Cosmic ray fluctuation parameter as indicator of 11-year cycle activity growth phase

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Abstract. The prolonged 23 cycle minimum has been tested on the basis of introduced by us the fluctuation parameter of galactic cosmic ray (GCR) intensity. Long-term forecast of the onset of new (24) 11-year cycle with an advance of ~1 year is given. Besides, a middle-term forecast of activity growth phase of the new 24 cycle with the advance of ~1 Sun rotation is presented. From results of the wavelet-analysis it follows that a low-frequency drift of 11-year cycle period has begun as long ago as the 22 cycle. It is necessary to notice that we have predicted the failure of 11-year cycle period (by our terminology it is called a «low-frequency drift») 3 years prior to its obvious manifestation in 2008-2010. Results of a trajectory analysis of GCR fluctuation parameter on a complex phase plane indicate that the greatest area is "covered" with a trajectory of the same 22 cycle. It is believed (in the view of G.V. Kuklin, 1982) that the greatest area of phase trajectory is an evidence of abnormal cycle before a «phase catastrophe». It is obvious that since the 22 cycle the prolonged failure of 11-year cycling has begun.

1. Introduction
To formalize the GCR intensity fluctuation dynamics on transitive regimes of solar wind turbulence the GCR fluctuation parameter has been introduced [1]. Earlier, as a result of analysis of dynamics of GCR fluctuations a conclusion on properties of self-similarity, scaling or fractality [2] was made. A low and finite value of correlation (fractal) dimension means, basically, not random character of GCR fluctuations in a vicinity of 11-year cycle maximum. The correlated behaviour of cosmic ray particles is of special interest from various points of view. First of all, it is important when studying a transitive regime to a solar cycle growth phase. At this time the probability of occurrence of the "colored" groups of particles, i.e. clusters is high. One can observe their evolution. The revealing of similar transitive regime would help to solve a problem of forecast of the growth phase and onset of geoeffective declining phase of the 11-year cycle.

2. Method
Parametrization of GCR fluctuation dynamics in the vicinity of interplanetary shock was carried out in [1]. It was established that the GCR fluctuation parameter was the effective instrument for studying of the transitive regime of fluctuations in a vicinity of shock. In language of the probability theory of continuous medium fracture the problem of studying of the transitive regime is reduced to a problem of determination of hazard function. The maximum of hazard function is, as a matter of fact, a...
PROBABILITY of achievement of critical value of an analyzed variable. In this case, this is the achievement of critical value of GCR intensity. This probability is defined by us as a GCR fluctuation parameter.

3. Results
In figure 1 are presents of calculation results of GCR fluctuation parameter in relative units (a solid curve, a scale on the left). Corresponding (27-day) values of GCR intensity in impulses (a scale on the right) are shown by a dotted line. The 90% level of "noise" is shown. The values of GCR fluctuation parameter with a value of P≥90% are considered to be significant, i.e. they are predictors of the geoeffective phase of the 11-year cycle. On the time axis the numbers of Sun rotations, according to the Bartels system, and years are plotted. Conventionally, the periods of sign-change of the general magnetic field of the Sun are shown. The significant signals-predictors of activity growth phase of the new 24 cycle has been registered on the 2421 (January, 2011) and 2433-2434 (January, 2012) rotations. After registration of the predictor, a sufficiently sudden decrease of GCR intensity on the subsequent rotations is observed. The second predictor in this year has been registered on the 2444 rotation (October, 2012).

4. Discussion
The introduced GCR fluctuation parameter has shown itself effectivley enough not only in a previous 23 cycle but also in the new 24 cycle of solar activity (figure 1). After registration of the first two predictors in January, 2011 and January, 2012 in both cases noticeable decreases of GCR intensity (figure 1) have been taken place. Each of this GCR intensity decreases corresponds to the active growth phase of new cycle 24. Thus, the introduced GCR fluctuation parameter has allowed us for the first time to give the forecast of geoeffective growth phase of the 11-year cycle, with the advance of ~1 rotation of the Sun (http://www.forsheek.ru/predlong.html). Perhaps, the last predictor registered in October, 2012 is an indicator of onset of the expected “maximum 2012” (some colleagues have already hastily shifted this maximum to onset 2013).

Correlation of annual values of GCR fluctuation parameter with annual values of GCR intensity is k=0,80, with Wolf numbers k =-0,74, with an index of "an electric field of solar wind" k =-0,76. The greatest value has an anticorrelation value of GCR fluctuation parameter with Dst-variation k =-0,85. It has been established that the introduced parameter is the inverse dependence relative to a regularity degree of the magnetic field. It means that the GCR fluctuation parameter can serve as the indicator of inhomogeneity degree of the magnetic field, for example, during the transition regime to the solar activity growth phase.

It is necessary to notice that we have predicted the failure of 11-year cycle period (by our terminology it is called a «low-frequency drift» [3]) 3 years prior to its obvious manifestation in 2008-2010. It follows from the results of wavelet-analysis of GCR fluctuation parameter (figure 2). It is visible that the low-frequency drift (it is shown by a vertical arrow) has begun as far back in the 22 cycle. The results of trajectory analysis on a complex phase plane indicate that the greatest area "is covered" by the trajectory of the same 22 cycle. The greatest area of phase trajectory is considered to be an attribute of abnormal cycle before the «phase catastrophe» (from the point of view of G.V. Kuklin). It is obvious that since the 22 cycle the prolonged failure of 11-year cyclicity has begun.

As a result, we have proposed a hypothesis for the existence of invariant of a "physical" 22-year cycle i.e. "amplitude-duration". If it is really so, then the following conclusion is obvious: the 22-year cyclicity is the self-oscillator mechanism of discrete (for a cycle) «release» of the surplus energy (the mechanism of regulation of Sun temperature constancy). If the 22-year cyclicity is a self-oscillatory regime, then the non-ordinary failure of the 11-year cyclicity is «phase catastrophe» which was observed earlier: during a Maunder minima in the second half of 17 century or during Dalton and Glaysberg minima at the beginning and at the end of 19 century.
Figure 1. Results of the ground GCR monitoring for the 1999-2012 period carried out by 5-min neutron monitor data of st. Oulu (Finland). The 27-day values of GCR intensity (in impulses) are presented by the dotted curve, a scale on the right. The 27-day values of GCR fluctuation parameter are shown by the solid curve, the scale on the left. The 90% significance level of GCR fluctuation parameter is given. On an abscissa axis the time (in years) and, corresponding numbers of Sun rotations by Bartels system are plotted. Conventionally, the sign-change periods of the solar magnetic field are shown. The predictors of the active growth phase have been registered on the 2421 (January, 2011), 2433-2434 (January, 2012) and 2444 (October, 2012) rotations.
**Figure 2.** Revealing of the low-frequency drift of the 11-year cycle period. On the upper panel of Figure the temporal change of analyzed annual values of GCR fluctuation parameter is shown. Below, there is the diagram of wavelet-analysis presented as “amplitude-time–frequency”. On this diagram the development in time or the evolution of 11-year variation period during the 20-24 (1970 - 2012) cycles is shown. The location of 11-year variation is shown by the arrow in the left part of Figure. The onset of drift of the 11-year variation period is indicated by the vertical arrow. On the right the global spectrum for the whole analyzed period is presented. On the abscissa axis – the time in years. At the bottom of Figure there is a bending curve around variations in relative units.

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