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Interactive database of cosmic ray anisotropy (DB-A10)

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Abstract

The worldwide neutron monitor network is a unique tool for obtaining with high accuracy the information on density variations, energy spectrum and anisotropy of comic rays at the Earth, outside its atmosphere and magnetosphere. These hourly averaged parameters were obtained over the whole period of cosmic ray monitoring by the ground level neutron monitor network (from 1957 till present) and are collected within the MySQL database. The Internet-project has developed for free access and supplying of cosmic ray density and anisotropy data in different formats.

Keywords: Cosmic ray anisotropy; Neutron monitor network; Data base

1. Introduction

In the energy range of 1–100 GeV cosmic ray (CR) intensity is nearly isotropic. A degree of anisotropy, as a rule, is less than 1%. However, no other CR characteristic is capable to give so a lot of information on conditions in the interplanetary space, as CR anisotropy (Dorman, 1974; Krymsky et al., 1981, and references there).

The form, direction, size and power spectrum of anisotropy are connected with concrete structures in heliosphere, with intensity, direction and degree of an irregularity of the interplanetary magnetic field (IMF), with a position of the heliospheric current sheet and also with the solar wind speed. Structural features and processes in a solar wind within the wide spatial (10^9–10^{14} cm) and time (10^3–10^8 s) scales, are reflected in the CR anisotropy observable at the Earth and can be studied with its help (Nagashima, 1971; Belov et al., 1999, 2003a, 2003b, 2006a, 2006b; Leerungnavarat et al., 2003). Thus, data on the anisotropy from ground level CR observations derived might be considered as reliable tool for interplanetary space diagnostics.

2. Technique of separation of anisotropy

Some variants of a technique of detection of CR anisotropy from ground based CR observations have been considered by Krymsky et al. (1966); Nagashima (1971); Alania et al. (1973), Baisultanova et al. (1987), Dvornikov and Sdodnov (1997), Belov et al. (2003a). In common, it is always a various modification of spherical analysis method.

Being limited to the zero and first harmonics, CR variations expected on the Earth at point i at the time moment t, are possible to be written down as following in Geocentric Coordinate System (GEO):

$$\delta^i(t) = A_0 C_0^i(\gamma) + (A_x, A_y, A_z) \left\{ \begin{matrix} Cos(t) & -Sin(t) & 0 \\ Sin(t) & Cos(t) & 0 \\ 0 & 0 & 1 \end{matrix} \right\} (C_x^i, C_y^i, C_z^i) + \delta_{err}^i \qquad (1)$$

where $\delta^i(t)$ is observable variation of counting rate at each station (point i), A_0 is isotropic part of CR variations (density), A_x, A_y, A_z are three components of CR anisotropy, and the system of these equations for many stations allows to derive these components, density and its spectral index for each hour; $\delta_{\rm err}^i$ is discrepancy between the model of CR variation and real CR observations at every station;

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$C_0^i(\gamma)$ and C_x^i, C_y^i, C_z^i are reception coefficients between variations outside the magnetosphere and variations observed at the ground at point i for different components. These coefficients depend on coordinates and altitude of the observational point and are calculated for each station separately (Yasue et al., 1982). Reception coefficients for zero harmonic A_0 ($C_0^i(\gamma)$) may be determined relatively simply (Belov et al., 2005), and we calculate them for each station:

$$C_0^i(\gamma) = \int_{Rc}^{\infty} R^{-\gamma} W^i(Rc, h, R) dR \qquad (2)$$

where $W^i(Rc, h, R)$ is the coupling function between CR variations above and inside the atmosphere at the level h (m, or mb) and at a point with geomagnetic cut off rigidity Rc (Dorman, 1974), $R^{-\gamma}$ is a rigidity part of power spectrum of zero harmonic with a power index $-\gamma$ which is defined from the relation $A_0 R^{-\gamma}$.

Calculation of reception coefficients of the first harmonic (C_x^i, C_y^i, C_z^i), on the contrary, is very labor-consuming since it is necessary to consider not only an atmosphere of the Earth, involving a coupling function $W^i(Rc, h, R)$, but also interaction of CR with the magnetosphere (Belov et al., 2005). Such calculations accounting asymptotic directions of the particles of different energy beyond the magnetosphere were performed for the NM network by Yasue et al. (1982) for those stations which were operating by that time (80th). For all additional stations in the last years arose these coefficients have been interpolated in our calculations from rigidity and latitudinal dependencies of C_x^i, C_y^i, C_z^i obtained by the known values from Yasue Tables. The matrix in Eq. (1) accounts the Earth rotation in geographic coordinate system (GEO) to fix axis X on the Sun direction. The solution of an inverse task, i.e., the solution of the equation (1) system by the RLS method (recursive least square error method having a fast convergence rate and a better minimum mean square error) relative to A_0, γ, A_x, A_y, A_z in approach of the first harmonic defines density A_0, its spectral characteristics γ and vector of anisotropy of CR (A_x, A_y, A_z) near to an orbit of the Earth outside its atmosphere and magnetosphere.

Hourly averaged values of these parameters have been calculated by mentioned above method of global survey (GSM), in version described by Belov et al., 2005, by the data from up to 130 neutron monitors throughout the epoch of CR monitoring, since 1957 till present time. The list of all implemented stations is given in Table 1 (see also Shea and Smart, 2000). We used neutron monitor data from IZMIRAN data base (http://cr0.izmiran.rssi.ru/mosc/main.htm), where they are collected in more complete volume than in any WDC. Of course, we calculated the CR variation parameters only after data correction for drifts, jumps (because of change of electronic or number of counters). But this is not a universal method (it is impossible), it is only data checking and verification by the way of comparison different stations with similar conditions (close coordinates, cut off rigidity and altitude). We calculate and publish such parameters for different time periods during at least 15 years. We could process data for 2–3 years during one year because of careful and long procedure of data preparing. That's why the main requirement to every station is its stable and reliable operating which can provide high quality data.

We should emphasize that not all and not a constant number of stations operated at every moment (due to breaks down, closing of stations, run the new ones and so on) and in various periods there was different number of stations; in the average it was 33–45 fully suited for calculations. A plenty of used stations has allowed us to provide both a good accuracy of obtained characteristics, and fully continuous data set on CR anisotropies over a whole considered period.

As the given technique is labor-consuming enough, it is important to make these data free accessible for the scientists. At the solving of many problems of solar terrestrial physics it is necessary to have variations of CR outside the magnetosphere instead of data of any individual station, let even reliably working, but containing the contribution of magnetosphere and atmospheric effects (e.g. Belov et al., 2003a). Data on variations of CR density and anisotropy near Earth above the magnetosphere for the cosmic rays of 10 GV rigidity presented in DB_A10 are the global CR characteristics and they don't depend on the local position of detectors. CR density variations, obtained for this rigidity (10 GV), have high accuracy and reflect all solar wind changes responsible for CR disturbances.

Among above-mentioned parameters the mean square deviations (*SigmaH* – the residual dispersion in the RLS method which is defined by discrepancy δ_{err}^i in formula (1)) of experimental data from that derived by the accepted model were calculated by the data of high latitude stations. This parameter evidences the adequacy of implemented model: in some periods a large discrepancy between real and model data (increase of *SigmaH*) indicates a possible impact of second and higher order harmonics, or existence of geomagnetic effect in cosmic ray variations.

3. General description of the data base DB_A10

The results of calculations are collected in the MySQL data base on CR anisotropy. A number of records in the DB-A10 database are about 4,50,000, capacity of 600 MB. As new calculations become available the monthly updating and updating in real time is being possible. Free access is available by the address: http://cr20.izmiran.rssi.ru/AnisotropyCR/Index.php.

The data is stored in a MySQL database, and access is provided through php scripts.

Using widely and successfully realized combination of script-language Php and MySQL databases, the Internet-project have been created on supplying of CR anisotropy data in different formats to a final user.

A usage of the Php language and MySQL in pair provides operability and rapidity for access to data even from