# GLE Observations in 23rd Solar Cycle at the Baksan Air Shower Arrays Andyrchy and Carpet

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## Abstract

Total counting rates of two Baksan extensive air shower arrays Andyrchy and Carpet were examined during 10 Ground Level Enhancements (GLE) of Solar Cosmic Rays (SCR) observed in current 23rd cycle of solar activity. In this case the threshold primary energy is equal to geomagnetic cut-off, $E_{min}$= 5.8 GeV. Significant increases (>3 st.dev.) above the galactic cosmic ray background were found during 6 GLE events from 10. The amplitudes of all increases make the tenth shares of percent. Therefore, they can not be registered by neutron monitors with a close geomagnetic cut-off.

## 1. Introduction

Neutron Monitors (NM) are usually used for studying of SCR in energy range from 0.5 up to 15 GeV. The Extensive Air Shower (EAS) arrays have a threshold of registration from several tens TeV up to hundreds TeV. They register also single particles – muon and electromagnetic components. The minimal primary energy in this case is determined by a geomagnetic cut-off, and the energy range is close to range of NM. The main advantage of EAS detectors is the greater counting rate. Characteristic statistical accuracy of NM is 1-0.5% by the 5-min data. The Andyrchy and the Carpet under the same conditions have accuracy 0.05% and 0.03%, accordingly. It allows registering weaker particle fluxes in 10 times.

First reliable registration of SCR on EAS-array has been made on the Carpet [1]. During powerful solar flare on Sep. 29, 1989 the Carpet has fixed large increase with amplitude (43.30±0.03)% in total counting rate and increase of (14.0±0.5)% in counting rate of threefold component. For last case it is mainly consist of local showers of low power ($E_{min}$= 10 GeV [2]). In current cycle of solar activity the world-wide network of neutron monitors fixed 10 GLE. The data of SCR registration on two Baksan EAS-arrays Andyrchy and Carpet during all these GLE events are submitted in the paper. Data of the Baksan Underground Scintillation Telescope on 23rd cycle are represented in the report [3].

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## 2. Description of Detectors

The Baksan Neutrino Observatory is located in a point with geographical coordinates 43.28°N and 42.69°E. The rigidity of effective geomagnetic cut-off makes 5.7 GV. The Andyrchy consists of 37 detectors constructed from plastic scintillator with area 1×1 $m^2$ and with thickness 5 cm. The distance between detectors makes 40 m. Center of the Andyrchy is at height of 2060 m above sea level. The Carpet is a detector of central part of EAS. 400 counters cover with a continuous layer the area 14×14 $m^2$. Each counter is container in size 70×70×30 $cm^3$ filled with liquid scintillator. The Carpet is at height of 1700 m a.s.l.

## 3. Methods of Analysis

Data of total counting rate of the Andyrchy and the Carpet were used for search of SCR increases during GLE. It consists mainly of single particles (≈99% counts). It is determined as hard component (high energy muons, ≈60% of counts), and soft particles (low energy muons and electromagnetic component, ≈40% of counts). Counting rate of the Andyrchy makes 11500 $s^{-1}$ and of the Carpet – 40000 $s^{-1}$. According to the theory of meteorological effects [4] it is necessary to take into account both barometric and temperature effects for single component of EAS-arrays. Atmospheric pressure is continuously measured on the Andyrchy and the Carpet with accuracy 0.1 mb. Data of a temperature profile of atmosphere above point of registration are absent. Continuous measurement of temperature is carried out only in a ground layer. It not always shows change of temperature in other layers of atmosphere. Connection between them has statistical, correlating character. In number of cases it is allowable to use surface temperature for data correction [4]. Special research of meteorological effects on the Andyrchy has been realized [5]. Correction becomes simpler due to use of relative intensity at studying of GLE. It is enough to remove the regular trend of intensity connected to a course of pressure and temperature. For this the regression factors received at simultaneous correlation of counting rate with pressure and temperature were used. If correlation appeared <0.7, then temperature correction was not made.

## 4. Basic Results

The GLE connected to flares on April 15 and 18, 2001 were most powerful in 23rd cycle. The greatest increases on the Andyrchy and the Carpet also are fixed during these events. Data of SCR registration on various installations during flare on April 15, 2001 are submitted on fig.1. The 5-min data of the Andyrchy and 4-min data of the Carpet are shown on the left panel of figure. The 5-min data of NM in Apatity and in Moscow are on the right. In all cases excess over a galactic background in percentage is shown. The amplitude of increases on the Andyrchy

and the Carpet makes 0.50% and 0.40%, accordingly. It approximately in 100 times is less, than increase in Apatity. First of all it is due to the cut-off rigidity on the Baksan (5.7 GV) is almost in 9 times more, than in Apatity (0.65 GV).

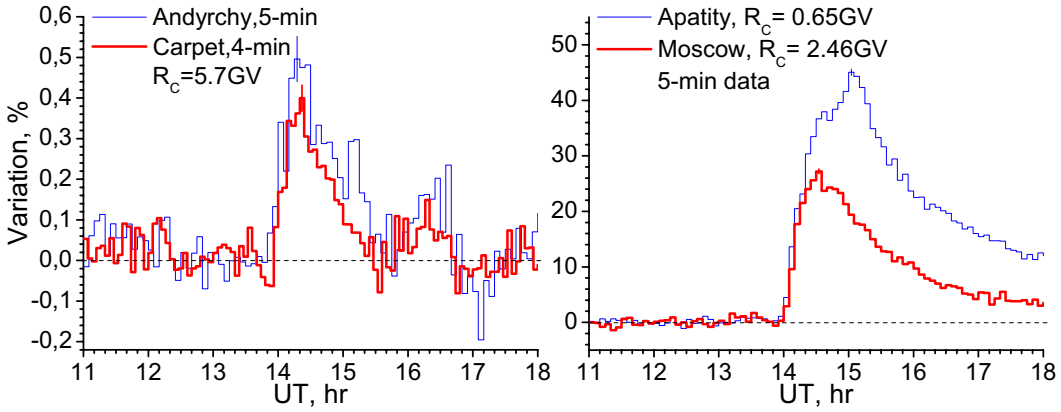


**Fig. 1.** Ground Level Enhancement of SCR during solar flare on April 15, 2001 according to registration on various installations.

Recalculation of secondary particles intensity of EAS-arrays is necessary for quantitative comparison with the NM data and for reception of a primary SCR spectrum. The response functions of EAS-arrays are need for that. Calculations of yield and response functions for the Andyrchy are submitted in paper [6]. Signals with amplitude 0.5% are not registered on standard NM. Only due to high statistical accuracy on the Andyrchy and the Carpet we see a reliable signal of $9\sigma$ and $13\sigma$ in a maximum of increase.

**Table 1.** The GLE events of 23rd cycle of solar activity.

| Date | NM Apatity | Andyrchy, 5-min | | Carpet, 4-min | |
|---|---|---|---|---|---|
| | Incr., % | Incr., % | St. dev. | Incr., % | St. dev. |
| 1997 Nov 6 | 10.5 (5min) | 0.19 | 3.5 | Not operated | |
| 1998 May 2 | 10 (5min)* | 0.30 | 5.5 | 0.41 | 13 |
| 1998 May 6 | 3 (5min) | 0.28 | 5.0 | Not operated | |
| 1998 Aug 24 | ∼2.5 (5min) | 0.31 | 5.7 | 0.23 | 6.8 |
| 2000 Jul 14 | 38 (1min) | Not operated | | 0.09 | 2.8 |
| 2001 Apr 15 | 46 (1min) | 0.50 | 8.9 | 0.40 | 13 |
| 2001 Apr 18 | 17 (1min) | 0.42 | 7.3 | 0.57 | 18 |
| 2001 Nov 4 | 3 (5min) | Lack of increase | | Lack of increase | |
| 2001 Dec 26 | 7.5 (1min) | Lack of increase | | Not operated | |
| 2002 Aug 24 | 5 (5min) | Lack of increase | | Lack of increase | |

* Data of NM Goose Bay

Data of the Andyrchy and the Carpet during all 10 GLE of the current cycle are submitted in table 1. Excess above a galactic background in percentage and the statistical importance in standard deviations in a maximum of increase are represented. Data of NM in Apatity are shown for comparison. During all events there are registration data or both Baksan arrays, or one of them. In 6 events from 10 the increases exceeding $3\sigma$ are found out. All increases make the tenth shares of percent. Therefore they cannot be fixed on NM with a close geomagnetic cut-off. Thus, data of the Andyrchy and the Carpet allow prolonging the SCR spectrum in the specified events up to 5.7 GV.

## 5. Conclusions

On the Andyrchy and the Carpet 6 increases of SCR are fixed from 10 GLE of 23rd cycle. The amplitudes in all cases make the tenth shares of percent. Such increases cannot be recorded on NM with a close geomagnetic cut-off. Only high statistical accuracy the Andyrchy and the Carpet allows detecting significant increases in the majority of events. There is an opportunity to prolong the SCR spectra in these GLE up to 5.8 GeV. Moreover, the high energy SCR are observed approximately in 50% of GLE. It was supposed, that particles of such energy are not present in the majority of them. Early there were data of EAS-arrays only for separate events: Sep. 29, 1989 – the Carpet [1, 2], Nov. 6, 1997 – MILAGRITO [7] and Apr. 15, 2001 – GRAND [8]. At the moment the Andyrchy and the Carpet give the largest quantity of high energy events in 23rd cycle.

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## 6. References

1. Alexeyev E.N. et al. 1991, Izv. AN SSSR, Phys. Ser. 55, 1874
2. Alexeenko V.V. et al. 1993, Proc. 23rd ICRC 3, 163
3. Karpov S.N. et al. 2003, Proc.28th ICRC, paper 008812-1 (this Conference)
4. Dorman L.I. 1958, Cosmic Ray Variations (Wright-Patterson, USA)
5. Boliev M.M. et al. 2003, Proc.28th ICRC, paper 009394-3 (this Conference)
6. Karpov S.N. et al. 2003, Proc.28th ICRC, paper 008812-3 (this Conference)
7. Ryan J.M. 1999, Proc. 26th ICRC 6, 378
8. Poirier J. and D'Andrea C. 2002, J. Geophys. Res. 107, 1815