

## Solar dynamo and the 27-day variations of the galactic cosmic rays intensity, solar wind and solar activity

A. GIL<sup>1</sup>, M.V. ALANIA<sup>1,2</sup>

<sup>1</sup> *Siedlce University, Institute of Mathematics and Physics, Siedlce, Poland*

<sup>2</sup> *Institute of Geophysics, Tbilisi State University, Tbilisi, Georgia.*

*gila@uph.edu.pl*

**Abstract:** The mechanism of the solar magnetic field's formation is mostly explained as a result of the functioning of the solar dynamo. The solar dynamo operates due to the connection and interaction between the processes of the convective zone and solar differential rotation. However, although based on the experimental data and modern theoretical studies the relationship between the solar dynamo and differential rotation is acceptably explainable, there is no research devoted to connections between the nature of the solar dynamo and the 27-day variation of the galactic cosmic rays intensity, which after all, is also related to the Sun's rotation around its axis. At the interface between these two phenomena we detected a new type of cycle with length of 3 to 4 solar rotations, which we called 3 to 4 Carrington rotations period (3-4 CRP) recurrence. We assume that the general cause of this phenomenon may be related to the similar cycle in the topological structure of the solar magnetic field lines created owing to the existence of the asymmetry of turbulent solar dynamo and solar differential rotation, transforming the Sun's poloidal magnetic field to the toroidal, and vice versa ( $\alpha - \omega$  effect). Mutual transmission of the poloidal and toroidal magnetic fields should have partially turbulent character due to corresponding mixture of various cyclical modes in different time scales. We show that our calculation based on the recent experimental data confirm our assumption.

**Keywords:** 27-day variation of the GCR, solar dynamo, differential rotation, solar wind

### 1 Motivation

It is well known fact that the solar dynamo acts in the large scale periodicities. Among them, the most obvious, morphologically linked with solar dynamo is 22-year magnetic cycle (e.g. [13]). There are also considered, based on cosmogenic radionuclides analysis, long-lasting periodicities, among them 87-years and its multiplicities [7]. But, there also exist mid-term quasi-recurrences. Howe et al. [4], using helioseismologic data, found very clearly visible periodicity of 1.3-years in the solar rotation tempo around the tachocline in the convective zone. Olemskoy, Choudhuri and Kitchatino [10] stated, that poloidal magnetic field, in the same time has regular recurrences in the dynamo cycles and irregular changes in short- time scales analogous to the solar rotation period. An interesting review of other quasi-periodicities appearing in the Sun behaviour can be found in [14, 6]. Gil and Alania [3, 2] found a new sort of quasi-periodicity, i.e. a distinct recurrence remaining three to four Carrington rotations period (3-4 CRP), studying the temporal behaviour of the amplitudes of the 27-day variations of the galactic cosmic rays (GCR) intensity, various parameters of solar activity (SA) and solar wind (SW). We are sure that the noticed quasi-periodicity, i.e. the 3-4 CRP recurrence is connected with the periodic configuration of the solar magnetic field. It exposes owing to the conversion of the poloidal magnetic field into the toroidal due to the solar magnetic dynamo and differential rotation of the Sun ( $\alpha - \omega$  effect).

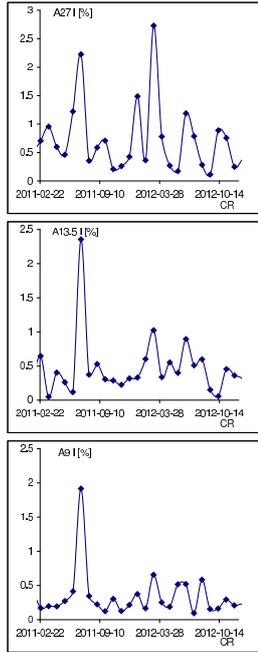
Our purpose in this paper is twofold: (1) to examine features of the 3-4 CRP recurrence of the 27-day variations of the GCR intensity, parameters of SA and solar wind using the recent experimental data; (2) to study the topologi-

cal structure of the Sun due to the temporal changes of the coronal green line intensity.

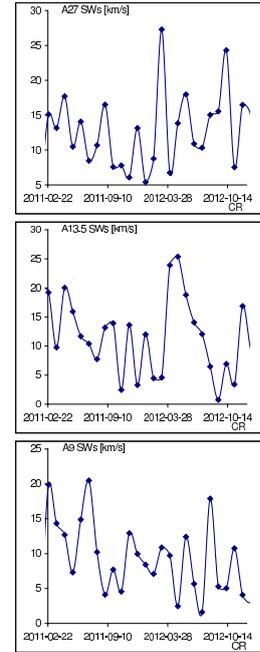
### 2 Recent experimental data and results

To investigate the properties of the 3-4 CRP periodicity using the recent experimental data, we consider daily data in the period of 2009-2013. We analyse different parameters measured on the Earth and in the nearest space around the Earth's orbit, among them the GCR intensity measured by Rome neutron monitor, solar wind speed (SWs), solar wind plasma temperature (SWT), the strength (B) of the interplanetary magnetic field (IMF) and sunspot number (SS-N). To find amplitudes of the 27-day variations of different parameters in this paper we use harmonic analysis method (e.g. [5]).

Results of calculations present Figures 1-5 (everywhere on the abscissa the unit is Carrington rotation (CR)). Figures 1a-5a show the sequence of seven 3-4 CRP, starting from February 2011 occurring in the described data. For comparison we present the behaviour of the second (Figures 1b-5b) and third (Figures 1c-5c) harmonics of the 27-day variations of the GCR intensity, solar wind speed, solar wind temperature, the strength of the IMF and sunspot number. One can see, that the 3-4 CRP recurrence is also visible in the amplitudes of the second and third harmonics of the 27-day variations of described parameters, not always so obviously as in the first harmonic changes, but still existing.



**Fig. 1:** Sequence of the 3-4 CRP cycling in 2011-2012 of the amplitudes of the first three harmonics of the 27-day variation of the GCR intensity by Rome neutron monitor, A27 I (1a), A13.5I (1b), A9I (1c).



**Fig. 2:** Sequence of the 3-4 CRP cycling in 2011-2012 of the amplitudes of the first three harmonics of the 27-day variation of the solar wind speed (SWs), A27 SWs (2a), A13.5 SWs (2b), A9 SWs (2c).

### 3 Examine the solar corona and discussion

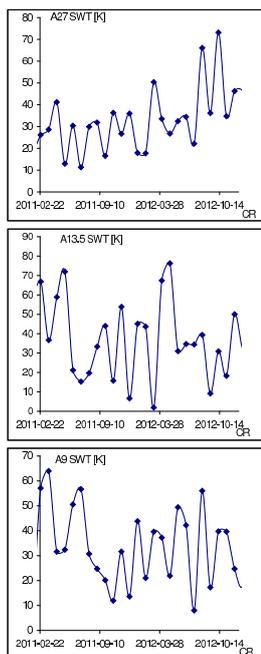
Mursula and Vippola [9] studying SW changes measured by various space probes showed that 1.3-years periodicity ([12]) is weaker in high heliolatitudes and stronger in the equatorial region. They [9] also reported, that 1.7-years periodicity ([8]) behaves opposite, being stronger in mid-latitudes. In [1] there can be found statement, that the manifestation of the rotation of the innermost part of sub-photospheric zones might be reflected in the solar corona behaviour.

To track the structures hidden in the solar magnetic field we study changes of the coronal green line intensity (CGLI) with wavelength of 530.3 nm, emitted by ionized iron Fe XIV (e.g. [15]) in the period of 1958-2008. We have calculated amplitudes of the first three harmonics of the 27-day variation of the CGLI at all points of the solar disc. Figures 6a-10a (everywhere on the abscissa the unit is Carrington rotation (CR)) shows the sequence of seven 3-4 CRP, starting from October 1996 occurring in the CGLI at few different points. We have found that the 3-4 CRP quasi-periodicity is mostly clearly visible in mid-latitudes and near the polar regions, especially in North hemisphere; possible this is an indication of the existence of stable North-South asymmetry of solar dynamo, while this recurrence does not exhibit in the equatorial regions. Moreover, we present the behaviour of the second (Figures 6b-10b) and third (Figures 6c-10c) harmonics of the 27-day variation of the CGLI at different points. One can see, that the 3-4 CRP recurrence is also noticeable in the amplitudes of the second and third harmonics of the 27-day variation of the CGLI, not constantly very clear, as in the first harmonic changes, however still existing. To compare with the 3-4 CRP quasi-periodicity visible in the amplitudes of the 27-day variation of the GCR intensity in the same period see the Figure 3a in [2].

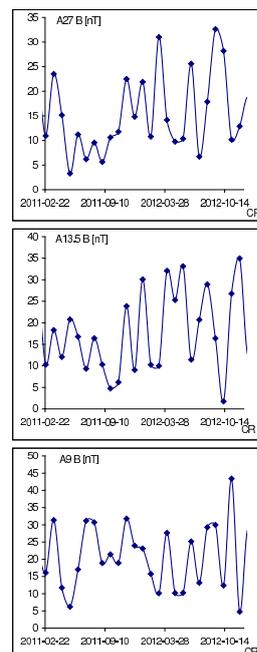
It has to be underlined that, owing to differential rotation of the Sun, when the helioequatorial zones execute 3-4 rotations, in the same time, polar zones perform only 2-3 rotations. Due to  $\omega$  effect the equatorial toroidal magnetic field lines are fully wrapped around the Sun and get to heliolongitudes with the source of the poloidal magnetic field lines (in the polar regions) from which the toroidal field was created. It appears that entirely wrapped toroidal magnetic field lines produce an unusual topological structure of magnetic field on the Sun, which characterizes the quasi-periodicity with duration of 3-4 CRP. One can suppose that the solar dynamo has turbulent character and the observed quasi-periodicities of the 3-4 CRP are results of changeable the  $\alpha - \omega$  effects (e.g. [11]).

### 4 Conclusions

1. We identify clearly established quasi-periodicity with duration of three to four Carrington rotations period (3-4 CRP) in the changes of the amplitudes of the first three harmonics of the of the 27-day variations of the recent experimental data (2009-2013): the GCR intensity, parameters of solar wind and solar activity.
2. We are sure that the 3-4 CRP recurrence is shaped by combined processes of the turbulent solar magnetic dynamo and differential rotation of the Sun leading to the conversion of the poloidal magnetic field into the toroidal ( $\alpha - \omega$  effect).
3. We showed that mostly in mid latitudes and near the polar regions the 3-4 CRP quasi-periodicity in the amplitudes of the first three harmonics of the 27-day variation of the coronal green line intensity is clearly visible. We believe that there exists the stable North-South asymmetry of the solar dynamo.



**Fig. 3:** Sequence of the 3-4 CRP cycling in 2011-2012 of the amplitudes of the first three harmonics of the 27-day variation of the solar wind plasma temperature (SWT), A27 SWT (3a), A13.5 SWT (3b), A9 SWT (3c).

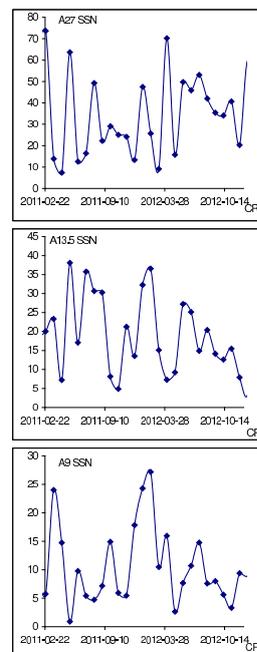


**Fig. 4:** Sequence of the 3-4 CRP cycling in 2011-2012 of the amplitudes of the first three harmonics of the 27-day variation of the interplanetary magnetic field strength (B), A27 B (4a), A13.5 B (4b), A9 B (4c).

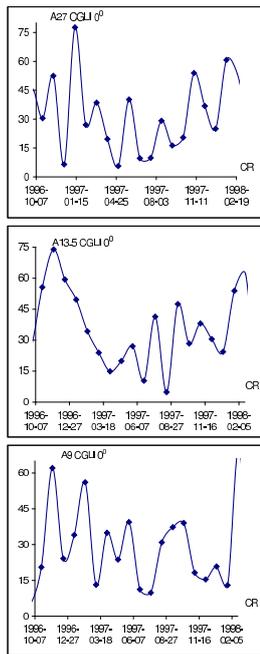
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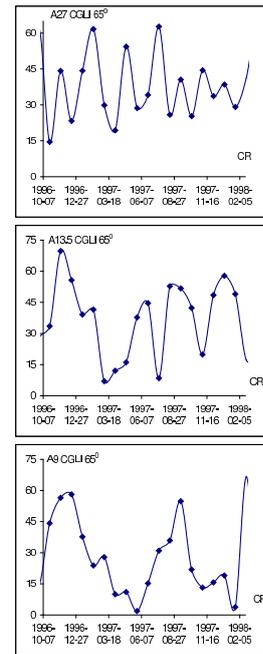
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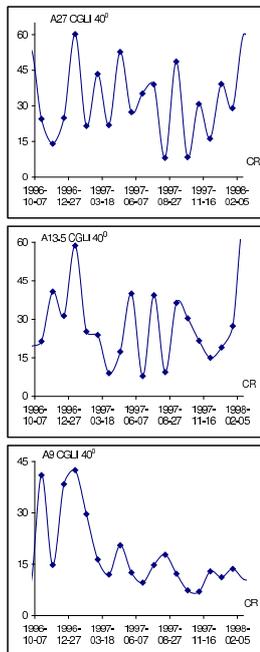
**Fig. 5:** Sequence of the 3-4 CRP cycling in 2011-2012 of the amplitudes of the first three harmonics of the 27-day variation of the sunspots number (SSN), A27 SSN (5a), A13.5 SSN (5b), A9 SSN (5c).



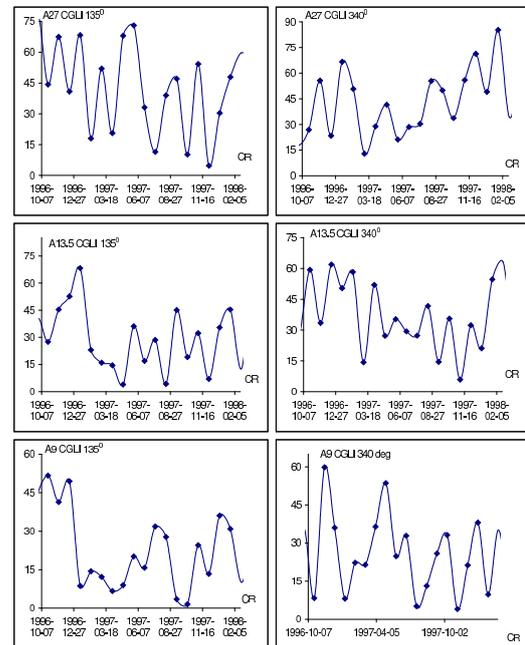
**Fig. 6:** Sequence of the 3 -4 CRP cycling in 1996-1998 of the amplitudes of the first three harmonics of the 27-day variation of the coronal green line intensity for  $0^\circ$  in absolute coronal units (acu), A27 CGLI  $0^\circ$  (6a), A13.5 CGLI  $0^\circ$  (6b), A9 CGLI  $0^\circ$  (6c).



**Fig. 8:** Sequence of the 3 -4 CRP cycling in 1996-1998 of the amplitudes of the first three harmonics of the 27-day variation of the coronal green line intensity for  $65^\circ$  in absolute coronal units (acu), A27 CGLI  $65^\circ$  (8a), A13.5 CGLI  $65^\circ$  (8b), A9 CGLI  $65^\circ$  (8c).



**Fig. 7:** Sequence of the 3 -4 CRP cycling in 1996-1998 of the amplitudes of the first three harmonics of the 27-day variation of the coronal green line intensity for  $40^\circ$  in absolute coronal units (acu), A27 CGLI  $40^\circ$  (7a), A13.5 CGLI  $40^\circ$  (7b), A9 CGLI  $40^\circ$  (7c).



**Fig. 9:** Left panel: Sequence of the 3 -4 CRP cycling in 1996-1998 of the amplitudes of the first three harmonics of the 27-day variation of the coronal green line intensity for  $135^\circ$ , A27 CGLI  $135^\circ$  (9a), A13.5 CGLI  $135^\circ$  (9b), A9 CGLI  $135^\circ$  (9c). **Fig. 10** Right panel: Sequence of the 3 -4 CRP cycling in 1996-1998 of the amplitudes of the first three harmonics of the 27-day variation of the coronal green line intensity for  $340^\circ$ , A27 CGLI  $340^\circ$  (10a), A13.5 CGLI  $340^\circ$  (10b), A9 CGLI  $340^\circ$  (10c).