induced by cosmic ray protons in meteoritic iron and nickel.

Our group has developed γ-ray spectrometers to measure the very low ^{44}Ti activity in meteorites (≈1 dpm/kg). The main challenge is the removal of the strong interference by ^{214}Bi γ's from the naturally occurring decay chain of the ^{238}U. In the underground (70 m.w.e.) laboratory of Monte dei Cappuccini in Torino, Italy, we have so far measured 21 chondrites which fell during the last 235 years (Bonino et al. 1995; Taricco et al. 2006). These measurements show a linear decreasing trend of ~43% in ^{44}Ti activity (GCR flux) during the past 235 years, superimposed on an ~87 year oscillation, with amplitude (peak to trough) of ~20%. These measurements have also been used to validate different solar activity reconstruction models (Usoskin et al. 2006).

2. New spectrometer: preliminary results

Recently we have set up a new spectrometer using the detectors described in Taricco et al. (2007): the main detector is a high efficiency and resolution hyperpure Ge crystal (mass ~3 kg) working in coincidence with a surrounding NaI(Tl) umbrella (mass ~90 kg; 7 photomultipliers). The assembly is housed in a thick Pb-Cd-Cu passive shielding with empty spaces filled with polyethylene to minimize radon from ambient air. The cavity for γ counting can accommodate a rock of mass up to ~1 kg.

We have developed and installed a multiparametric Ge-NaI acquisition system (Fig. 1a), which allows to flexibly filter spectroscopic information after data acquisition by choosing optimal Ge-NaI coincidence energy windows, crucial for selective ^{44}Ti activity detection. Moreover, we have developed the managing software embedded in the control electronics in order to allow autonomous acquisition and storage of data for the long-duration meteorite measurements.

Figures 1b,c show some preliminary results, notably the efficient removal of the ^{214}Bi 1155 keV γ peak in detector background and Dhajala meteorite spectra after filtering the acquired data with coincidence windows.

This new γ-ray spectrometer system can possibly be used to measure meteorites which fell even more than two centuries ago.

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