27-day variation of galactic cosmic rays in the 23rd cycle

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Abstract
We study the 27-day variations of the galactic cosmic ray (GCR) intensity and anisotropy connected with the solar rotation in the last cycle of solar activity. It is very interesting to study present minimum epoch, because of astonishingly low solar activity. We established that the amplitudes of the 27-day variations of the galactic cosmic ray intensity and anisotropy in the minimum epochs of solar activity in the positive polarity periods are greater than in the negative polarity period are related with the heliolongitudinal asymmetry of the solar wind velocity. We found that the long - lived active regions of the heliolongitudes are the sources of the long-lived 27-day variation of the solar wind velocity during the A > 0 polarity period. We compare our recent findings of the last minimum epoch of solar activity with our earlier results.

Introduction

The minimum epochs of solar activity are characterised by the relatively quiet Sun, with a well established direction of the regular interplanetary magnetic field (IMF) and minimal disturbances in the heliosphere. For the minimum epochs a contribution of the drift effect of the galactic cosmic rays particles (due to the gradient and curvature of the regular IMF) can be revealed reasonably purely in different classes of the GCR variations (Fig. 1). This is essentially important for the GCR variations with relatively small amplitudes, e.g. for the 27-day variations of the GCR intensity and anisotropy. In [1] was found incontrovertible evidence that the sizes of the solar wind parameters and recurrent cosmic ray modulations are ~50% larger when A > 0 (A is the direction of the solar global magnetic field) than during A < 0. In papers [2-5] was demonstrated that the amplitudes of the 27-day variations of the GCR intensity and anisotropy are greater in the minimum epochs of solar activity for the positive polarity period than for the negative polarity period of solar magnetic cycles. In [6] was shown that severe recurrent changes of the stream of protons take place in the positive A>0 periods rather than in the negative A<0 periods. In a theoretical hybrid model [7] was shown that the Fisk heliospheric magnetic field can explain several properties of the recurrent cosmic ray variations. Nevertheless, the amplitudes of the 27-day variation of the GCR intensity generated only by the existence of the Fisk's field are very small in a comparison with the experimental results, and there remains a general problem of the reality of the Fisk's type magnetic field in the minimum epochs of solar activity [8].

Data and results

The daily average values of the isotropic and anisotropy components of galactic cosmic rays were found based on the hourly values obtained by Moscow neutron monitor data; then we calculated the amplitudes of the 27-day variations of the GCR intensity and anisotropy by means of daily data using the harmonic analyses method. The amplitudes of the 27-day variations of the anisotropy and intensity of GCR are presented in the Fig. 2ab for the minimum epochs of 1965-67, 1985-1987 and 2007-2009 (A<0) as well as 1975-1977 and 1995-1997 (A>0). Figs. 2ab show that the amplitudes of the 27-day variation of the GCR anisotropy (Fig. 2a) are greater in the all minimum epochs of solar activity for the A>0 polarity periods than for A<0 polarity periods of the solar magnetic cycles, while the amplitude of the 27-day variation of the GCR intensity for current minimum epoch (A<0) has the same level as for previous minimum epoch (A>0). This peculiarity we ascribe to the clearly established 27-day variation of the GCR intensity in 2007-2009, which generally is an exception for the A<0 polarity periods.

In this paper we analyze also the magnitude of the heliolongitudinal asymmetry of the solar wind velocity (SWV), GCR intensity and anisotropy depending on the polarity. Using the frequency filters method [10] we demonstrate some features of the 27-day variation of the SWV, GCR intensity and anisotropy for the sequence of the individual Carrington rotations in the A>0 and A<0 polarity periods. The frequency filters method decomposes a time series into frequency components. We use band pass filter characterized by two period (frequency) bounds. It transmits only the components with a period within these bounds. We investigate periodicity bound within 24-31 days (27-28 days in the middle) using daily data of SWV, GCR intensity as well as radial and tangential components of GCR anisotropy obtained by Moscow neutron monitor for the periods of 1995-97 (A>0), 2007-09 and 1985-87 (A<0). Results of the filtered daily data are presented in Figs. 3 for the above mentioned periods. Generally, the point is that the greater amplitudes of the 27 day variation of the GCR intensity for the A>0 polarity period than for A<0 polarity period usually observed by neutron monitors experimental data [1], [2], and the similar results obtained for the anisotropy [3-5] can be generally related with the greater amplitudes of the 27-day variation of the solar wind velocity in the A>0 than in A<0 polarity periods.

Moreover, we calculated the phases of the 27-day variations of the SW velocity, the GCR intensity and anisotropy (Fig. 4), by the harmonic analyses method. Fig. 4a shows that the distribution of the phases of the 27day variation of the SW velocity and GCR intensity have sharply established maxima for the current minimum epoch (A<0 polarity period) and they are opposite (about 180 degrees). This behaviour doesn't coincide with our previous findings [5], that the phases of the 27-day variations of the SW velocity and the GCR intensity have not clear maxima for the A<0 polarity period. In the distribution of the phases of the 27day variation of the GCR anisotropy there are not any visible regularities (Fig. 4b). There is a tendency of the existence of the second harmonic of the solar rotation period (~13-14 days) and it corresponds to our previous findings [5]. We assume that the clear 27-day variation of the solar wind velocity in the A>0 polarity period is the reason of the existence of the regular 27-day variations of the GCR intensity and anisotropy. Analyses of the phase distribution of the 27day variation of the solar wind velocity show that the long lived active heliolongitudes exist on the Sun, especially for the A>0 polarity period of the solar magnetic cycles.

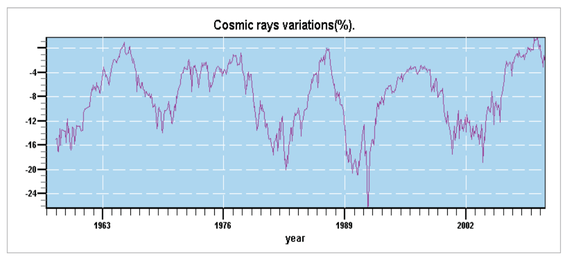

Fig. 1 Monthly Moscow neutron monitor variation for the whole period of observations [http://helios.izmiran.rssi.ru/cosray/months.htm]

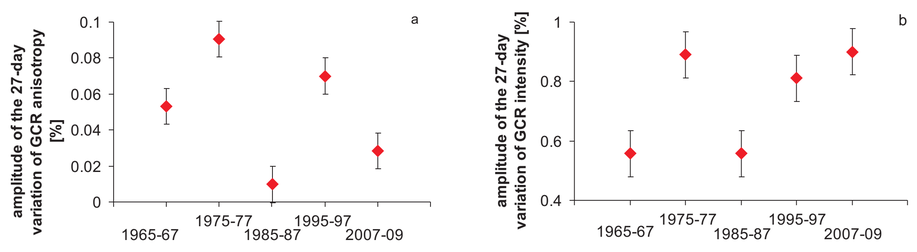

Fig. 2ab Amplitudes of the 27-day variations of the GCR anisotropy (2a) and intensity (2b) in different (A>0: 1975-77, 1995-97 and A<0: 1965-67, 1985-87, 2007-09) polarity epochs of solar magnetic cycle

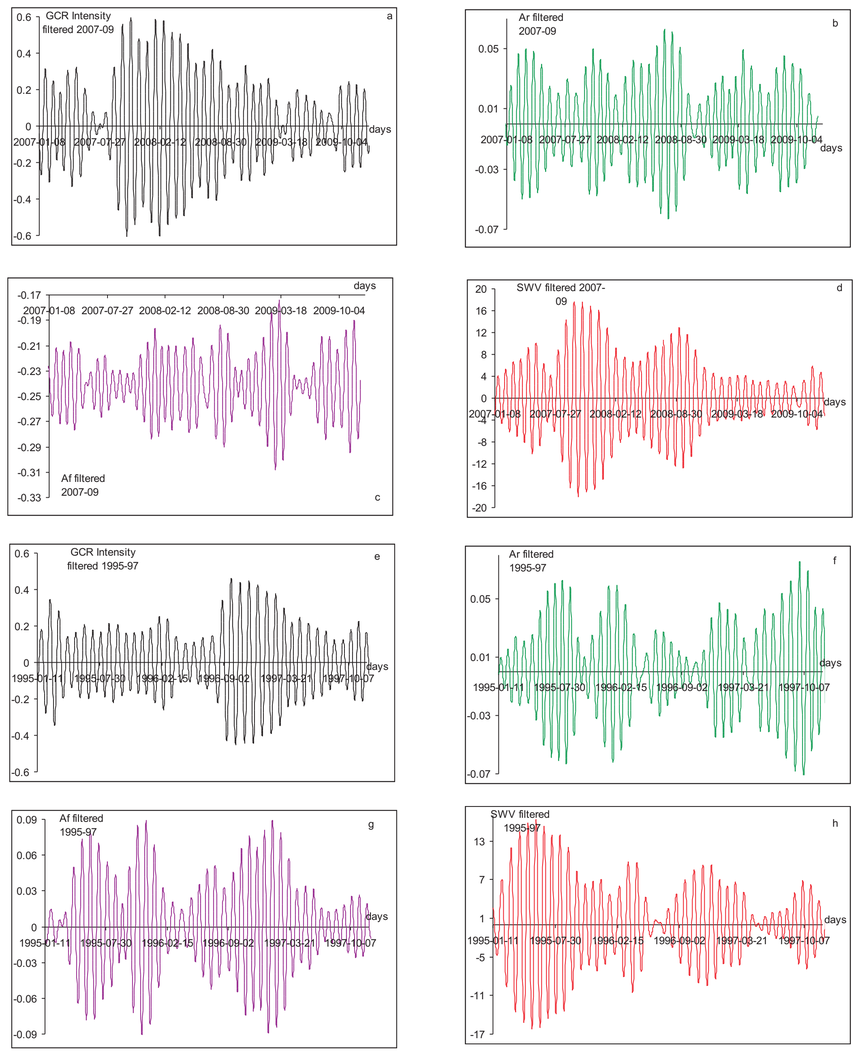

Fig. 3a-l Results of filtering data in the last tree minimum epochs: 2007-09 (3a-d), 1995-97 (3e-h), 1985-87 (3i-l) for the GCR intensity (3a, e, i), Ar (3b, f, j) and Af (3c, g, k) components of the GCR anisotropy, and solar wind velocity (3d, h, l).

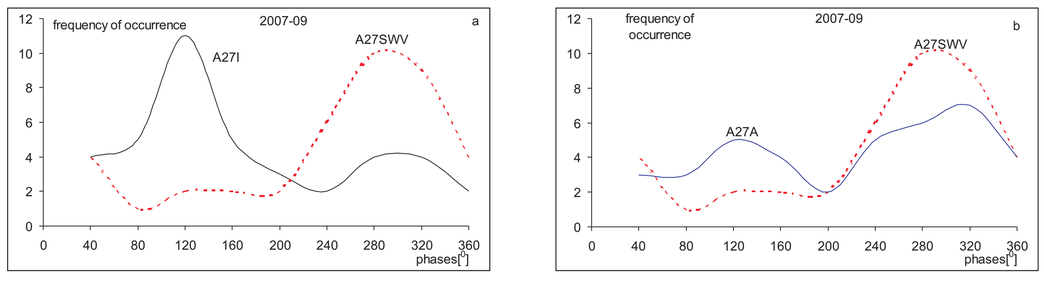

Fig. 4ab Phases of the 27-day variations of the GCR intensity (4a) and anisotropy (4b) in comparison with phases of the 27-day variation of the solar wind velocity (4ab, red line) in the current minimum epoch, i.e. 2007-09. On the horizontal axes are presented heliolongitudes in degrees.

CONCLUSION

Current minimum of solar activity in the 23rd cycle is a very exceptional; it is especially visible in the behavior of the 27-day variations of the galactic cosmic rays intensity and solar wind velocity.

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