Registration of the Solar Activity during Cycle-23 with the ANI Cosmic Ray Observatory facilities

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Abstract

The detection of the GeV Cosmic Rays (CR) intensity, associated with Solar flares (Sf), provides a useful tool for investigating the processes of particle acceleration, providing a permanent long-term source of information. Studies of the complicated intensity-time profiles and pronounced anisotropy patterns of CR variations, registered by the world net-work of Neutron Monitors (NM), are expected to lead to a detailed understanding of the dynamic magnetic structures of the heliosphere and of the physical processes of the Sun. We are discussing additional research possibilities of multidetector investigations of the Ground Level Events (GLE) and CR modulation effects by the facilities of the Aragats Cosmic Ray Observatory (ACRO), located at - $44.16^\circ E$, $40.5^\circ N$, 2000 and 3200 m a.s.l.) .

1 Introduction:

The intensity variations of GeV CR provide information about complex transient structures in the near-Earth interplanetary medium and about the interference of such structures with the Galactic CR flux (modulation) and the Earth magnetosphere. Galactic CR serves as a probe of the heliosphere as they enter under the influence of interplanetary shocks and Solar Wind, trying to remove CR from the inner Solar System. The analysis of short term bursts of muon intensity recorded at the Baksan underground scintillation telescope indicates a high correlation with energetic Sf phenomena, thus demonstrating the possible signature of solar particle acceleration up to 500 GeV (Karpov, 1997).

The potential of coordinated measurements of the GLEs and CR modulation effects with various ground-based detectors, accomplished with advanced multidimensional data analysis methods seems to be greater than generally assumed so far. At ACRO several installations measuring the CR background are in operation. There are two standard 18-NM-64 monitors located on the altitude of 2000m and 3200m (the latter one is planed to start operation Summer 1999). Data from 1996 on are available in the WEB[2].

The Solar Neutron Telescope (SNT)[3], is a part of the World Neutron Network (WNN) (Muraki, 1991), managed by the Solar-Terrestrial Laboratory of the Nagoya University. Locatind on widely spread latitudes the WNN stations are inspecting the Sun full day, monitoring neutrons of GLEs. The details of the apparatus are given by (Matsubara, 1997; Flückiger, 1998). The telescope located at Mt. Aragats is similar to those located in Mt. Chacaltaya and Mt. Gornergrat. The difference is the use of 60 cm thick scintillator instead of 40 cm and an anticoincidence shielding vetoing only the vertical flux. In the ANI Extensive Air Shower experiment (Danilova,1992) scintillators (approx. 300 m.sq.) are continuously recording the background for the detector calibration purposes. At the altitude 2000m the muon scintillation telescope of 8 m.sq. is under construction for measuring anisotropy of muon arrival directions. All this installations will be supported by the GPS timing facilities (the SNT already has it), remote control and data acquisition via Internet radio-modem connections. As an example of the possibilities of the physical inference based on multi-detector measurements, the correlation analysis of the NM and SNT data is described in next section.

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[2]http://crdlx5.yerphi.am/neutron/

[3]http://crdlx5.yerphi.am/solar.html

2 Correlation analysis of the Neutron Monitor (NM) and Solar Neutron Telescope(SNT) data:

N.Bostanjyan (Bostandjan, 1998) put attention to the differences in the performance of NM and SNT (sensitivity to neutron energy, as well as detection efficiency). In addition the possibility of detecting the variations of CR intensity flux like Forbush decrease (FD) (Forbush, 1937) was pointed out.

The FD (with significant lasting many hours decrease of overall CR intensity) is accompanied by rather complicated short term sequence of intensity fluctuations. This highly anisotropic pre-cursors are connected either with particle trajectories that trace to the CR depleted region behind the powerful interplanetary shock, or with viewing particles reflected from the shock (Belov,1994; Hofer, 1997).

A very complicated shape of the FD events with several decreases and increases is an appropriate test for comparing the NM and SNT data.

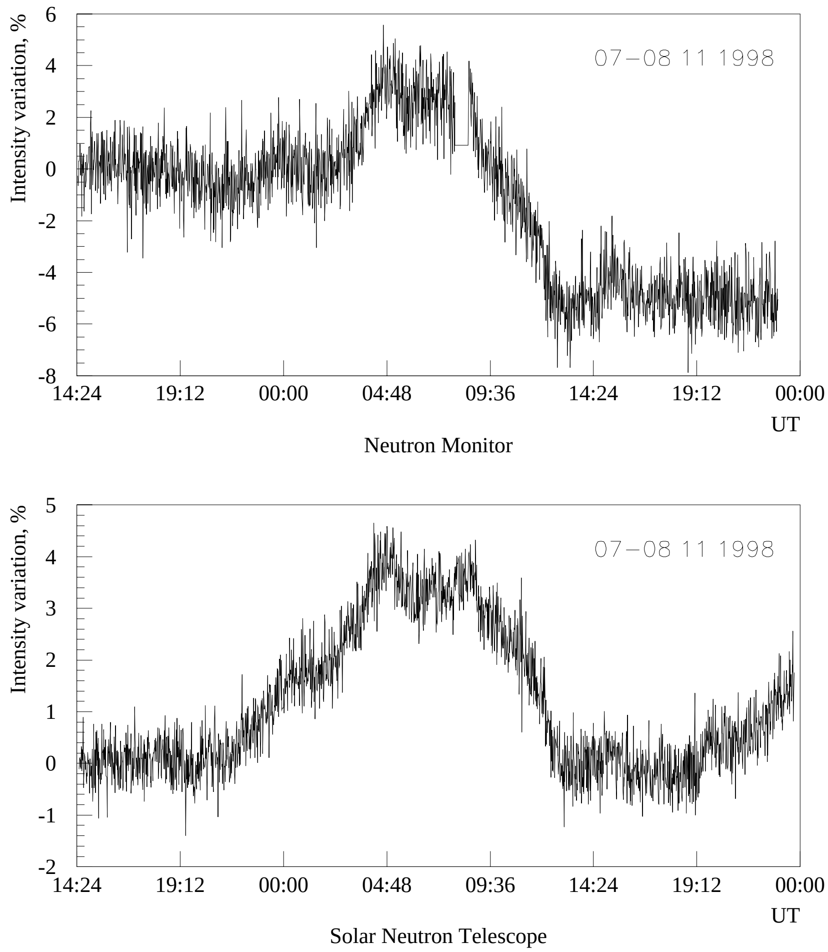

Figure 1: Forbush decrease of the CR intensity from November 7th,1998, NM and SNT one-minute data

For the correlation analysis we select three events. Two were FDs from the 7th of November, 1998 and 22nd January, 1999. The event registered at 3rd-4th May 1998 displays a gradual increase of the CR flux intensity during 6.5 hours with a maximum of 4.5% above the average. For both installations one-minute data were used (SNT telescope 10 sec. data were integrated).

The cross-correlation coefficients with *lag k* are calculated by the formula:

$$r_k(x,y) = \frac{\sum_{i=1}^{N}(x_i-\mu_x)(y_{i+k}-\mu_y)}{(N-1)\sigma_x\sigma_y} \tag{1}$$

where x_i and y_i are the N point intervals of the NM and SNT one-minute Time Series (TS). The quantities μ_x, σ_x and μ_y, σ_y are the correspondent mean values and variances of chosen TS intervals, comprising N counts. The *k* value of the *lag* is optimized to give maximal correlation. For most cases of TS *k=0*, indicating the consistency of data from both installations.

The values of the correlation coefficients r for selected events were equal:

1. For the event of November 7th-8th, 1998 (fig. 1) : $r = 0.8$,

2. For the event of January 22nd-23rd , 1999 (fig. 2) : $r = 0.69$,
3. For the event of May 3rd-4th , 1998 (fig. 3) : $r = 0.7$.

The control correlation coefficient calculated for the CR background only registered by SNT and NM varies in range of r = (0.01-0.1). Note, that NM data was corrected for the atmospheric pressure and SNT data didn't yet corrected for pressure and temperature. The appropriate correction of SNT data will increase the values of correlation. After establishing firm relations between data from two installations the fine-grain structure of the events has been investigated. For each separate local variation in the time profiles of FD a correlation analysis has been performed.

The results are as follows: For the FD of November 7th-8th, 1998 (fig. 1) the correlation coefficient for the increase time-interval was r = 0.86 and for the decrease time-interval r = 0.95. As seen in the (fig. 1) the increase-interval consist of three small increases and three subsequent decreases with a total duration of 3 hours. The correlation coefficient for the first peak is r = 0.75, and r = 0.02 and r = 0.08 for the second and third one, respectively.

The FD of January 22nd-23rd, 1999(fig. 2), displays two increases and decreases. The correlation coefficient for the first increase is r = 0.01, and for the second r = 0.74, for the first decrease r = 0.79, and the second decrease r = 0.91. The peak in the middle of FD consists of two moderate increases and decreases with a duration of 3 hours (with r = 0.6 and r = 0.02 respectively).

For the event of May 3rd-4th, 1998 (fig. 3) the value of correlation coefficient is r = 0.7 for increase, and r = 0.78 for decrease.

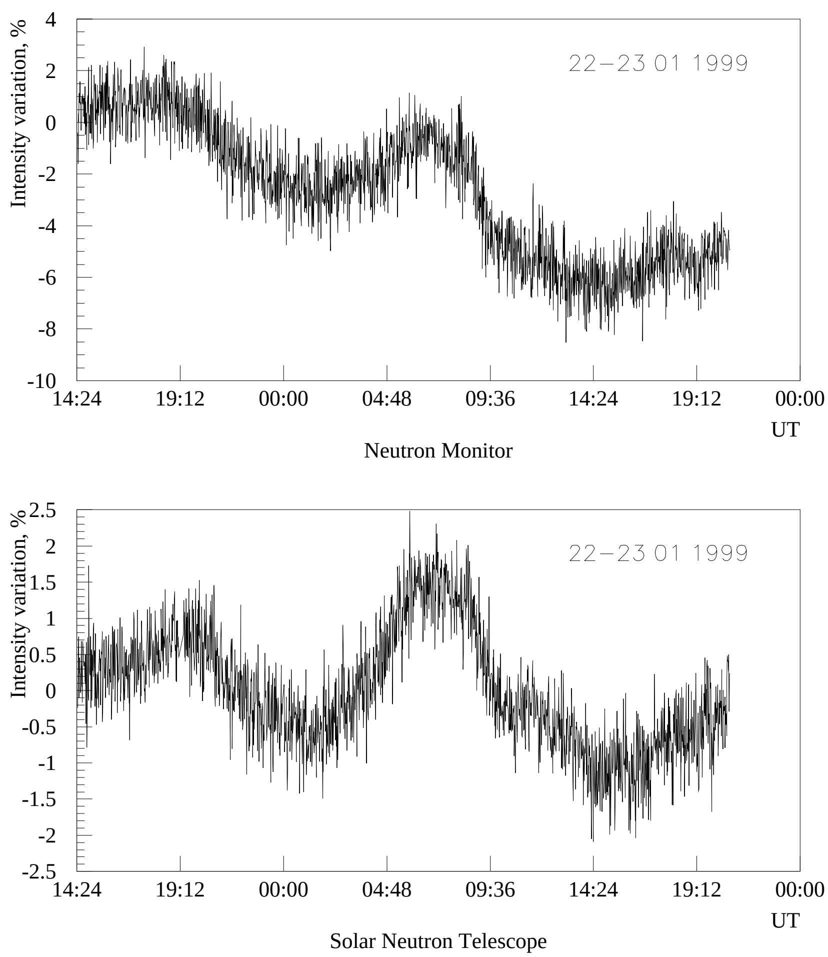

Figure 2: Forbush decrease of the CR intensity from January 22nd-23rd, NM and SNT one-minute data

Without further discussion of the observed correlation coefficients, the statistical reliability of the correlations is proven to be very high. That feature provides a firm basis of a detailed analysis of stochastic acceleration processes, establishing a "laboratory" for investigation of particle acceleration at shocks inside the heliosphere and the dynamics of huge magnetic structures in the heliosphere, by the measurements of the galactic CR variations with networks of SNT and NM.

3 Conclusion:

The World Neutron Network comprises installations located at

- Mt. Gornergrat, Switzerland $(7.8°E, 46°N$, 3135m a.s.l.);
- Mt. Aragats, Armenia $(44.2°E$, $40.5°N$, 3200 m a.s.l.);
- Mt. Norikura, Japan $(138°E$, $36°N$, 2770m a.s.l.);
- Mt. Mauna Kea, Hawaii $(205°E$, $20°N$, 4200m a.s.l.);
- Mt. Chacaltaya, Bolivia, $(292°E$, $16°S$, 5250m a.s.l.).

It is able to detect CR variations and provides opportunities of detailed analyses of CR modulation additionaly to the World Neutron Monitor Network. The results on the FD shape investigations are still preliminary, only indicating the perspectives of a joint analysis of the NM and SNT data. The physical interpretation of the features of FD intensity-time profiles in the terms of the shock-associated CR modulation effects will be done only after precise simulation of the SNT response function for estimation of the detection efficiencies of different particles. In spite of the methodical character of the discussion, we hope that the correlation analysis of data from different detection devices will help to reveal multidimensional features of different Solar events.

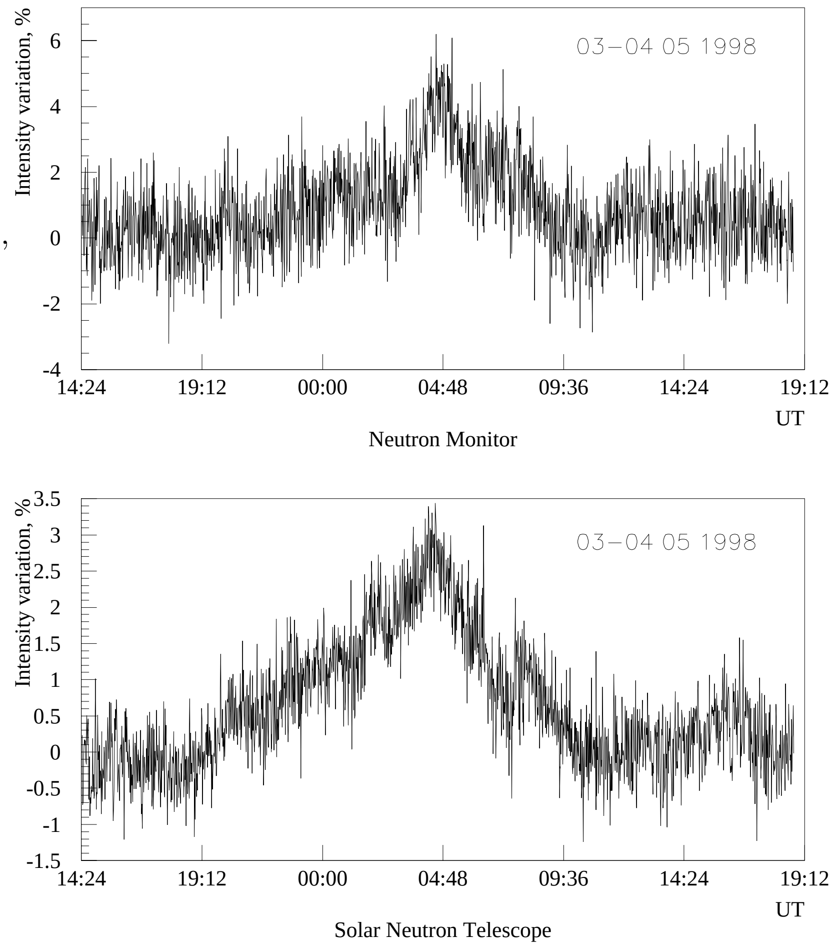

Figure 3: Gradual increase of the CR intensity from May 3rd-4th, 1998, NM and SNT one-minute data

4 Acknowledgements:

The work has been partly supported by a research grant (No.96-825) of the Armenian Government and by the ISTC project A116.

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