Observed and Expected Features of the 27-day Variations of Galactic Cosmic Rays

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Abstract

The 27-day variations of galactic cosmic rays (GCR) during the period of 1976–2001 have been studied. A significant differences have been found between the amplitudes of the 27-day variations of GCR obtained by the non corrected for Forbush decreases (Fds) data and the corrected for Fds data, e.g. the well known Gnevyshev's gap is not so single valued seen based on the data corrected for Fds, and the maximum of recurrent variations is observed after the end of global solar magnetic field inversion. It is supposed that one of the general roles of the differences of the amplitudes of the 27- day variation of GCR in different qA>0 and qA<0 solar magnetic cycles must be belonged to the heliolongitidunal asymmetry of the solar wind velocity.

1. Introduction

Although 27-day variations of GCR intensity and anisotropy have been studied about 60 years discussions about its nature continue till today [1]. One of the possible origins of the recurrent GCR variation may be the stable asymmetry of the heliosphere connected with the asymmetry of the solar activity distribution [2]. During and near solar activity maximum observed GCR variation is sum of recurrent and other short term variations, mostly Forbush decreases (Fds) of GCR intencity. It's important to exclude Fds from the data to study fine structure of recurrent variation. It is the purpose of the present work to define accurately recurrent variations taking into account Fds. In the present work we try to find more realistic simulations for quantitative comparisons with observations.

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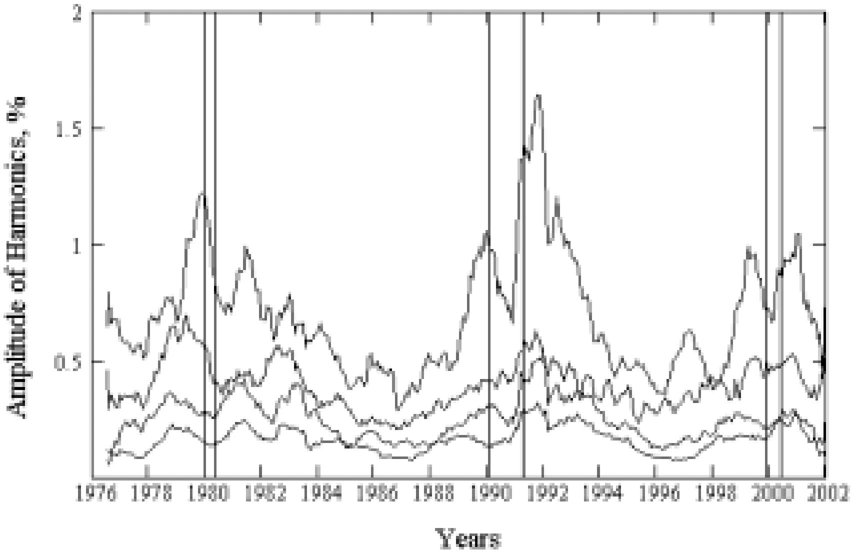

Fig. 1. The temporal changes of 13-point running averages of the amplitudes of the first four harmonics (from top to bottom) of GCR intensity 27- day variations for Kiel neutron monitor during 1976–2001. The vertical lines correspond to the moments of solar magnetic field inversion.

2. The data and method

Daily data of Oulu, Kiel and Tbilisi neutron monitors for the period of 1976–2001 containing the both negative and positive solar magnetic cycles were basically used for analysis. Daily intensity of GCR was treated by standard Fourier analysis to determine the amplitude and phases of 27-day variations during each Carrington rotations. During the discussed period there were observed more than 160 cases of Fds with magnitude $\geq 4\%$ according to the high latitude neutron monitors [3, 4]. In contrary to [5] in the present work we rechecked our data and corrected it to all discussed Fds separately and prolonged our study for more wide period of observations.

3. Discussion of the experimental results

The changes of 13-point running averages of amplitudes of the first four harmonics of 27- day variations of GCR intensity during 1976–2001 are given on the Fig. 1. The vertical dashed lines correspond to the start and end moments of solar magnetic field inversion [6].

Our corrected for Fds data clearly shows that at least the Gnevyshev effect [7] in GCR recurrent variations is suppressed, while the data with Fds reveals two peak maximum for all harmonics of recurrent variations (plot isn't presented).

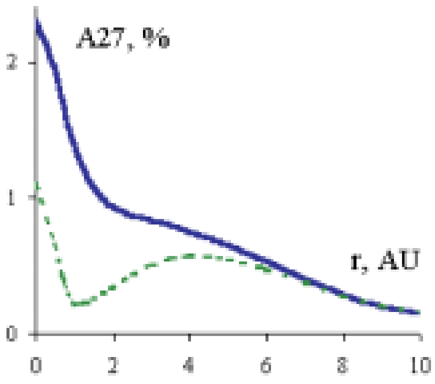

Fig. 2. a Radial changes of the amplitudes of the 27-day variation of GCR for $\gamma = 0^0$; solid curve for qA>0 and dashed curve for qA<0

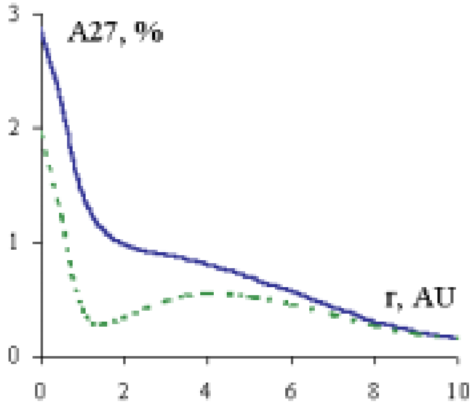

Fig. 2. b As in fig.2a for $\gamma = 20^0$;

Observed data of GCR intensity is well described by the first 4 harmonics. Correlation coefficient between the observed (corrected for Fds) and calculated data (the sum of the first 4 harmonics) is equal to 0.984. Analyses reveal, that the high order harmonics exist at all levels of solar activity and the data corrected for Fds clearly show that GCR recurrent variations are larger during positive solar magnetic cycle.

4. Model Calculations

Parker's three dimensional (3-D) transport equation has been used to describe the 27-day variations of GCR.

$$\frac{\partial N}{\partial t} = \nabla_i(\kappa_{ij}\nabla_j N) - \nabla_i(U_i N) + \frac{1}{3R^2}\frac{\partial(R^3 N)}{\partial R}(\nabla_i U_i) \tag{1}$$

where N, and R are density (in interplanetary space) and rigidity of GCR particles, respectively; U_i is the solar wind velocity; t- time; and K_{ij} is diffusion tensor consisting from the symmetric and antisymmetric (responsible for drift) parts [8,9]. The equation (1) has been solved numerically taking into account drift due to gradient and curvature of the IMF and the heliospheric neutral sheet (HNS) drift as in [10,11]. The expected amplitudes of the 27-day variations (A27) are presented in figure 2a,b (fig.2a for two- and fig.2b for three dimensional IMF, γ is the angle between the magnetic field lines and radial direction in the meridian plane).

It is seen from this figures that A27 are greater for qA>0 solar magnetic cycle, than that for the qA<0 cycle. In suggested model the parameter which causes 27-day variations of GCR is the heliolongitudinal asymmetry of the solar wind velocity.

5. Conclusion and Acknowledgement

The important role of the differences of the amplitudes of the 27-day variations of GCR in different qA>0 and qA<0 cycles play an involving of the oppositely directed drift streams of GCR by the heliolongitudinally asymmetry solar wind velocity.

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6. References

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