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ON THE INDICES OF COSMIC RAY VARIABILITY.

K. Kudela [1], I.M. Martin [2], P. Bobik [1]

[1] *Institute of experimental Physics, SAS, Kosice, Slovakia*

[2] *UNICAMP, Campinas, SP, Brazil*

Abstract

The indices of cosmic ray (CR) activity, based on (a) the simplified measure of anisotropy, and on (b) temporal variability of count rate at a single neutron monitor (NM) are examined for the period of high interplanetary and geomagnetic activity (1991) and for the period 1997-1998. They can be useful, along with indices defined by other authors, for purposes of checking signatures of CR flux behaviour in selected types of studies related to space weather.

1 Introduction

Count rates of NM are formed by various processes both of interplanetary and magnetospheric origin. There are several approaches to define the CR activity indices. One of them, the scintillation index, is a measure of inversions in the amplitude power spectra of CR signal (e.g. Kozlov and Tugolukov, 1992). Another one is using the integral of power spectrum density of CR over the frequency range, where IMF can influence CR flux (Kudela and Langer, 1995). Recently, a sophisticated approach of characterizing CR activity has been presented by (Belov et al, 1998): indices based on global survey method of NM s, and indices at a single station. Here we construct, in a simplified way a measure of anisotropy in equatorial plane and that of temporal variability at a single station, and discuss their relations to geomagnetic activity described by Dst.

2 Anisotropy measure

Using data set of NM hourly count rates (N^i) at a few high latitude stations (i=1,...,5, Cape Schmidt, Inuvik, Goose Bay, Apatity and Tixie Bay), from data base (Watanabe, 1998), adjusted their asymptotic longitudes directions according to (Bieber and Evenson, 1997, Shea and Smart, 1975), and omitting their longitudinal extent, at each hour the following approximation was fitted by the method of least squares: $N^i = A_0 + A_1.\cos(\Lambda-\Lambda_0^i)$, where Λ_0^i is the asymptotic longitude in GSE. As a result, the values A_0 , A_1 , and Λ, being the CR density, amplitude of the first harmonic and direction of the anisotropy were found. Goodness of fit (S2) was measured by sum of squares of differences between measured and fitted values, divided by A_0. Two normalizations were used: (i) averaging of the count rates at individual station over one year and adjusted it to unity, and (ii) measuring the count rate deviation from the average over past 24 hours at any particular station. For CR density profile, normalization (i) was used. Fig.1 displays the the set of A_0 (shifted by -200 and being in per cents), and S2 for year 1991, when strong interplanetary

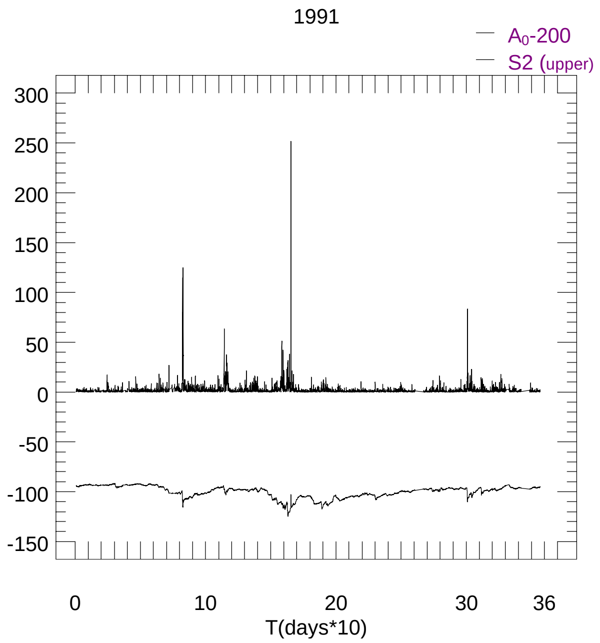

Fig.1

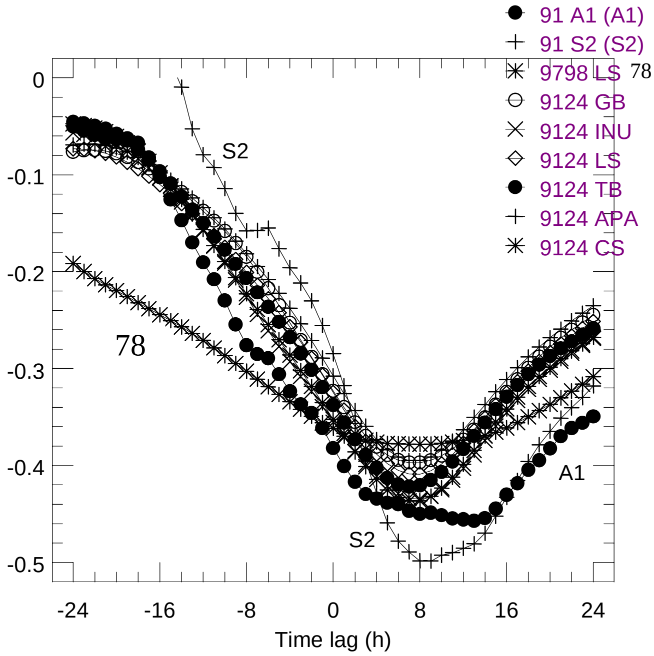

Fig.2

and geomagnetic activity ocurred (Shea et al, 1995) .In Fig.2 the crosscorrelations of time series of S2 and A1 (X(t)) and Dst (Y(t+k)), where k is time lag in hours are displayed along with crosscorrelations, based on variability of count rates at individual stations. The asymmetry of both profiles is apparent. The crosscorrelation of S2 with Dst, having its extremum at 8 hours is well pronounced, which is probably related to the fact that type of anisotropy is more complicated than that using only first harmonic here. The profile of A1, although with relatively small slope at k>3, has a minimum at 13 h, indicating its potential usefulness for longer time predictions of Dst. According to (Bieber and Evenson, 1997, 1998) in one paricular case the strong enhancement of field-aligned anisotropy of CR was observed during 9 hours prior to shock arrival. The same event, which is not a Forbush decrease, analyzed by profiles of several NM s is also consistent with enhancement of count rate variability well prior to the Dst depression (Storini et al, 1998). Analysis of two more events done recently (Bieber and Evenson, 1999) have shown that precursor anisotropies are detectable at least 6 hours ahead of the CME shock.

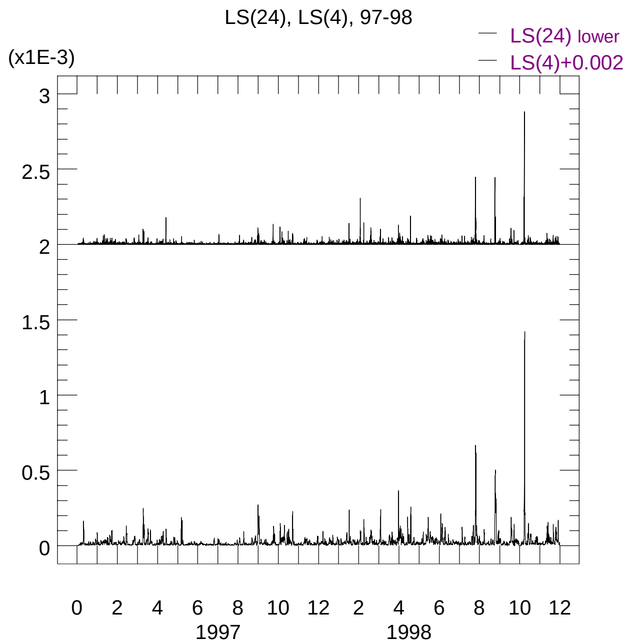

Fig.3

3 Variability on individual station

Figure 2 is displaying also crosscorrelations of values V(24) being the dispersion of count rate normalized by its average at a particular station for the interval (t-24,t) and Dst at time t. For 1991 the minimum is between 6-8 hours and profiles for the 5 stations mentioned in par.1 along with that for Lomnicky stit (LS) are similar for the year 1991. For period 1997-1998 the crosscorrelation of LS(24) has a broader profile, however the asymmetry with respect to time (-12 h) is still observed. The variabilities at different scales, namely 4, 8, 12 and 24 hours were constructed for LS data. Fig. 3 is showing the profiles of two of them. There is a large variety of relation between CR variability (manifestation of anisotropy if observed for long time

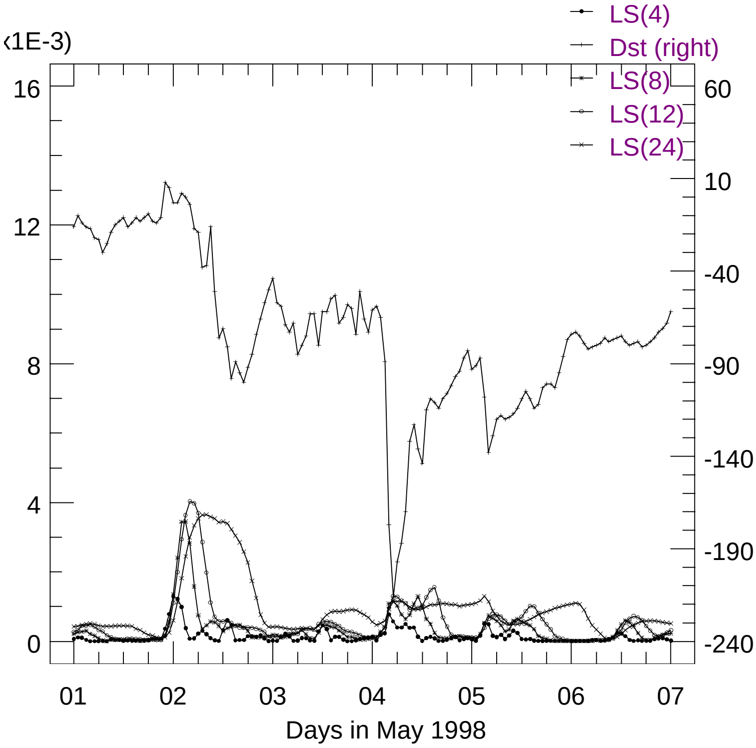

Fig.4

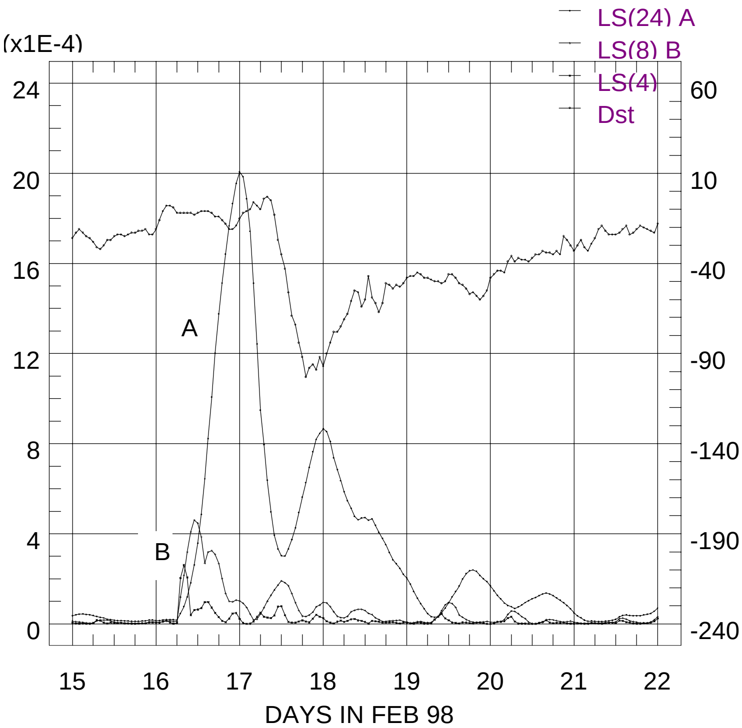

Fig.5

period at one station) and geomagnetic activity timing. An example of evolution of LS(4), LS(8), LS(12) and LS(24) for the period May 1 - 6, 1998 is displayed along with Dst in Fig. 4. This interval was a disturbed one and corresponds to a selected space weather event (http://www.astro.lu.se/~henrik), and discussed also in connection with satellite problems (Baker et al, 1998). There is a large increase of LS(4) and consecutively of LS(8), LS(12) and LS(24) apparent after 2200 on May 1, about 8 hours prior to Dst strong decrease. Later, the complicated structure with a smaller increase of LS at the time of major decrease of Dst on May 4 (-218 nT) is apparent. Probably the anisotropy was changing much faster than 24 hours and thus a single station having large extent of longitude acceptances is not well reflecting the anisotropy. A different situation is displayed for period February 15 - 21, 1998 (Fig.5). The Dst depression on February 17 reaching -100 nT is well preceded by a strong enhancement of variability on all scales displayed here about a day ago. This Dst depression had relatively simple character and more than 2 days before there was no significant change in geomagnetic activity.

4 Summary

Different approaches introducing indices of anisotropy and of variability of CR at NM energies are needed to be tested for their eventual relevance in space weather studies. The simplified indices discussed here are indicating that the anisotropy they reflect is in general ahead of the Dst depressions (their minima), consistently both with earlier statistical studies and with detailed anisotropy studies before and during several strong geomagnetic disturbances. However the variety of timing between the onset of CR anisotropy and Dst decrease is observed: from 1-2 hours (Hofer and Flückiger, 1999) to probably 1 day (case in Fig.5 here) . When the network of high latitude NM s (Bieber and Evenson, 1995) will be in operation, the equidistant coverage of acceptance longitudes with all cut-offs determined by the atmosphere will form a homogeneous set of data for real time checking of the anisotropy CR. Thus more extensive studies of CR signatures regarding space weather events using NM s will be possible.

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