Cosmic Rays during IHY/CIP 57 Campaigns

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***Abstract*—Some results obtained from cosmic ray measurements during the IHY/CIP 57 campaigns (June 7 [+/- 7 days] and December 7 [+/- 7 days], 2007) are described here. Particular attention is paid to the behaviour of the first harmonic of the cosmic ray diurnal variation recorded by the SVIRCO Observatory and Terrestrial Physics Laboratory of Rome (INAF/IFSI-Roma, Italy).**

1. Introduction

IN the 50th anniversary of the International Geophysical Year (IGY), the 2007 IHY (acronym for International Heliophysical Year) activities were built up on four programme elements: Science, Observatory Development, History and Outreach (see, for instance, [1]). Work for the four elements is performed in Italy by the institutions reported in the upper panel of Fig. 1. An Italian Web site was built up (http://ihy.oato.inaf.it) and the Sun-Earth Observing Network (see lower panel of Fig. 1; e.g. [2]-[3]) gave its contribution. Indeed, the IHY officially runs from March 2007 to 2009 but in 2007 many scientific efforts were performed to accomplish IHY requirements. Among them, a National Coordinated Investigation Programme (CIP 57, proposed by M. Storini) was lunched: *Solar Minimum Watching with Italian SINERGIES and more*. The scientific goal was the investigation of solar minimum features in Solar-Terrestrial Relations just during the time intervals characterized by a null sub-Earth point on the Sun (i.e. around June 7 [first observational campaign] and December 7 [second observational campaign], as can be derived from the ecliptic inclination of the Sun's rotation axis). Preliminary results suggest that:

- during the first campaign (May 31 – June 14, 2007) only three active regions (NOAA/USAF Group 10958 [CMP day: ~ 3.9], 10959 [CMP day: ~ 5.6] and 10960 [CMP day: ~ 7.7]) crossed the solar visible disk. H-alpha and X-ray solar flares were associated only to the 10960 region. The two largest soft X-ray flares were: M7.0 @ 02:12:00 of June 3 and M8.9 @ 05:13:00 of June 4. The solar corona was almost radio-quiet on May 31, radio-active on June 1-6 and 9, then it was progressively tending to a radio-quiet level at the end of the investigated period. On June 3 spectral observations underlined type IV and type II radio emissions, while SOHO/LASCO showed poor CME events during the first campaign.

- during the second campaign (November 30 – December 14, 2007) only four active regions (NOAA/USAF Group 10976 [CMP day: ~ 3.9], 10979 [CMP day: ~ 4.0], 10977 [CMP day: ~ 6.9], and 10978 [CMP day: ~ 12.0] crossed the solar visible disk. The two largest soft X-ray flares were: B9.4 @ 16:06:00 of December 9 and C4.5 @ 10:03:00 of December 13. The available data indicated an almost radio-quiet corona during the investigated period, with a tendency to a slight increase around the end. No type II and/or type IV radio emissions were observed and again poor CME events were registered too.

More details on solar activity features during the selected campaigns can be found at http://sgd.ngdc.noaa.gov/sgdpdf.

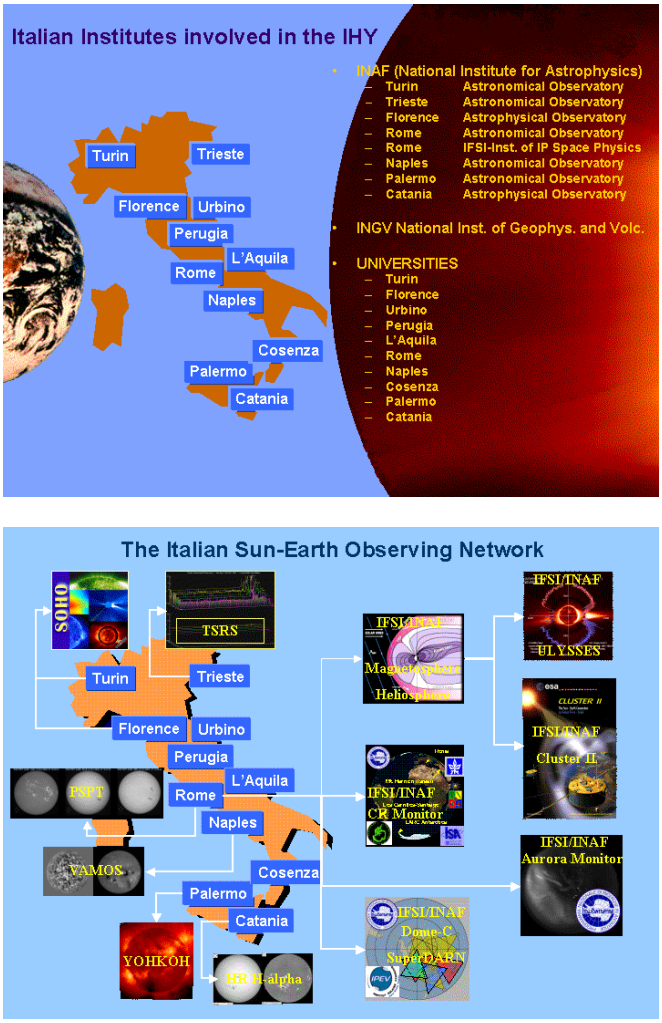

Fig. 1 – Italian Synergies for IHY activities (2007-2009).

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2. A MINI-NETWORK FOR COSMIC RAYS

During 2005 several Institutes from the National Research Council (Consiglio Nazionale delle Ricerche – acronym: CNR) of Italy were taken over by the National Institute for Astrophysics (Istituto Nazionale di Astrofisica – acronym: INAF). Also the Istituto di Fisica dello Spazio Interplanetario (acronym: IFSI) passed to INAF with its measurements sites. In Figure 2 the cosmic ray observatories supported by the INAF/IFSI-Roma partnership are shown.

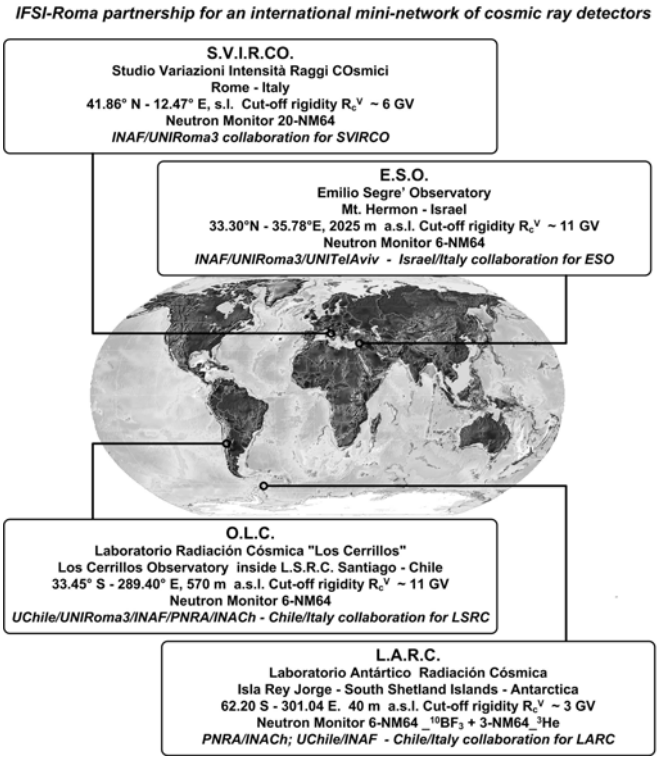

Fig. 2 – INAF/IFSI-Roma for a mini-network of neutron monitors.

During the two IHY/CIP 57 Campaigns all the cosmic ray detectors were running. Figures 3 and 4 illustrate the response of the LARC (first and second panels from top), SVIRCO (third panel) and OLC (fourth panel) neutron monitors to the incoming of galactic cosmic rays. In each panel the upper trends show the anti-correlation between the measured pressure level and the counting rate, while the lower plot reports the pressure corrected data.

Figure 3 shows that the near-Earth environment was reached mainly by three interplanetary perturbations during the first campaign. A moderate modulation of the cosmic ray intensity (I) is easily identifiable for each event (start: June 1, June 7 and June 13). The ratio $\Delta I/I$, estimated on daily basis, follows the rule for co-rotating solar wind macrostructures ($\Delta I/I \sim 0.5$ % for a speed variability $\Delta V/V \sim$ 100 km/s; see [4] and references therein). Hence, no relevant transient interplanetary perturbations were traveling from the Sun to the Earth, as supported by the absence of Forbush decreases [5-6].

Figure 4 reveals a similar scenario during the second campaign: moderate modulation phenomena inside a period characterized by an increasing cosmic-ray intensity level. More precisely, three events can be identified (start: Nov. 29 [not shown in the figure], Dec. 4 and Dec. 8).

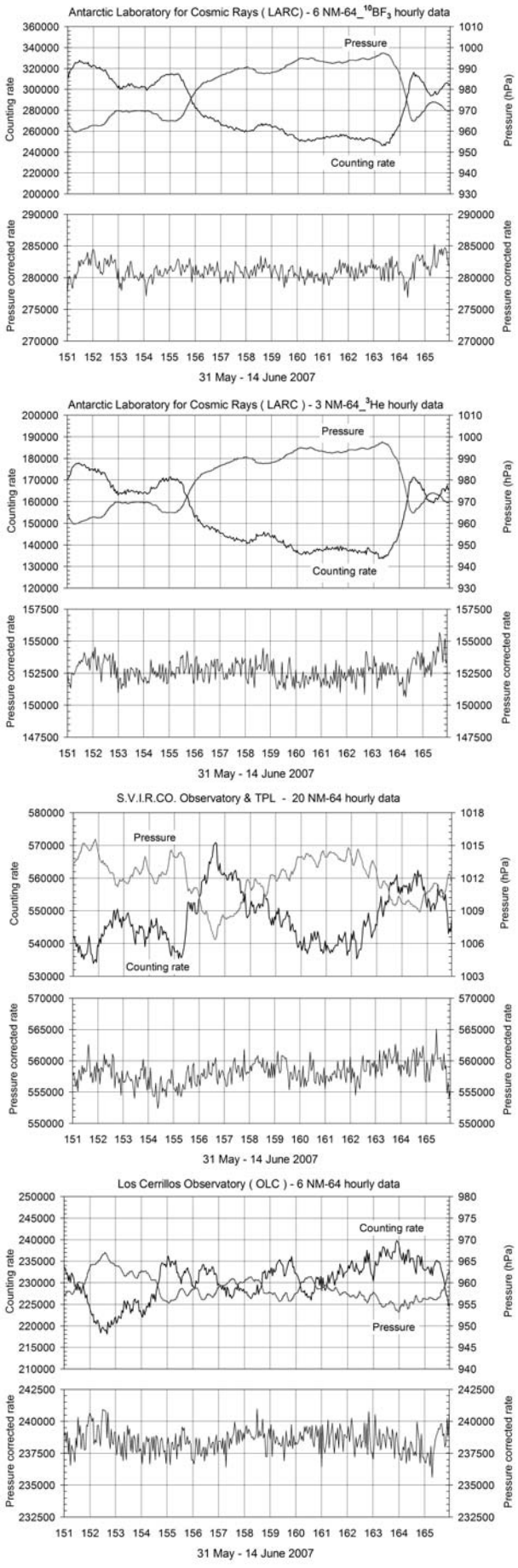

Fig. 3 – Pressure and cosmic ray intensity as derived from LARC (6-NM-64_$^{10}BF_3$ and 3-NM-64_^{3}He detectors), SVIRCO (20-NM-64 detector) and OLC (6-NM-64 detector) during the first IHY/CIP 57 campaign performed during 2007 by INAF/IFSI-Roma.

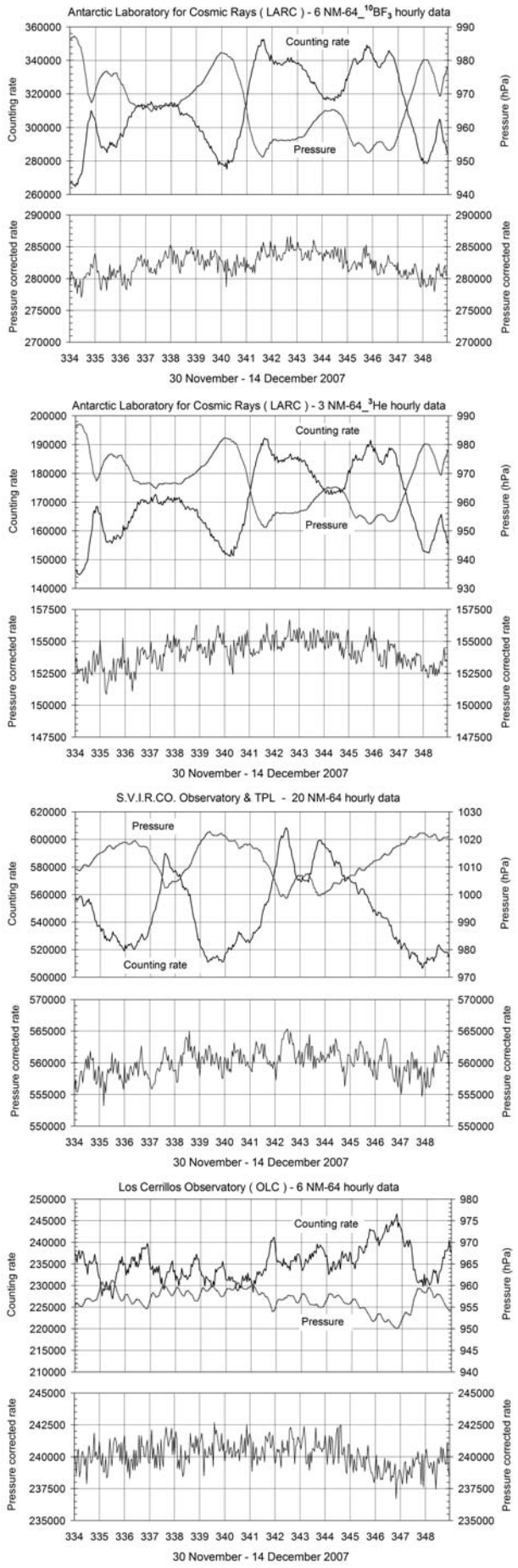

Fig. 4 – Pressure and cosmic ray intensity as derived from LARC (6-NM-64_$^{10}BF_3$ and 3-NM-64_^{3}He detectors), SVIRCO (20-NM-64 detector) and OLC (6-NM-64 detector) during the second IHY/CIP 57 campaign performed during 2007 by INAF/IFSI-Roma.

Next Section describes the observed behaviour of the diurnal wave registered at the SVIRCO Observatory and Terrestrial Physics Laboratory (TPL) of Rome during the campaigns.

3. Diurnal Wave From SVIRCO Data

The data of the nucleonic component of cosmic rays obtained in Rome by the 20-NM-64 detector are corrected for pressure variations at a reference level of 1009.25 hPa (see [7] for 2007 data) and normalized to the average of the counting rate of the past maximum in cosmic ray data (Jan.-Feb. 1997 - 100 % rate: 554946 cts/h – 17-NM-64).

The corrected hourly rates are routinely processed to obtain the 24h- and 5h-running averages. Finally, for each day, the difference between the two time series is treated with the Fourier Technique, in order to determine the amplitude (in percent) and the time of the maximum (in UT) of the three harmonics of the diurnal variation.

The daily amplitudes [A_k(k=1,2,3)] and Phases [Φ_k(k=1,2,3)] of the diurnal harmonics, together with the A_o term of the Fourier reference level are published as INAF/IFSI-Roma Reports (see [8] for 2006-2007).

Figure 5 shows the daily average nucleonic intensity (upper panel), the amplitude (middle panel) and phase (bottom panel) of the first harmonic of the diurnal wave for an extended period around the first campaign (May 15 – June 30, 2007). To notice the low level of the first harmonic amplitude (< 0.2 %) and the oscillating character of the corresponding trend for the first harmonic phase (range: 21 UT – 07 UT) during the campaign period.

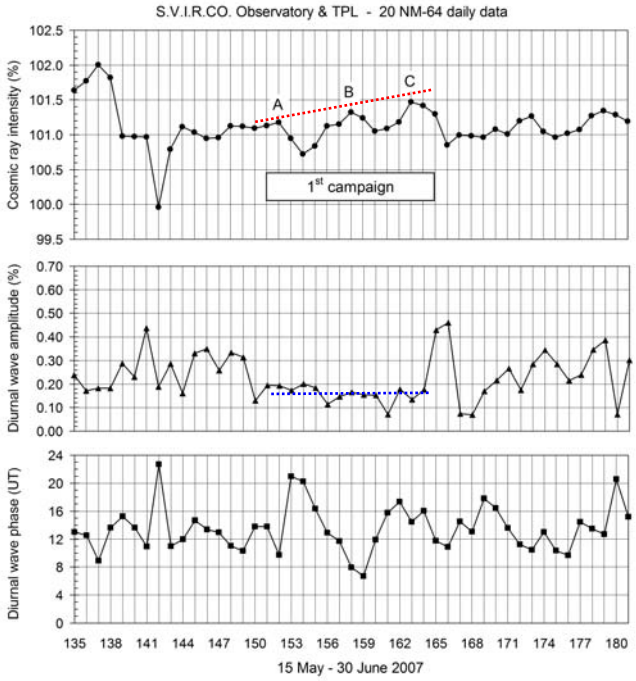

Fig. 5 – Cosmic ray intensity, amplitude and phase of the first harmonic of the diurnal wave at Rome from May 15 to June 30, 2007. A, B and C refer to the start of the moderated cosmic ray modulations. The dotted segment in the upper panel underline the increasing intensity trend and in the middle panel the relative low amplitude of the first harmonic of the diurnal wave.

Figure 6 reports the same parameters of Figure 5 for an extended period around the second campaign (November 15 – December 31, 2007). In this case the oscillating feature is observed in the amplitude of the first harmonic of the diurnal wave, while its phase is shifted towards the morning hours. More precisely, the phase is roughly constant from November 30 to December 3 (~ 14 UT) and decreases till ~ 8 UT (December 10) to recovers after then.

In the next Section we will show the reconstruction of the amplitude of the first harmonic of the diurnal wave.

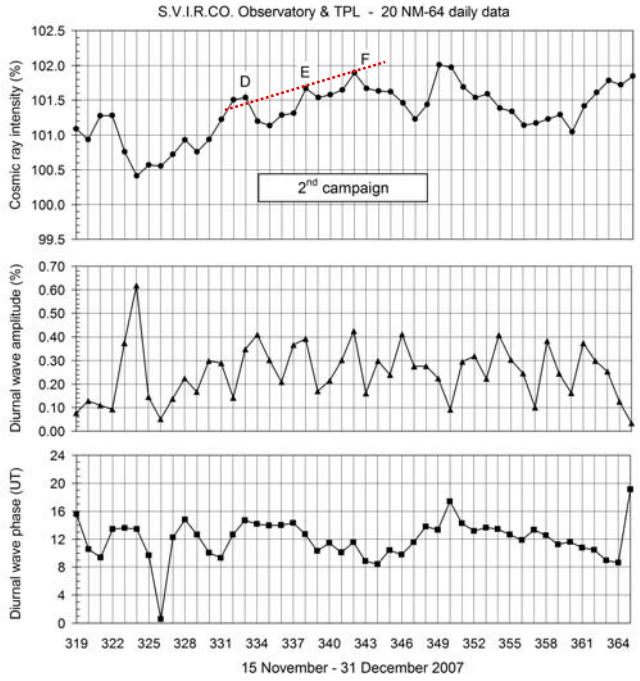

Fig. 6 – As in Fig. 5 for November 15 to December 31, 2007. D, E and F refer to the start of the moderated cosmic-ray modulation phenomena.

4. DISCUSSION

The preliminary analysis of the cosmic ray data registered by the mini-network of neutron monitors during the IHY/CIP 57 campaigns has just demonstrated that the Solar-Terrestrial System was near the minimum level of solar activity during 2007 (see Figure 7 for monthly values between July 1957 and October 2008). In fact, the monthly average of the SVIRCO intensity during October 2008 was 102 % but this value was already reached on daily basis during 2007 (see Figures 5 and 6). Hence, the performed campaigns can help to characterize the minimum phase of solar activity in the inner heliosphere. Nevertheless, we have also underlined for the campaigns that each event recovery is to an intensity level greater than the one of the pre-event (dotted segments).

In summary, the interplanetary perturbations traveling in the inner heliosphere during the experimental campaigns were able to produce small and short-term modulation effects on the galactic cosmic ray population. They are:

- $\Delta I/I \sim 0.6$ % : A event,
- $\Delta I/I \sim 0.3$ % : B event,
- $\Delta I/I \sim 0.7$ % : C event,
- $\Delta I/I \sim 0.4$ % : D event,
- $\Delta I/I \sim 0.2$ % : E event,
- $\Delta I/I \sim 0.8$ % : F event,

as derived from SVIRCO (Rome; ~ 6.3 GV) daily data. However, no transient high-speed solar wind streams were present in both periods and no Forbush decreases were registered, as expected from a nearly quiet Sun.

We have reconstructed the amplitude of the first harmonic of the diurnal wave and it is reported in Figures 8 and 9 for 15 May – 30 June and 15 November – 31 December, respectively. It is possible to observe that the wave is generally contained in the interval ± 0.4 % (except for 20 November).

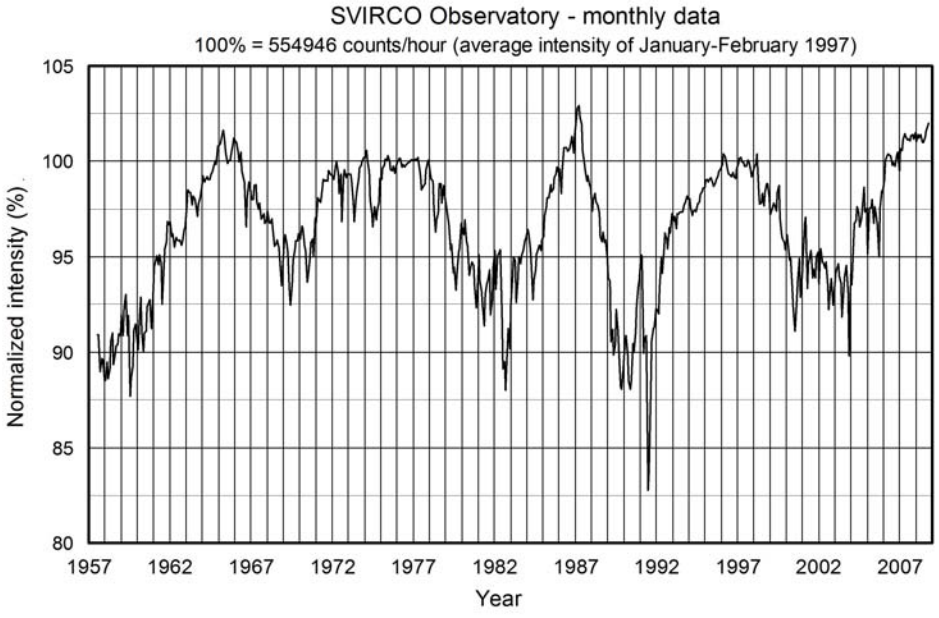

Fig. 7 – Time history of the monthly pressure-corrected data from SVIRCO neutron monitor (Rome – Italy), covering July 1957 to October 2008.

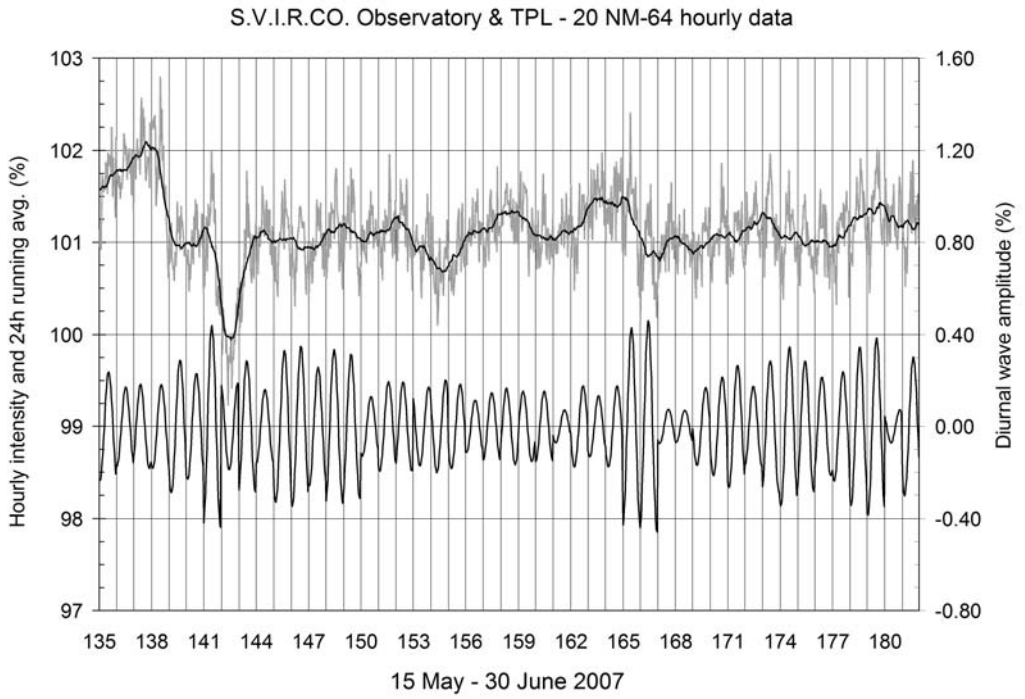

Fig. 8 – Hourly pressure-corrected data from SVIRCO neutron monitor with the 24h-running means (upper graph) and time history of the reconstructed first harmonic of the diurnal wave (lower graph) for the first IHY/CIP 57 Campaign.

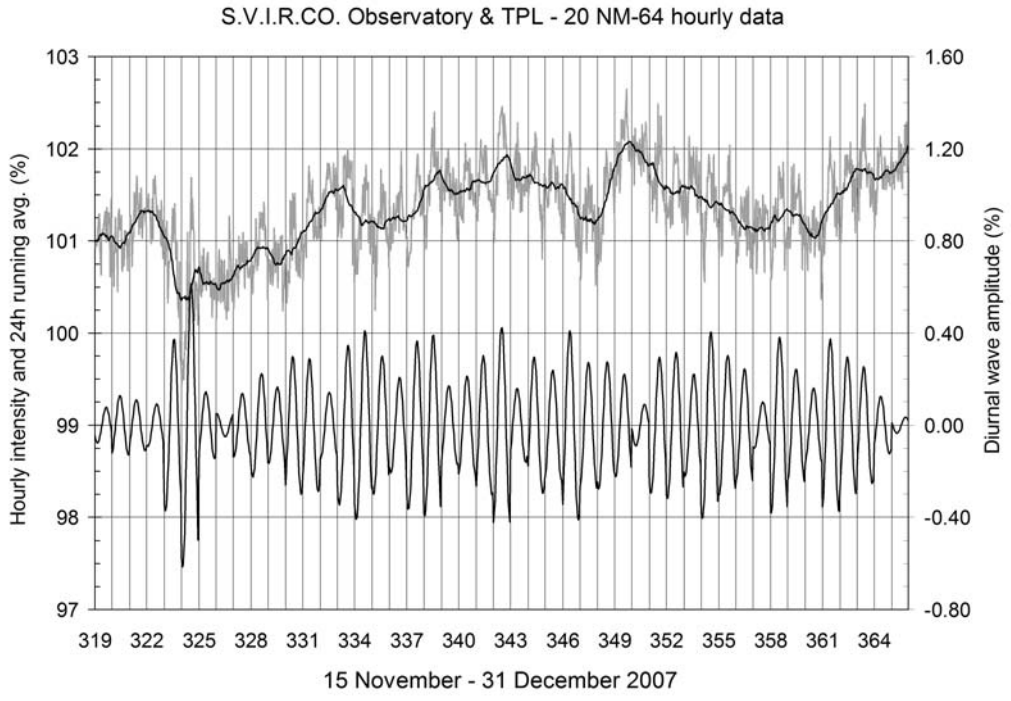

Fig. 9 – Hourly pressure-corrected data from SVIRCO neutron monitor with the 24h-running means (upper graph) and time history of the reconstructed first harmonic of the diurnal wave (lower graph) for the second IHY/CIP 57 Campaign.

From Figures 8 and 9 we notice that the low amplitude of the first harmonic of the diurnal wave, identified during the first campaign, is also present in the period 16-18 May and even lower during 16-17 June and 15-18 November. On the other hand, during the second campaign the wave variability is more regular but with an enhanced shift of its phase (towards the morning hours; see Sect. 3). Certainly, these features are interesting and deserve a special study, which will be presented in a forthcoming paper. Francia et al. [9] investigated the solar-wind magnetospheric coupling for the first campaign. They found that during the whole period, the geomagnetic field did not show any development of storms whereas a low geomagnetic pulsation activity (in the Pc5 and Pc3 frequency range) was present. The power of the Pc3 pulsations showed a diurnal modulation with minimum values around midnight; this feature is explained with the magnetospheric penetration of upstream waves.

6. Conclusion

The IHY/CIP 57 campaigns allowed to identify, in the solar modulation of galactic cosmic rays, interesting features mainly related to corotating solar-wind streams. In particular, the behaviour of the first harmonic of the diurnal wave (registered by the Rome neutron monitor) points out the existence of a peculiar status of the interplanetary medium at solar cycle (n° 23) minimum.

The characteristics of the near-Earth environment during both campaigns are yet under study and a complete account will be provided in a forthcoming paper.

Acknowledgements

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