Performance test of a large modular cosmic-ray detector

F Signoretti, M Storini, M F Marcucci and M Laurenza

Institute for Space Astrophysics and Planetology, National Institute for Astrophysics, Area di Ricerca Tor Vergata, Via del Fosso del Cavaliere 100, 00133 Roma, Italy

E-mail: signoretti@fis.uniroma3.it

Abstract. Recently, details of modular cosmic ray detectors developed by the staff of the SVIRCO Observatory and Terrestrial Physics Laboratory (Rome, National Institute for Astrophysics) were published (Signoretti and Storini, 2011). Data recorded during June 2011 by a modular mobile neutron detector, equipped with a large helium counter (5.08 cm in diameter, 191 cm long) and assembled with twenty-three modules, were carefully checked and used to investigate the detector response to the perturbations originating on the Sun and travelling through the interplanetary medium. We show that at the Rome rigidity threshold (about 6.3 GV) the registered intensity well accounts for the macro perturbations in the near-Earth Space. Nevertheless, to investigate the fine structure of the perturbations the modular detector should operate at mountain altitudes or in polar areas.

1. Introduction

The launch of the two spacecraft of the BepiColombo mission to Mercury (collaboration ESA/JAXA), scheduled by August 2014, was postponed by one year. Until then we continue to observe the progress of solar activity during the current sunspot cycle (n° 24).

Despite December 2008 is considered as the period for the solar minimum of cycle n° 23, a long near quiescent period characterized the transition between the past and the new cycle, and the first significant Forbush decrease, in the galactic cosmic ray intensity, was identified during February 2011, as described in a previous paper [1].

In June 2011 a low/moderate solar activity was observed (see Sect. 2) and such period was used to investigate the response of a large modular cosmic-ray detector (see Sect. 3) to the traveling interplanetary perturbations reaching and overcoming the Earth (see Sect. 4). Results are discussed and some conclusions are derived.

2. Solar/Interplanetary conditions during June 2011

The solar activity during June 2011 was characterized by no X-class and only two M-class X-ray flares. The first flare (07 June: M2.5/2N, Region 11226: S21 W64) was accompanied by Type II and Type IV radio emissions and a solar proton event was identified in the terrestrial environment (start: 08:20 UT, maximum: 18:20 UT, following NOAA/SWPC definition). Nevertheless, the entity of the event was very low (see http://www.swpc.noaa.gov/ftpdir/indices/SPE.txt). The second flare (14 June: M1.3/SF; Region 11236: N15 E77), with no registration of Type II and/or Type IV radio emissions, did not produce a NOAA/SWPC proton event. The period showed some solar filament eruptions and coronal mass ejections with solar wind (SW) streams coming also from coronal holes.
Moreover, no Ground Level Enhancements (GLEs) were observed by the world-wide network of ground-based cosmic ray detectors [2]. In summary the activity level of the Sun can be classified as low/moderate during the whole month. For the sake of completeness the maximum and minimum daily values of some involved parameters have been reported in Table 1.

**Table 1.** Daily data of some solar/interplanetary parameters. Numbers inside brackets refer to the day of the month.

| June 2011       | Sunspot Area | Radio Flux | Proton Fluence [>100 MeV] | IM Field | SW Speed |
|-----------------|--------------|------------|---------------------------|----------|----------|
|                 | (10^8 hemi.) | (10.7 cm)  | (part/cm^2 day sr)        | (nT)     | (km/s)   |
| Maximum         | 720 [03]     | 114 [01]   | 1.5 e+05 [07]             | 10.9 [05]| 610 [24] |
| Minimum         | 10 [12]      | 85 [12]    | 2.5 e+03 [23]             | 3.2 [27] | 328 [30] |

3. **Test of a large modular cosmic-ray detector at SVIRCO Observatory and TPL in Rome**

Recently, Signoretti and Storini [3] introduced a smart modular design of neutron detectors fit for the purpose of assembling new cosmic ray monitors with helium counters of different lengths. Details of the realization and aspects of the performances of such detectors were discussed as well. Figure 1 illustrates the single elements and the assembly of the large (216 cm long) modular detector operating at the SVIRCO (Italian acronym for Studio Variazioni Intensità Raggi Cosmici) Observatory and Terrestrial Physics Laboratory of Rome [4].

![Figure 1. The assembly of a large modular cosmic-ray detector.](image-url)

The SVIRCO Observatory (41.86° N, 12.47° E, altitude about 0 m a.s.l.; cutoff rigidity about 6.3 GV) is provided with a double air-conditioning system and the temperature inside the detector rooms is maintained in a range of 23°-28° C, meanwhile the relative humidity is kept below 60%. A special care is applied to the atmospheric pressure measurements which are carried out by three high-precision barometers. These instruments, achieving a resolution up to 0.01 hPa, are continuously cross-checked for the best measuring accuracy and reliability. Furthermore the barometers are equipped with different types of transducer namely: vibrating cylinder, aneroid and quartz, therefore throughout their
different behaviours, it is possible to point out the occurrence of any long-term drift and eventually to re-calibrate the instruments.

Since January 2005 the Observatory has been equipped with a standard super neutron monitor (IQSY type; [5]) in the 20NM-64 configuration. The overall stability of the neutron monitor is controlled by means of the section ratios. The hourly counting rate of each section, divided by the total rate, is plotted in real time on a daily diagram. Moreover, the daily averages of these ratios are separately plotted, as percentage, in monthly histograms (see [6] for the 2011).

At the beginning of 2007 a small (90 cm) mobile neutron detector (realized with a modular design) was added to the Observatory and during 2010 another modular detector (in the largest configuration) started operating. The two modular detectors have been housed in a room separated from the 20NM-64 one in order to verify their reliability in various environmental operating conditions.

The data recorded at SVIRCO Observatory during June 2011 are reported in figure 2. Panel 1 shows the tri-hourly normalized rate of the large modular neutron detector together with the one of the standard 20NM-64 (modular neutron detector 100% = 142 cts/minute, 20NM-64 100% = 9100 cts/minute). Panel 2 displays the trend of the hourly averages of the atmospheric pressure and panel 3 the ones of the ambient temperatures measured in the two separated rooms. Finally the panel 4 reports the hourly relative humidity inside the Observatory.

The monitoring of the ambient parameters shows that there was a good control of the environmental conditions, except for the night of June 10, when an “open doors” to public visitors happened. Moreover, the coherence of the data recorded by the super monitor and the modular detector is adequate, despite the large difference between their counting rates.

Figure 2. Panel 1: time history of the nucleonic intensity recorded by the 20NM-64 and by the modular detector during June 2011. Panel 2: trend of the atmospheric pressure. Panels 3 and 4: environmental parameters inside the Observatory.

4. Conclusions
Figure 3 collects the daily averages of some interplanetary/terrestrial data for June 2011 (http://omniweb.gsfc.nasa.gov/cgi/nx1.cgi). In panel 1 it is plotted the proton flux for energies greater than 30 MeV whereas panels 2 to 5 display the SW parameters. Panels 6 and 8 report two geomagnetic indices and panel 7 compares the intensities registered by the two cosmic-ray detectors.
As it can be seen the detector responses to interplanetary perturbations are equivalent on daily basis. For example, the response to the last SW stream, which is coming from a coronal hole, demonstrates the well-known associated characteristics in either case.

Conversely the investigation of events with a fine resolution can restrict the use of the modular detector unless it is located or moved somewhere it is possible to get an adequate counting rate, such as mountains or polar areas, taking advantage of its small volume and reduced cost, compared with the ones of a standard detector.

Figure 3. Daily averages of some interplanetary/terrestrial parameters (see the text).

Acknowledgements
Part of this work was performed inside the ASI/INAF contract I/022/10/0. The modular cosmic-ray detector was mainly funded by the National Antarctic Research Program of Italy. The Rome super monitor (20NM-64) is currently supported by INAF/UNIRomaTre.

References
[1] Signoretti F, Laurenza M, Marcucci M F and Storini M 2012 Proc. 32nd ICRC (Beijing, China, 11-18 August 2011) 11 267-70
[2] Mavromichalaki H et al. 2011 Adv. Space Res. 47 2210-22
[3] Signoretti F and Storini M 2011 Astrophys. Space Sci. Trans. 7 11-14
[4] Storini M and Signoretti F 2009 Adv. Space Res. 44 1221-31
[5] Hatton C J and Carmichael H 1964 Can. J. Phys. 42 2443-72
[6] Signoretti F, Re F, Massetti S, Storini M and Parisi M 2012 Report IAPS/INAF 2012-11