# On Accuracy of Solar Cosmic Ray Anisotropy and Intensity Deduced from NM Data

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## Abstract

Typical fittings of solar cosmic ray variations registered by the neutron monitor (NM) network do not consider real values of proton fluxes observed by satellites. However, a sharp knee of the proton spectrum may exist in the energy range of high latitude NM's during ground level enhancements (GLE) and storm particle events. This may lead to great misinterpretation of NM data, when the CR anisotropy and absolute intensity during GLE's and Forbush decreases are studied. In a case of GLE's the knee energy, but not the geomagnetic (or atmospheric) cutoff, would determine a count rate of particular NM, i.e. an impact of lower energy part of solar proton spectrum typically is overestimated. Contrary, during Forbush effects storm particles may contribute considerably to count rate of high and middle latitudes NM's. The solar proton events July 14, 2000 and November 4, 2001 illustrate the problem.

## 1. Introduction

In the middle energy range we have a little knowledge of how the solar proton spectrum behaves, because an effective energy range of high latitude NM only marginally overlaps with the highest energies measured aboard spacecrafts. It is the turnover in the spectrum that carries the most information representing possible limits of acceleration, release and propagation processes [6]. Besides, the problem is additionally complicated, because the NM sensitivity below 3 GV is not well known [1].

Some recent observations (see [5,7–9]) underlined the problem of the spectrum knee for solar ions with energy of several 100 MeV/nucleon. However, typical fittings of the NM solar variations do not consider a possible knee of the proton spectrum for high and middle latitudes NM's [2–3]. A proton spectrum is assumed to be unbroken power law below about 2 GeV and is not normalized to real proton fluxes observed by satellites. A difference between CR variations registered by NM with cutoff $< 3$ GV is arbitrary attributed to effects of CR anisotropy, but it might be caused partly by effects of the spectrum knee.

This paper attracts attention to the problem and illustrates it by examples

pp. 3419–3422 

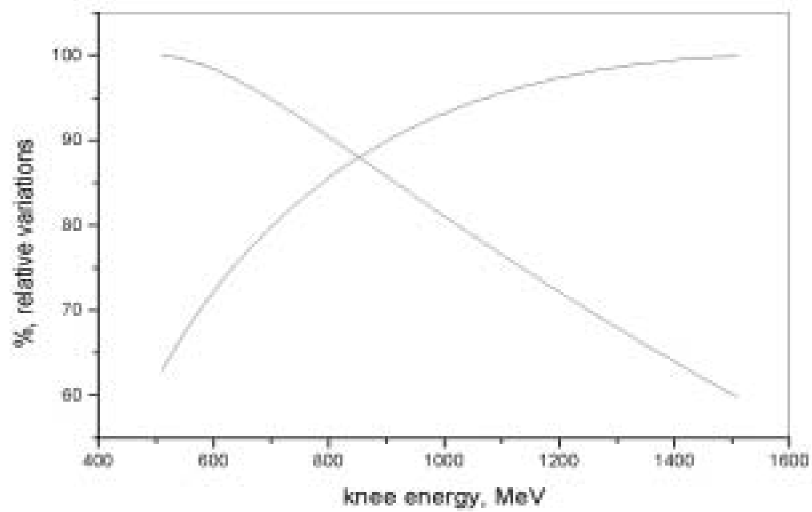


**Fig. 1.** NM variations associated with the spectrum knee at different energies. Rising curve — $J_1(E) \sim E^{-4.5}$ and $J_2(E) \sim E^{-5.5}$. Decaying curve —$J_1(E) \sim E^{-3.5}$ and $J_2(E) \sim E^{-4.5}$.

of GLE events of July 14, 2000 and November 4, 2001.

## 2. Rough Estimates

Let us estimate possible errors due to existence of the spectrum knee. If the spectrum of solar protons is broken at a knee energy $E_0$ into two parts $J_1(E)$ and $J_2(E)$ and the NM sensitivity is $g(E,x)$, then we have

$$\delta N = \frac{\int_{E_1}^{E_0} g(E,x) J_1(E)\, dE + \int_{E_0}^{E_2} g(E,x) J_2(E)\, dE}{\int_{E_1}^{E_2} g(E,x) J_2(E)\, dE}. \tag{1}$$

Figure 1 shows results of the calculations assuming that the NM sensitivity for rigidities below 3 GV is $g(E,x) \sim E^{3.1}$ [1] and the spectrum of solar protons is a broken power law with $\delta\gamma = 1$. So for 10% GLE a possible maximum error is about 6%.

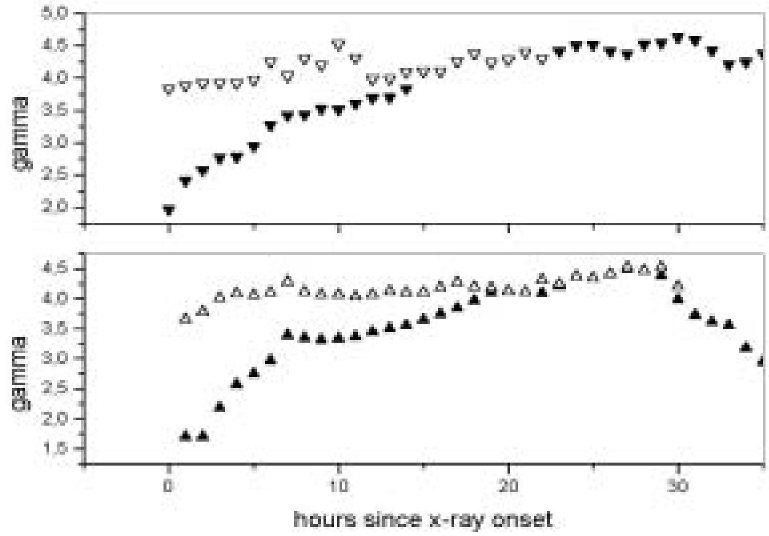


**Fig. 2.** Power law indexes of proton spectra deduced from data of Apatity and Moscow NM (open), 84-200 and 110-500 MeV GOES channels (black) for events of July 14, 2000 (up triangles) and November 4, 2001 (down triangles).

## 3. Discussion

A power law spectrum derived from data of the 84–200 and 110–500 MeV GOES-10 proton channels leads in some cases, for instance during the GLE events of July 14, 2000 and November 4, 2001 [7] to unreasonably large variations of NM count rate, i.e. the spectrum should be much softer for NM energies (Fig. 2). During these events a difference between power law indexes for $< 500$ MeV and $< 1600$ MeV was greater than considered in the previous section. Therefore, NM variations of several percents might be attributed to effects of the spectrum knee.

Another problem arises during Forbush effects accompanied by giant storm particle events, when the spectrum of storm particles may spread continuously to NM energies.In this case storm particles may contribute considerably to count rate of high latitudes NM's. These effect must be accounted estimating CR anisotropy and changes of the cutoff rigidity from data of NM survey.

## 4. Summary

- A sharp knee of the proton spectrum existing in the energy range of high latitude NM's during ground level enhancements (GLE) and storm particle events may lead to misinterpretation of NM data.
- In a case of GLE's the knee energy, but not the geomagnetic (or atmospheric) cutoff, would determine a count rate of particular NM, i.e. an impact of lower energy part of solar proton spectrum typically is overestimated.
- Contrary, during Forbush effects storm particles may contribute considerably to count rate of high and middle latitudes NM's.

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