Solar dynamo problem in the 27-day variation of the galactic cosmic rays intensity

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Abstract

It is very well known that differential rotation can produce a toroidal field from a poloidal one. But the nature of a vise-versa process arises a problem how to describe the physical mechanism which generates poloidal component of the magnetic field. Maybe galactic cosmic rays studies can bring some answers. Analysing a long period changes (1958-2009) of the 27-day variation of the galactic cosmic rays intensity, solar activity, solar wind and geomagnetic activity parameters we found a clear recurrence in the temporal changes of the amplitudes of the 27-day variation of the GCR and in some parameters of solar activity and solar wind. For being precise, we recognize noticeably established recurrence (cycling) with duration of three Carrington rotations period (3-CRP). We assume that a creation of the 3-CRP could be related with the Sun's differential rotation causing a conversion of the Sun's poloidal magnetic field into the toroidal ($\alpha\omega$ effect).

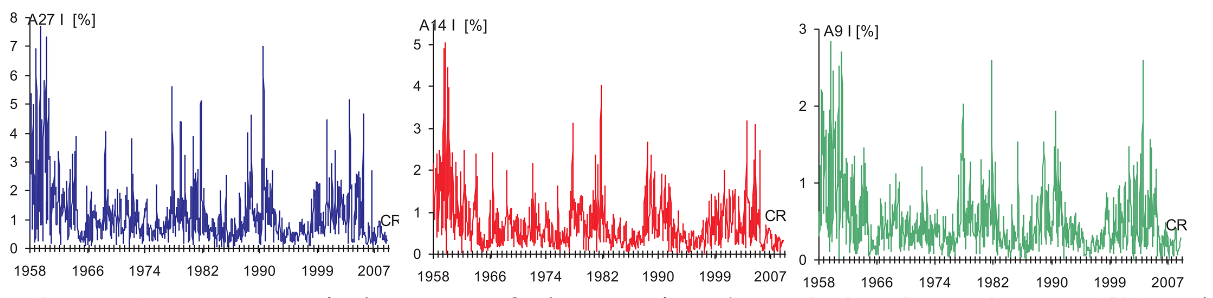


Fig. 1abc Temporal changes of the amplitudes of the first (A27 I[%]; 1a), second (A14 I[%]; 1b) and third (9 I[%]; 1c) harmonics of the 27-day variation of the GCR intensity calculated using Kiel neutron monitor in 1958-2009

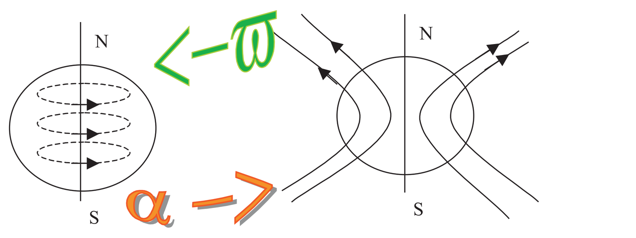
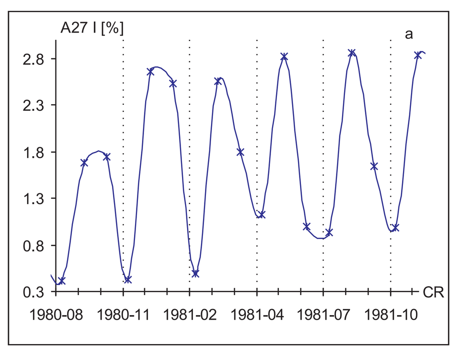
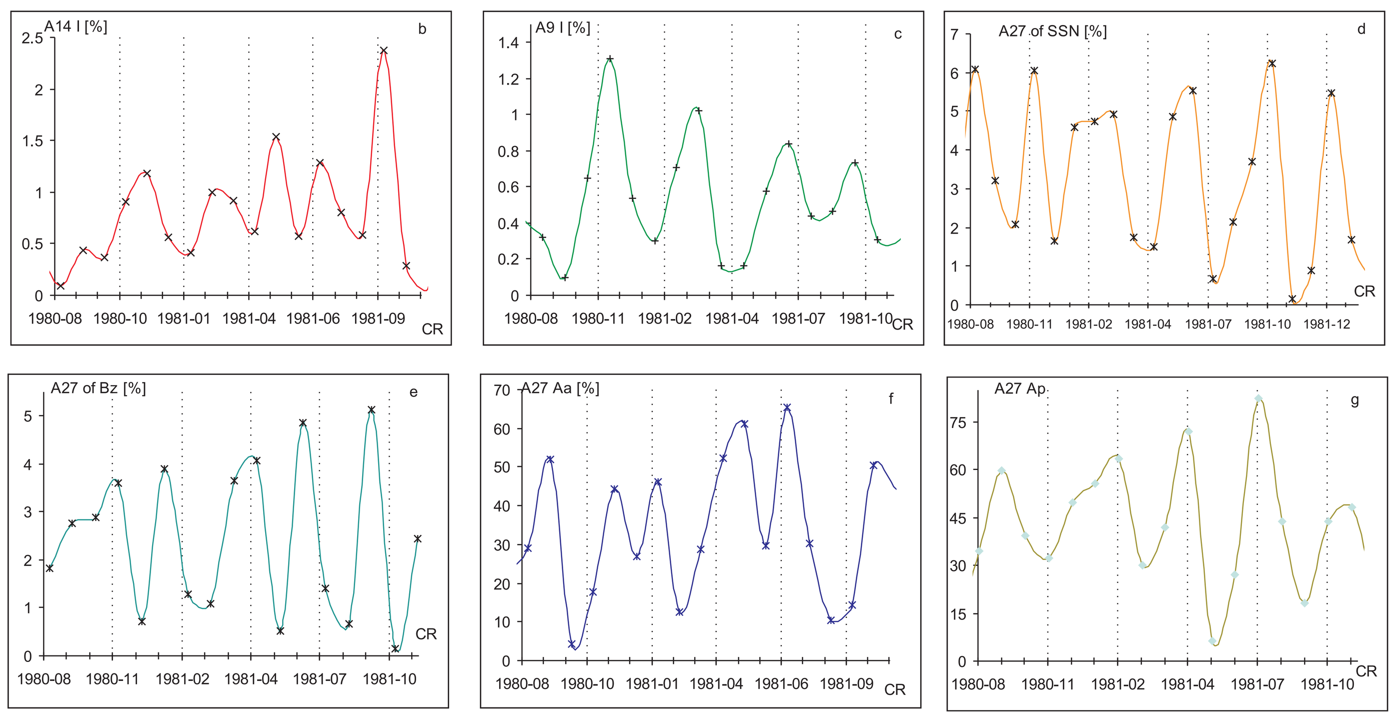


Fig. 2 Schematic $\alpha\ \omega$ effects (based on http://solarscience.msfc.nasa.gov/dynamo.shtml)





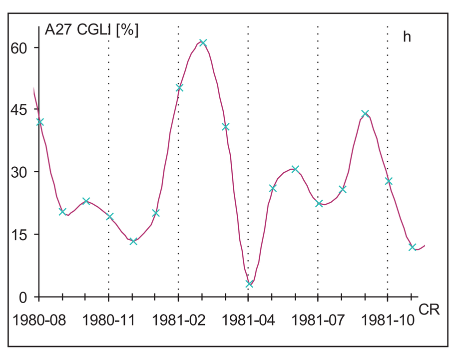
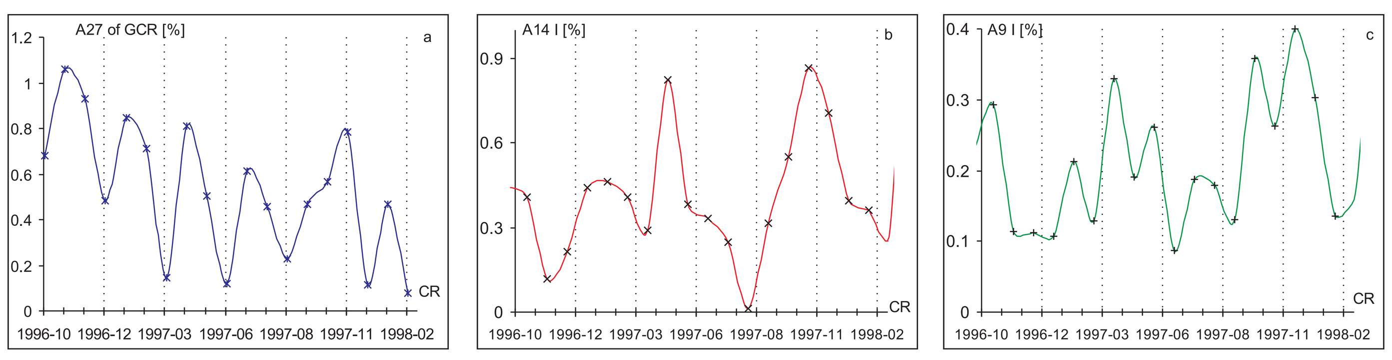


Fig. 3a-h Sequences of six of the 3 -CRP cycling in the 1980-1982 (maximum epoch of solar activity) of amplitudes of the 27- day variation of: the first harmonic of GCR intensity by Kiel neutron monitor (3a), the second harmonic of GCR intensity by Kiel NM (3b), the third harmonic of GCR intensity by Kiel NM (3c), the relative sunspot number (SSN, 3d), the Bz component of IMF (3e), the Aa index (3f), the Ap index (3g) and coronal green line intensity (CGLI, 3h).



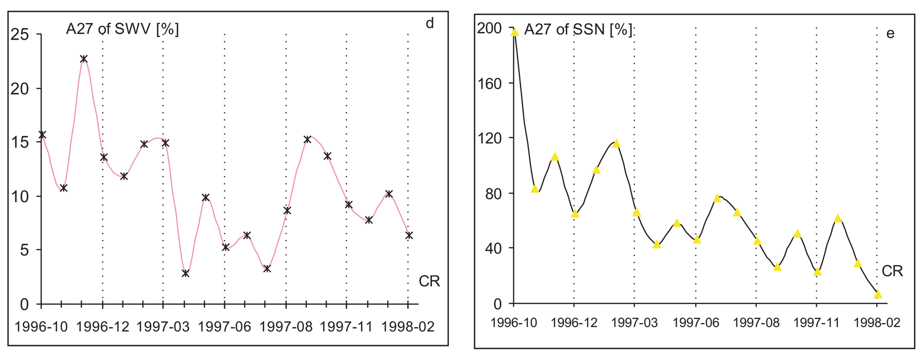


Fig. 4a-e Sequences of six of the 3 -CRP cycling in the 1996-98 (minimum epoch of solar activity) of amplitudes of the 27-day variation of the first harmonic of GCR intensity by Kiel neutron monitor (4a), the second harmonic of GCR intensity by Kiel NM (4b), the third harmonic of GCR intensity by Kiel NM (4c), the solar wind velocity (SWV, 4d), the relative sunspot number (SSN, 4e).

Analyzing long period changes of the amplitudes of the first, second and third harmonics of the 27 day variation of the galactic cosmic rays (GCR) intensity (Fig. 1abc) one can undoubtedly observe 11-year wave for each harmonic. At the same time, more careful analyses show that there are patterns with different cycling, among them more clearly established one is three Carrington rotations period which was firstly recognized in paper by Gil & Alania (2010). Namely, relatively clear recurrence (cycling) with duration of three Carrington rotations period (3-CRP) was found. This finding we relate to $\alpha\omega$ effect (e.g. Parker, 1993; Roald & Thomas, 1997). Figure 2 shows a schematic diagram of this effect.

When the equatorial regions perform 3 rotations (with the sidereal rotation period of ~25 days, or with the sinodic period of ~27 days) and polar regions only perform 2 rotations (with the sidereal rotation period of ~34-35 days, or with the sinodic period of 36-37 days) the equatorial magnetic lines are fully wrapped around the Sun and reach the heliolongitudes where are located theirs origin in the polar region. It seems that fully wrapped magnetic field lines create structure of magnetic field on the Sun which has cycling character. It is especially seen in the changes of the amplitudes of the 27-day variation of the GCR intensity. It is important to underline that besides the 3-CRP cycling there is observed 4-CRP, too. One can suppose that the rates of the Sun's differential rotation changes versus heliolatitudes, i.e. the difference of the rotation periods is changeable between the equatorial and polar regions, or solar dynamo has turbulent character and the observed quasi-periodicities with 3-4 CRP are results of fluctuations of the $\alpha\omega$ effects. The above-mentioned cycling processes on the Sun are observed preferentially at the ascending and descending epochs of solar activity.

In this paper we analyze daily data of: GCR intensity from Kiel neutron monitor in 1958-2009 (http://cr0.izmiran.rssi.ru/kiel/main.htm), solar wind velocity (SWV), strength and components of interplanetary magnetic field (B, Bx, By, Bz) in 1973-2010 (we excluded periods with lot of gaps, http://omniweb.gsfc.nasa.gov/), sunspot numbers (SSN), solar radio flux (SRF), Aa index, Ap index, Kp index and DST index in 1958-2010 (http://spidr.ngdc.noaa.gov/spidr/). Using harmonic analysis method (e.g. Gubbins, 2004) the amplitudes of the first, second and third harmonics of the 27-day variation of the GCR intensity and the amplitudes of the 27-day variations of the above mentioned parameters of solar and geomagnetic activity have been calculated. It is well known that the periodicity of about 27 days occurs in these parameters (e.g. Kudela, 2009; Ruzmaikin et al., 2001; Richardson et al., 1999). As examples of our results we show only two periods. Fig. 3 presents sequences of six of 3-CRP cycling in the maximum epoch of solar activity, i.e. 1980-1982. There are observed similar changes (as in amplitudes of the harmonics of the 27-day variation of GCR intensity) in the solar activity parameters: sunspot numbers (SSN), solar wind velocity (SWV), components of the IMF (Bx, By, Bz), coronal green line intensity (CGLI) and rather weaker in the geomagnetic activity parameters (DST, Ap, Kp indexes). One can observe from Fig. 3 that in the maximum epoch there exists a relation between the 27-day variation of the GCR (Fig. 3a) and Bz component of the IMF (Fig. 3e). It is worth to note that Selot et al. (2009) have found a linear correlation between the interplanetary magnetic field strength, the north - south component (Bz) of the IMF vector and the 27-day variation of the GCR intensity. Fig. 4 presents sequences of six of 3-CRP cycling in the minimum epoch, i.e. 1996-1998. The 27-day variation of the GCR (Fig. 4a) in this period is rather associated with the solar wind velocity changes (Fig. 4d). We suppose, that it can be a valid statement, that in the minimum epochs the 27-day variation of the GCR intensity is caused by the 27-day variation of the solar wind velocity, but in the maximum epochs decisive role in the creation of the 27-day variation of the GCR intensity plays the 27-day variation of the Bz component of the IMF.

The occurrence of this phenomenon we conformed using method of spectral analysis. We have found power spectra density of the amplitudes of the 27-day variations (A27). Figure 5ab presents result for the amplitudes of the 27-day variations of the Aa index and the GCR intensity.

The 3-CRP cycling appearance has rather sporadic character. It can exists even two years, but after that it disappears, so as to emerge again after few rotations. However, we underline that our study is only a beginning stage of the investigation of the just found 3-CRP cycling of the 27-day variations of the GCR intensity, solar activity and solar wind parameters, and it needs a further special investigation.

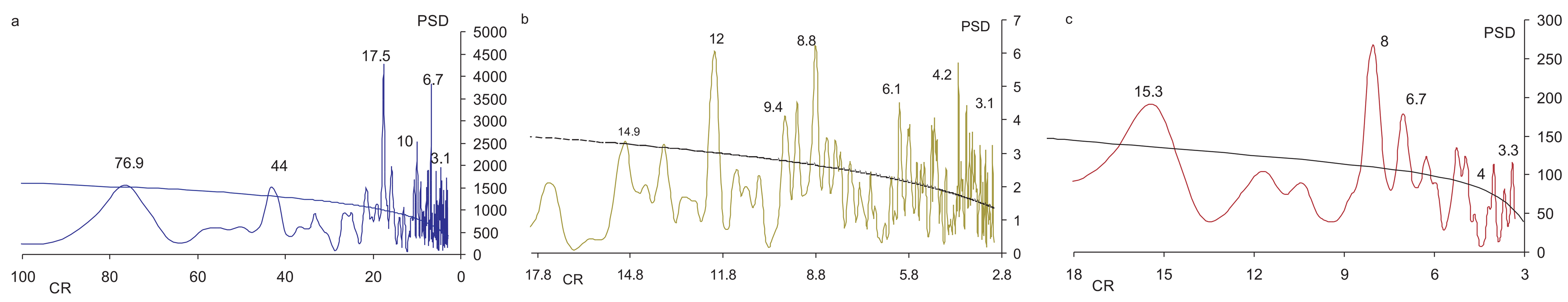


Fig. 5abc PSD of the amplitudes of the 27-day variations of Aa index in the period 1958-2010 (a), the GCR intensity in the period 1958-2009 (b) and solar wind velocity in the period 1997-2010 (c), on the abscissa are Carrington rotations (CR).

Conclusion:

We recognize relatively clearly established recurrence with duration of three Carrington rotations period (3-CRP) in the temporal changes of the amplitudes of the harmonics of the 27-day variation of the GCR intensity and in the 27-day variations of some parameters of solar activity and solar wind. We assume that the 3-CRP could be related with the Sun's differential rotation causing a conversion of the Sun's poloidal magnetic field into the toroidal ($\alpha\omega$ effect).

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