ARRHYTHMIA OF 11-YEAR CYCLICALITY OF THE SUN AS A VIOLATION OF THE 22-YEAR CYCLE INVARIANT

V.I. Kozlov

Yu. G. Shafer Institute of Cosmophysical Research and Aeronomy SD RAS, Yakutsk, Russia, cosmoprognoz@mail.ru

ABSTRACT

The increase in the area of the solar cycle 23 detected by cosmic rays was a harbinger of the failure of 11-year cyclicity (http://www.forshock.ru/predvlong.html): in accordance with the author's hypothesis about the invariant of the 22-year cycle, an increase in the area of the 23 cycle was followed by a decrease in the area (energy intensity) of the next 24 cycle. The decrease in energy-intensity is accompanied by a decrease in the relative variation in the luminosity of the Sun, which in the 24th cycle decreased to the level of the average value of the three preceding cycles, i.e., almost by half. Before the start of the new 25th cycle (2019-2021), an anomalous long-term increase in the radiation background is predicted. The *conservation* of the invariant of the 22-year cycle corresponds to the restoration of the 11-year cyclicity in the 25th cycle, that means the fulfillment of the following physical criterion: the level of GCR radiation background in the maximum of cycle 25 (2024-2025) should be significantly *below* the level of GCR radiation background in the maximum of 24 cycle (2014-2015). In this case, the current extraordinary failure of cycles 23-24 will have the status of "*local*". **Violation** of the invariant of the 22-year cycle correspond non-restoration of the 11-year cyclicity in the cycle 25, that means the following criterion is fulfilled: the level of GCR radiation background in the maximum of the upcoming 25 cycle (2024-2025) should be significantly **higher** (or equal), i .e. not lower than the background radiation level in the maximum of 24 cycle (2014-2015). In this case, the status of a non-ordinary failure of 23-24-25 cycles will change from local to **global**, with all the ensuing consequences.

Keywords: cosmic rays, GCR intensity fluctuations, solar activity, inversion of the magnetic field of the Sun, failure of 11-year cyclicity.

INTRODUCTION

From time to time a problem is intensively discussed in the literature: is described the behavior of solar activity by a finite and low-dimensional attractor what would be indicated on possible of exist a regular process? In [1], no affirmative answer to this question was received. Perhaps this is due to the low information content of Wolf numbers. So, in [2] it was noted that the Wolf numbers because of the specific rule of their counting, can hardly be a smooth function of the true dynamic variable. A plausible estimate of the correlation (fractal) dimension, i.e. the yield of the d(n) monotonous dependence on the plateau for value of dimension **d**=**2.5-3** in the vicinity of the maximum and in the beginning of the 11-year cycle declining branch was obtained us by data the cosmic ray scintillation index [3-4]. Neither by intensity of the galactic cosmic rays (GCR) nor by a Wolf numbers not possible correct estimate obtained of correlation dimension.

The phase of completion of the inversion of the global magnetic field of the Sun, as the most geo-effective, and is of most interest in terms of forecast extreme manifestations of Space weather. The geo-effectiveness of the polarity reversal phase is due to the fact that in the vicinity of the maximum and at the beginning of the decline branch of the 11-year cycle, the highest sporadic activity is recorded, accompanied by a series of CME and shock waves. The identification of limited and low-dimensional, i.e. partially deterministic process in variations of the GCR flicker index is, obviously, an indication of the principal possibility of predicting the period of the maximum sporadic activity of the Sun. The conclusion about the principle possibility of the prognosis of the active phase of the solar cycle, made by us base on obtained above the low and finite magnitude of the correlation dimension , was commented in sufficient detail in the relevant section of the monograph [5] devoted to the theme of fractals in the Cosmos.

METHOD

It seems that the most complete information about the process is contained in the density of the distribution function, i.e. in the empirical frequency histogram of the source data. All that remains only is to highlight the potentially possible regular signal from the noise-like signal. Naturally, a potentially possible useful signal can be contained in the second and subsequent moments of the GCR intensity distribution function.

From the probabilistic theory of continuous medium destruction and reliability theory, it is known that the generalized Weibull-Gnedenko distribution function describes the system reaching the critical limit before a conditional crisis or “catastrophe” [6]. In our case, this can be considered as a transitional mode to the active phase of the 11-year cycle. In the language of this probabilistic theory, the problem of determining the transition regime is reduced to the problem of determining the function of the failure rate of a system that has exhausted its resources. The maximum of the failure rate function, or the maximum of the Risk function, is, in fact, the probability of reaching a critical value of the analyzed variable, in this case, the intensity of cosmic rays. The ratio of the density of the Weibull-Gnedenko distribution function to the “reliability function” is the desired probability (the Risk function) or the parameter of cosmic ray fluctuations [7].

PROBABILISTIC IDENTIFICATION THE TRANSITION REGIME TO ACTIVE PHASE OF A SOLAR CYCLE

In Fig. 1 are presents the results of the mid-term monitoring of cosmic rays for the period from 1999-2019. For the analysis of short-period variations of the parameter with periods from six months or more, a low-frequency trend was excluded, which is, in fact, an 11-year variation. Harbingers active phases of cycle 24 were registered at the following interval times. Harbinger of the BEGINING (24 cycle) - on the back 2407: December 2009, a dotted arrow (see also Appendix 2). The harbinger of the GROWTH phase was registered on the rotation 2421: January 2011, solid arrow (ibid, Appendix 2). The harbinger of the MAXIMUM phase was registered - on the turnover

2434: January 2012, the solid arrow (Appendix 2). The precursor of the phase of the inversion of the magnetic field was registered on the back of 2449 in early 2013 (the dotted arrow in Fig. 1). The harbinger of the beginning of the geo-effective phase of the branch descending (after completion of the polarity reversal of Sun magnetic field at the end of 2013) was registered on the back of 2469: July 2014, solid arrow in the same figure.

The dotted arrow (green) in Fig. 1 presents a precursor of a quite unexpected ACTIVIZATION of solar activity in the vicinity of the MINIMUM phase of the current solar cycle 24 in July-September 2017 (turnover 2509-2511). Obviously, the time interval corresponding to revolutions 2504-2508 (from the third decade of February to June 2017) represents a transitional regime to a rather unexpected active phase in the vicinity of the minimum of the 24th cycle ending. Really, in July and September 2017, large Forbush effects (~ 7%) and geomagnetic storms were recorded, which caused a sharp and deep decrease in 27-days values of GCR intensity on solar turnovers 2509-2511 (see Fig. 1). The relatively small variations in GCR intensity with precursors in mid-2019 are due to the passage of the Earth's orbit of high-speed flows or long-lived solar wind “jets” from coronal holes, which is common for phase of 11-year cycle minimum.

The low values of the parameter of the fluctuations of the GCR (encapsulated in the oval in Fig. 1), recorded after the harbingers against the background of low values of cosmic ray intensity, mean the diagnostics of the predicted phases of a solar cycle. In particular: the phase of the MAXIMUM sporadic activity: turnover 2437-2442 (March-July 2012). Geo-effective phase of the BEGINNING of the recession of the current cycle: turnover 2471-2479 (September 2014 - March 2015) and the quite unexpected phase ACTIVIZATION in the vicinity of the minimum of the current 24 cycle (July-September 2017). Thus, the introduced parameter of cosmic ray fluctuations allows, with an advance $\Delta \mathbf{t} = \mathbf{3} \pm 1$ solar rotations, to give a medium-term forecast of the active phases of the 11-year solar cycle: http://www.forshock.ru/predlong.html.

It should be noted that the moments of registration of harbingers in cosmic rays coincide with the onset of the magnetic field restructuring in the complexes of activity on the Sun. This follows from the results of comparison of the moments of registration of harbingers (Fig. 1) in cosmic rays and the results of solar observations presented in [8]. Magnetic field changes were observed at the growth and declining phases of both maxima (recorded in the annual mean values of Wolf numbers in 2012 and 2014), i.e. at the phases of their maximum variability. Thus, it can be preliminary concluded that the harbinger in a cosmic rays is an indicator of the restructuring of the solar magnetic field at the transient regime to active phase of a solar cycle.

TRANSITION OSCILLATORY PROCESS OF INVERSION OF SUN GENERAL MAGNETIC FIELD IN COSMIC RAYS

To make sure that the location of the precursors in cosmic rays reflects the real situation in the interplanetary medium, a joint analysis of the intensity of cosmic rays and the parameters of the solar wind is carried out below: the variability (dispersion) of the interplanetary magnetic field (IMF) and the speed of the solar wind. For analysis, we used the results of direct measurements on the ACE American spacecraft (http://www.srl.caltech.edu/ACE/ASC/level2/). Indeed, in the growth phase and in the vicinity of the maximum of the new 24th cycle, the annual variation of the IMF dispersion (Fig. 2) and the solar wind plasma velocity (Fig. 3) are noticeably pronounced. This coincides with the annual, on average, frequency of registration of the harbingers registered by us in the analyzed period. Therefore, we can conclude that the harbinger in cosmic rays is indeed an indicator of the restructuring of the magnetic field of the Sun in transition to the active phase of the solar cycle. This is consistent with current solar observation data: in [9–10], a quasi-periodic or “pulsed” structure of the growth phase of a new 24 cycle with a period of ~ **1** year is noted.

As follows from the results obtained, the largest variation in the mean-turn values of the GCR fluctuation parameter is reached in the vicinity of the maximum, on the phase of reversal of the general magnetic field of the Sun and at the geo-effective phase of the beginning of the decline branch of the 11-year cycle (Fig. 1). It was also found that the higher the amplitude in maximum of the cycle, the shorter the duration of the polarity reversal process (after completion of which, the restoration of GCR intensity begins). And, on the contrary, the lower the amplitude of the cycle, the longer the polarity reversal phase. Indeed, the duration of the field inversion process for “low” cycles (20 and 23), in fact, is twice as long as that for the “higher” cycles 21 and 22 (Fig. 4). The inverse dependence of the duration of the field inversion process on the cycle amplitude revealed us by use cosmic rays indicates the possible presence of a binary coupling invariant of the characteristics of the 11-year cycle “amplitude - duration”. In addition, the mere presence of a transitional oscillatory process of changing the sign of the total magnetic field of the Sun allows us to explain from a single point of view the so-called “failure (s) of Gnevyshev” [11-12], which observed usualy in the vicinity of the maximum of the 11-year cycle, including and “quasi-two-year” variations, as well as “semi-annual” variations of the interplanetary magnetic field [13].

More “low-frequency” than usual [7], i.e. the annual polarity reversal wave (Fig. 2-3) means a longer duration of the inversion process not only in the previous 23, but also in the new 24 cycle (2011-2013). From the fact of the longer duration of the polarity reversal process, as well as the possible presence of the Invariant of the 11-year cycle, one would expect a low amplitude of the maximum of the current 24 cycle, that and follows from the data in GCR intensity (Fig. 1). The amplitude of the new 24 cycle turned out to be significantly less than the amplitude of the previous

23 cycle. This is undoubtedly an argument in favor of the hypothesis of the invariance of the binary connection "amplitude - duration" of the 11-year cycle. Our results are consistent with the results of [14], where an inverse relationship was also established between “time between polarity reversals and cycle amplitude”.

It is important to compare the fluctuation parameter of the GCR with the key modulation parameter **k** = **ωτ** introduced in [15] to characterize the degree of regularity of the field. Here ω is the gyro-frequency of particles in a regular magnetic field τ is the average time between the scattering events of particles. The modulation parameter is assumed to be constant for the entire heliosphere and independent of the particle energy, although it will be vary in during a solar activity cycle. It is assumed that the magnitude of the modulation parameter reflects the relationship between the intensity of the regular and turbulent field. The regular field in the time of the maximum is much less than the turbulent field. On the contrary, the intensity of the turbulent field is maximal during the maximum of the cycle: first the intensity of the turbulent field increases linearly with time, reaches a maximum during the polarity reversal, and then decreases linearly [15].

The relationship between the fluctuation parameter of the GCR and the degree of turbulence of the solar magnetic field follows also from the comparison of the GCR parameter with the "efficiency index of the solar multipole", which reflects the contribution of the quadrupole component of the solar magnetic field. This indicator was introduced in the works of the IZMIRAN group [16-17]. It is good (R=**0.83**) correlates with the main parameter of solar activity - Wolf numbers (Appendix 3). Below, we compared the fluctuation parameter of the GCR with the "efficiency index of the solar multipole" IZMIRAN. Their comparison shows that the envelopes of variations in the GCR fluctuation parameter and variations of the “solar multipole efficiency index”, on average, are consistent with each other (Fig. 4). This is confirmed by a rather high (R = **-0.77**) value of the coefficient of their regression connection, in general (Fig. 5). Thus, the fluctuation parameter clearly reflects the contribution of the quadrupole component of the solar magnetic field, which is largely due to the restructuring of the solar magnetic field in the vicinity of the maximum (Fig. 4) of the 11-year cycle.

Indeed, as follows from the results of analysis of [18], the contribution of the quadrupole component of the solar magnetic field is dominant in the vicinity of the maximum of the solar cycle. In this sense, the unsteady oscillatory process in cosmic rays in the vicinity of the maximum of the solar cycle (Fig. 4) is an indicator of the transition regime of inversion of the solar magnetic field. This is confirmed by the analysis of the fluctuating component of the solar magnetic dipole for the same 3 cycles of solar activity 21-23 [19]. These authors conclude that during the field inversion, the component of the magnetic dipole does not vanish. It has a fluctuating nature and therefore is not described (http://www.aanda.org/articles/aa/pdf/2014/07/aa23319-13.pdf) in the framework of the traditional theory of dynamo of the mean field.

EFFECT OF INCREASING OF DURATION CYCLE 23 IN COSMIC RAYS

The phase of the field inversion is manifested in the form of sharp and deep decreases in GCR intensity at the beginning the decline branch of the 11-year cycle: in 1972, 1982, 1991, 2003 and in 2014 (Fig. 6). These periods are known as geo-effective phases of the beginning the decline branch of the 11-year cycle. It is quite evident that the phase of completion of the inversion of the field is also manifested in the parameter of the fluctuations of the GCR. In each case, the location of the geo-effective phase is manifested in low, i.e. diagnostic value of the parameter of cosmic ray fluctuations (see Fig. 6).

The presence of an 11-year cycle in the GCR fluctuation parameter is obvious. This follows from a simple comparison of intensity values (dotted curve - open circles, scale on the right) and the introduced parameter of fluctuations of GCR (solid curve - triangles, scale on the left). Concerning the relationship between the fluctuation parameter of GCR and traditional indices of solar and geomagnetic activity, the following should be said (Appendix 3): correlation of the annual values of the fluctuation parameter with the GCR intensity R=**0.80**; With Wolf numbers (R= **-0.74**); with the index of the "electric field of the solar wind" R= **-0.76**. The most value is the anticorrelation of the fluctuation parameter of the GCR with the Dst-variation (R= **-0.85**). Obviously, that their high correlation connection is due of the 11-year variation in the analyzed parameters.

This is confirmed by the results of wavelet analysis (a diagram of the periods of variations in the middle part of Figure 7): the 11-year variation in the parameter of fluctuations of galactic cosmic rays is revealed quite distinctly. Attention is drawn to the appearance of a "low-frequency drift" of the period of the 11-year variation, i.e. increase the duration of the "low" (by amplitude) of cycle No. 23. This very important result confirms conclusion, which was obtained by us earlier by the GCR flicker index [20]: the higher the amplitude of the cycle at the maximum, the shorter the duration of the polarity reversal process. And, vice versa: than lower the amplitude of the cycle, the longer the field inversion process.

The increase the duration of the 23 cycle with the "low" amplitude should be expect if the hypothesis proposed by us about the invariant of the binary connection "amplitude - duration" of the 11-year cycle does indeed hold. Conclusion about increase the duration of the solar cycle number 23, in other words, the fault of 11-year periodicity, was made in 2006 [20]. Now this conclusion is confirmed on new base, with using introduce by us the GCR fluctuation parameter. Essentially, that the fact of increasing the duration of the "low" by amplitude of cycle 23 is an independent experimental evidence for the reality of the above invariant, its expected consequence. Information about that the "cycle length, in turn, negatively correlates with the height of the cycle" is given in a recent paper [21].

PREDICTOR OF SOLAR CYCLICITY FAILURE IN COSMIC RAYS AT THE LANGUAGE OF PHASE PORTRAITS

Why is so important the fact increase of the duration of cycle 23? The fact is that the appearance of a low-frequency "substrate" in the spectrum of 11-year cycle may precede the failure of 11-year cycle [22]. And our studies confirm this [23]. In terms of studying the nature of a failures 11-year cyclicity special interest is approach of G.V. Kuklin [24], who analyzed failures of solar cyclicity by using the Lorentz system. The Lorentz system is able to describe the various stages in the evolution of the system: from the appearing of convection - the appearance of self-oscillations when the critical temperature is exceeded, and until the self-oscillations disappearing with decreasing temperature.

The failure of the 11-year cycle is manifested not only in the change in the cycle duration, but also in its amplitude. Record high of the value of GCR intensity in the four-year period 2007-2010 (Fig. 6) is connected, first of all, with the weakening of the global dipole field of the Sun. And such data has already appeared. As shown in [25], the magnetic moment of the solar dipole in 2008 decreased to values typical for the early twentieth century. At the same time, local fields are also anomalously low [26]. Such a long period with complete disappearance of sunspots was observed only at the beginning of the last century.

It is important to note that the hypothesis of the presence of an invariant of the 11-year cycle "amplitude-duration" was a logical consequence of a holistic approach to the analysis of variations of solar activity. It is natural to further develop the holistic approach by analyzing the "phase portraits" of solar cycles on the complex phase plane. To this end, we apply the method of trajectory analysis of oscillations on the complex phase plane using an analytical signal. An analytical signal is a mathematical model of the original signal. On the complex plane, it is represented by a vector whose modulus and phase angle vary from the argument, and the projection of the signal to the real axis is equal to the value of the original signal (Appendix 5).

The "phase portraits" of the 11-year cycles are shown in Fig. 8. They were calculated from the average annual values of the GCR fluctuation parameter. In the upper part of the figure, the time course of the analyzed parameter is shown. The numbers of all cycles are shown on the time scale. The *largest* area, describes the trajectory of the 23 cycle (shown in *red*). The increase in the area of the cycle begins in 2006 (the point on the phase trajectory No. 32). The largest area swept out by the phase trajectory is considered to be a sign of an anomalous cycle before begin the "phase catastrophe" [24], in fact - its harbinger.

In this case, now, at least, we are at the stage of an extraordinary recession of solar activity and, as a maximum, in the initial phase of the prolonged failure of the 11-year cycle of the Sun, with all the consequences that follow. First of all, we mean the expected anomalously high level of cosmic-ray intensity, compared with most cycles of the last century. For the first time, a similar forecast was given by us with use cosmic rays in 2006 [20]. An abnormal increase in the background radiation was then registered a year later, during the four-year period 2007-2010. (shaded area in Fig. 6). As a result, in the language of "phase portraits" is received an independent confirmation of the conclusion about the precursor in cosmic rays of the failure of the 11-year cyclicity of the Sun in the modern era - the era of "Space era".

THE INVARIANT WITH CHARACTER SCALE OF 22-YEAR CYCLE

Above, it was found that an increase in the area of the "phase portrait" of a solar cycle serves as a harbinger of the failure of the 11-year cycle. An estimate of the area of the observable curve of the solar cycle can be obtained in different ways: by estimating the area of the 11-year cycle that is swept under the observable curve and by estimating the area swept out by the phase trajectory on the complex phase plane. The physical meaning of the term "cycle area" is more transparent in the second variant (the area swept out by the phase trajectory on the complex phase plane) than in the first one. The area of the "phase portrait" has the dimension of "phase volume" or ACTION, with the dimension: "energy x time". In this sense, for a fixed (in time) cycle its area is a characteristic of the energy-content, the change of which from cycle to cycle can be traced, for example, by the relative variation of Sun luminosity, i.e. by the relative change of 11-year variation of the "solar constant": http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant.

Below is an estimate of the areas of phase portraits of solar cycles 21-24, i.e. characteristics of their energy intensity (by data of the GCR fluctuation parameter). The areas of cycles 21 and 22 are practically identical (Fig. 9). The invariance of the area, as a characteristic of the energy intensity, indicates the conservatism of the system during two consecutive cycles 21 and 22. Conservativeness, in this sense, is violated for the next two cycles 23 and 24. Violation of the conservatism of the system means the existence of cycles with different energy-content (different areas). This and is observed in cycles 23 and 24 (Fig. 9): the maximum area falls on the 23rd cycle, followed by a clear decline in the area of "failure" 24th cycle, starting from 2006. It is noteworthy that the relative variation of the solar luminosity, as a possible characteristic of the energy-intensity of the cycle, began to decrease in 24th cycle, in fact, starting from the same 2006 (Appendix 4).

Obviously, the averaging of the areas of pairs of neighboring cycles will preserve the invariance of the areas of pairs of 11-year cycles: 21-22 and 23-24, i.e. the immutability of the areas of neighboring 22-year cycles or their "energy-intensity". This may mean the conservatism of the system (the Sun) in the broad sense, i.e. the presence of an invariant with a characteristic scale of the duration of the physical 22-year cycle. Provided that the indicated invariant is preserved, after the failure of 11-year cyclicity in 23-24 cycles, the functioning of the dynamic system (Sun) in the next 25 cycle (2021-2030) should be restored!? This will mean that the “Gnevyshev-Olya” rule is fulfilled, according to which, the amplitude of the forthcoming odd cycle 25 should be greater than the amplitude of the even cycle 24. In the case of cosmic rays, the fulfillment of the “Gnevyshev-Olya” rule corresponds to the following physical criterion: the background radiation level GCR at a maximum of cycle 25 (2024-2025) should be significantly *lower* than the level of radiation background of GCR at a maximum of 24 cycles (2014-2015). In this case, the current non-ordinary failure of 23-24 cycles will have the status the “*local*”, as in the case of a local (according to our notions) failure that occurred, for example, in the cycles 19-20.

GLOBAL FAILURE OF SUN 11-YEAR CYCLICITY AS VIOLATION OF 22-YEAR CYCLE INVARIANT

And only in case of violation of the invariant with a characteristic scale of a 22-year cycle, i.e. violation of conservatism in a broad sense, we are confronted with a situation of global failure of the 11-year cyclicity or "phase catastrophe". An example of this is the global minimum of solar activity, known as the minimum of the Maunder, the minimum of Dalton and the minimum of Glaysberg. Violation of the invariant of the physical 22-year cycle means a violation of the conservatism of the system: a decrease in the relative variation of the solar luminosity, similar to, what is currently observed in the current 24 cycle (Appendix 4). And, as a consequence: failure of energy regulation regime (self-oscillations) in the convective zone of the Sun. Since there is no need in a "discrete" (for a cycle) "released out" or regulating "excess" energy, for lack of it. With this view, and emergence and violations of cyclicity are organically related to each other by the commonness of the approach to cyclicity as a mechanism for regulating energy.

In this, by our view, and consist the nature of solar cyclicity (11-year and 22-year). Solar cyclicity is nothing but a self-oscillatory mechanism regulation of energy (in convective zone) of the Sun, which stabilizience his temperature [20]. Thus, we have unique opportunities for monitoring and studying the regime of the disruption of regulation of energy (self-oscillations) in the convective zone of the Sun by using high-resolution cosmic rays data. In particular, this will be possible in the modern era, if the 11-year cycle is NOT restored in the 25th cycle (2021-2030).

Not restoring the 11-year cycle in the 25th cycle would mean a violation rule of the “Gnevyshev-Olya” rule, according to which the amplitude of the upcoming odd 25th cycle should be greater than the amplitude of the even cycle 24. In the case of cosmic rays, a **violation** of the “Gnevyshev-Olya” rule corresponds to the following physical criterion: the level of GCR radiation background in the maximum of the upcoming 25 cycle (2024-2025) should be significantly **higher** (or equal), i.e. **not** lower than the background radiation level at a maximum of 24 cycles (2014-2015). In this case, the status of an non-ordinary failure of 23-24-25 cycles will change from *local* to **global**, with all the ensuing consequences

ABOUT POSSIBLE CONSEQUENCES OF THE GLOBAL FAILURE OF A 11-YEAR CYCLICITY

Our conclusion about the nature of solar cyclicity finds, on the whole, is confirmed in work [27], based on energy estimates of magnetic energy dissipation. In particular, it is asserted that "it is impossible to exclude the possibility that the variations in luminosity are due not only to the dissipation of magnetic energy, but more directly to convective flows". And further: "... in our opinion, are quite worthy of attention the hypothesis that the additional energy release of the Sun at the maximum of the cycle is provided by more intensive heat transfer to the surface from the convective zone or due to the viscous dissipation of small-scale convection directly near the surface. As a result, the authors of [27] draw the following conclusions:

1. The physical nature of the processes leading to cyclic changes in solar luminosity remains unclear.

2. Dissipation of magnetic energy, apparently, is not the main energy channel for explaining variations in luminosity.

If the scenario of the global failure of the 11-year cycle is realized, an anomalous multi-year increase in the radiation background of galactic cosmic radiation is predicted, similar to the one that was registered in 2007-2010 (Fig. 6). The increase in the intensity of GCR contributes, as is well known, to the intensification of the process of cloud formation [28], the intensification of convective processes in the atmosphere and, as a result, the increase in the amount of precipitation and the decrease in temperature on a planetary scale. In this is concluded alternative to the global warming process. Obviously, all this will have a significant significance only in the event a global violation (failure) of 11-year cyclicity, i.e. violation of the 22-year cycle invariant.

ACTUALITY THE CHANGE OF PARADIGM OF “LINEAR SUPERPOSITION” OF PERIODIC WAVES OF ACTIVITY

Violation of the invariant of the physical 22-year cycle, i.e. implementation of the global failure scenario of the 11-year cyclicity (in case of not restoring the 11-year cycle in the 25th cycle) could mean the reality of non-linear regimes of the evolution of the solar magnetic field. It is obvious that the failure of the 11-year cycle according to the "phase catastrophe" scenario differs from the generally accepted scenario of the "linear superposition" of periodic waves (11 years and 200 years, etc.). In accordance with the scenario of "linear superposition," the onset of a protracted failure of the 11-year cycle is expected only from the middle of the 21st century.

It should be very important underline that the conclusion about the realization on the Sun of a non-trivial nonlinear regime of "*self-organized criticality*", when very irregularly, i.e. catastrophically (which and complicates the forecast) released the energy excess stored in system [20], *deprives* of the physical grounds the ideology of "*linear superposition of waves*" (11 and 200 years) as applied to the physics of the Sun. In this case, becomes obvious the reason of *delay* on half of century of global solar activity malfunction, which was predicted by proponents of the ideology of "linear superposition" only to the middle of 21st century. In reality, the non-ordinary failure of the 11-year cyclicity *bega*n with the 23 cycle, i.e. in the *early* 21st century and continues now, according the forecast which was done with use of cosmic rays in 2006 [20].

To date, the first signs of violation of the invariant of the 22-year cycle have already appeared, i.e. the first signs of a global failure of 11-year cyclicity. Kind of record of the era of the "Space Age" (the number of "spotless" days of 2008 was passed). Next in line is a "record" in the level of radiation background of galactic cosmic rays in 2009 (Fig. 6 - shaded area). Both of these signs are only *necessary* conditions for a global failure of 11-year cyclicity, because so far only concern the minimum activity of the Sun. A **sufficient** condition will be the fulfillment of the following physical criterion: the level of GCRs radiation background in the maximum of the upcoming 25 cycle (2024-2025) should be significantly **higher** to (or equal), i.e. **not** lower than the background radiation level in the maximum of cycle 24 (2014-2015). If the specified “necessary and sufficient” physical criteria are met, the status of an extraordinary failure of 23-24-25 cycles will change from *local* to **global**, with all the ensuing consequences.

CONCLUSION

And finally, it should be said, that the author’s long-term research on the transitional regimes of the solar wind (various scales) to the active phase of the 11-year cycle are reflected in the Space Weather monograph [29] recently published by Elsevier in the United States, prepared by the team of well-known Russian and foreign authors:

“Several years ago, it was confidently established that a parameter of fluctuations of GCRs may be used as an indicator of the 11-year cycle activity growth phase [23]. Due to long-term observations of GCR fluctuations, these authors, in fact, have predicted a phase upset in solar activity for cycle 24. Developing this approach, authors [7] do not exclude so-called “phase catastrophe” in cycle 25 (2020–2030), similar to the epoch of Dalton’s global minimum. This warning, in our opinion, deserves attention”.

RESULTS

1. The parameter of fluctuations of cosmic rays is an *indicator* of the degree of turbulence of the magnetic field changing during the solar cycle. High values of the GCR fluctuation parameter are indicators of the small-scale turbulence of the magnetic field on the transition regime to an active phase of the solar cycle. Low values of the fluctuation parameter are an indicator of a large-scale structure with relatively a regular field directly during the active phase of the solar cycle.

2. With the use of cosmic rays, the first time was given the *middle term prognosis* of the active phase of solar cycle, with advance Δ**t=3**±1 Sun`s rotations: http://www.forshock.ru/predlong.html. This is due to the fact that the precursor in cosmic rays is an indicator of the restructuring of the magnetic field on the transient regime to the active phase of the solar cycle.

3. In cosmic rays is detected transient oscillatory process of inversion of Sun global magnetic field [30]. An inverse relationship is established between the duration of the field inversion process and the amplitude of the solar cycle. The dependence obtained underlies the hypothesis about of the binary connection *Invariant* of the characteristics of an 11-year cycle: "*amplitude x duration*", which describes variations in the amplitude and duration of the solar cycle within the limits of the constancy of the area (energy intensity) of its "phase portrait" on the complex phase plane, where energy intensity is a characteristic of excess energy drained in a single cycle. In this sense, solar cyclicity is a self-oscillating mechanism of discrete (per cycle) *regulation* of the energy (in convective zone) of the Sun, which ensures the stability his temperature.

4. In case of violation of conservatism, i.e. not preserving the area (energy intensity) of the "phase portrait" of the 11-year cycle, it can be argued that conservatism is preserved in a broad sense when the area is preserved for a pair of neighboring cycles, which is equivalent to the hypothesis of the INVARIANCE of the 22-year cycle. The *increase* in the area (energy intensity) of the "phase portrait" of the solar cycle 23 was the *harbinger* of the failure of the 11-year cycle. Indeed, in accordance with the invariant of the 22-year cycle, after an increase in the area of the prior cycle 23, there was a decrease in the area (energy intensity) of the subsequent, current cycle 24.

5. A decrease in the area or energy intensity of the current cycle is accompanied by a decrease in the relative variation in the luminosity of the Sun, which in the 24th cycle decreased to the level of the (http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant) average value of the three previous cycles, i.e., almost *twice*. Prior to the start of the new 25th cycle (2019-2021), an *abnormal long-term increase* in the GCR radiation background is predicted (the first such forecast for cosmic rays was given by us in 2006).

6. Preservation of the invariant of the 22-year cycle corresponds to the restoration of 11-year cyclicity in the 25th cycle, which will mean the fulfillment of the "Gnevyshev-Olya" rule, according to which, the amplitude of the upcoming odd 25 cycle should be greater than the amplitude of the even cycle 24. The implementation of the rule "Gnevyshev- Olya "corresponds to the fulfillment of the following physical criterion: the level of GCR radiation background in a maximum of cycle 25 (2024-2025) should be significantly *lower* than the level of GCR radiation background in the maximum of cycle 24 (2014-2015). In this case, the current non-ordinary failure of cycles 23-24 will have the status of "*local*", as in the case of a local (in our opinion) failure that occurred, for example, in cycles 19-20.

7. Violation of the invariant of the 22-year cycle does correspond to **not** the restoration of 11-year cyclicity in the 25th cycle, which would mean a violation of the "Gnevyshev-Olya" rule, according to which the amplitude of the forthcoming odd cycle 25 should be greater than the amplitude of the even cycle 24. Violation of the "Gnevyshev's rule-Olya "must comply with the following physical criterion: the level of radiation background of the GCR in the maximum of the upcoming 25 cycle (2024-2025) should be significantly **higher** (or equal), i.e. **not** lower than the background radiation level in maximum of cycle 24 (2014-2015). In this case, the status of non-ordinary failure of 23-24-25 cycles will change from *local* to "**global**", with all the ensuing consequences.

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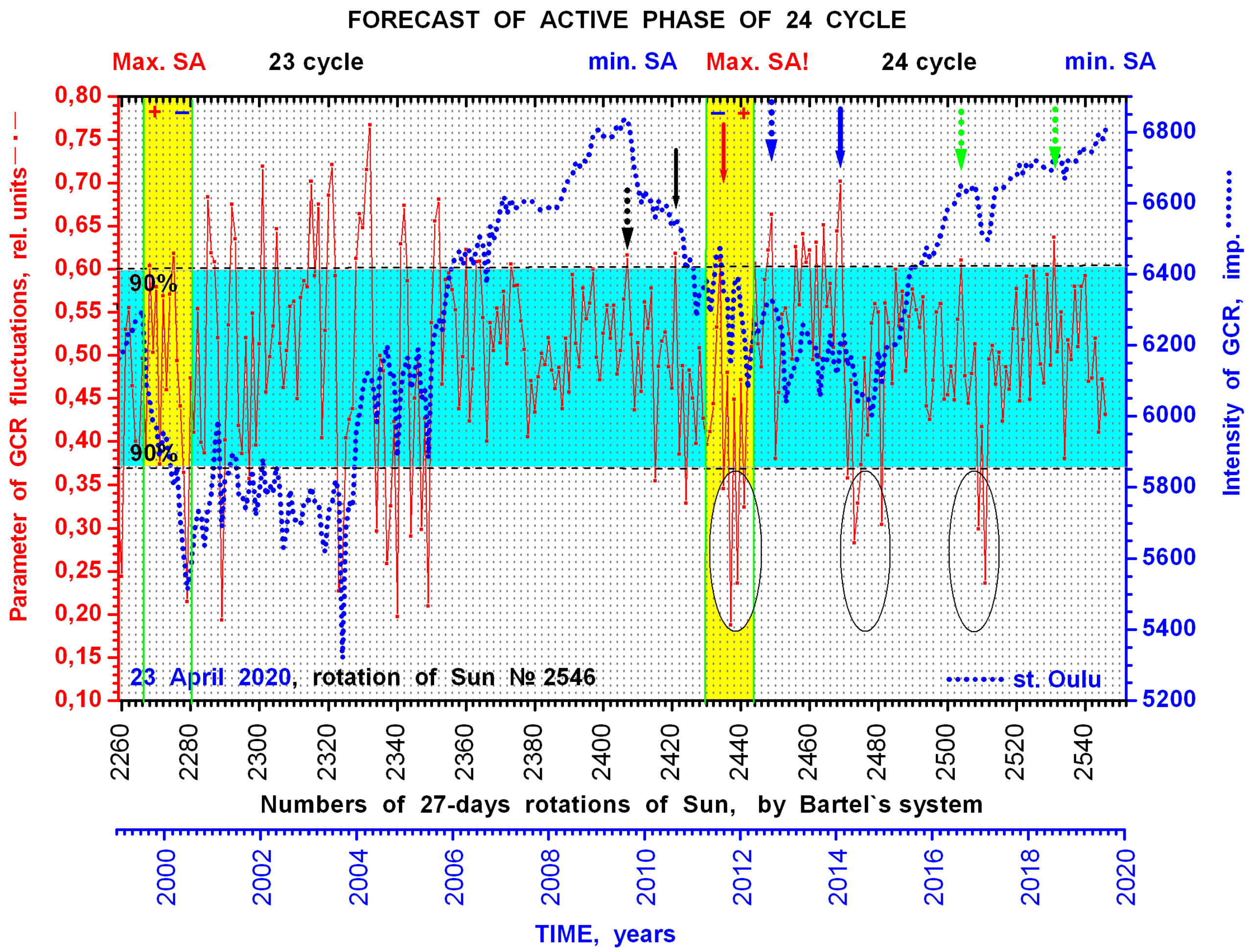


Fig. 1. The solid curve is the 27-day GCR fluctuation parameter values in relative units, the scale on the left. A 90% significance level is shown. The dashed curve is the cosmic ray count rate in pulses over 5 minutes, averaged over 7776 points of five-minute values during each revolution of the Sun. Harbingers: THE BEGINNING of the 24th cycle is indicated by a dotted arrow, the GROWTH phases of the current cycle are shown by a solid arrow in black, the MAXIMUM phase of cycle 24 are shown by a solid arrow by red, the ending of the polarity-reversal phase by a dashed arrow by blue, and the geoeffective phase of the beginning of the decline branch by a solid arrow by blue. LOW fluctuation parameter values in 2011-2012, 2014-2015, and 2017. (enclosed in an oval) - means the DIAGNOSTICS of the active phases of the solar cycle.

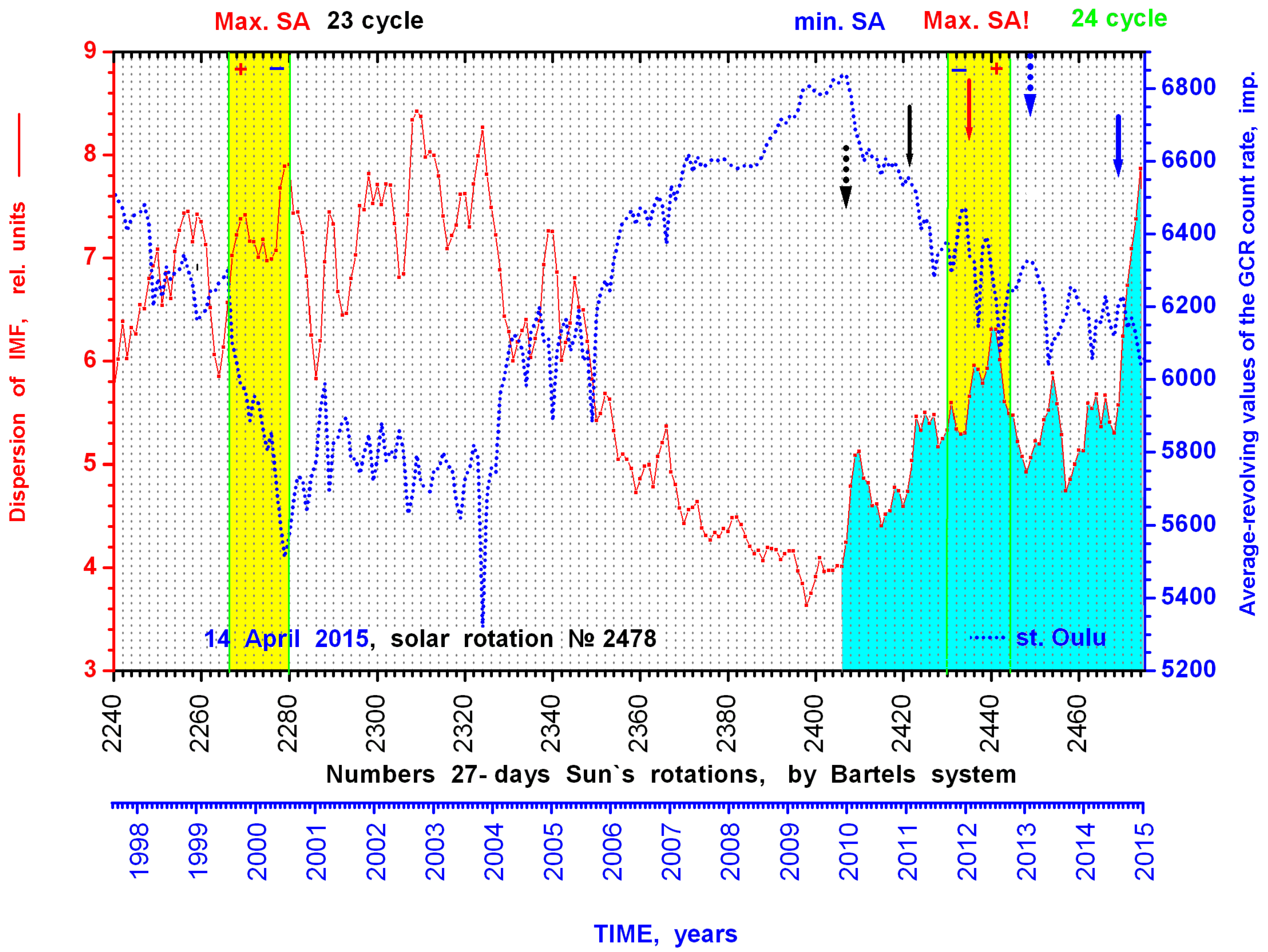


Fig. 2. Comparison of 27-day values of the count rate of cosmic rays in pulses (dashed curve) and dispersion of the interplanetary **magnetic field** intensity (a continuous curve) by data a space vehicle the ACE /12/, at 23-24 cycles of solar activity: 1997-2014. Precursors in cosmic rays are shown by vertical arrows. All precursors are preceded to global maxima in intensity of a magnetic field. Both in fluctuations parameter and in magnetic field intensity the **annual** variation is registered.

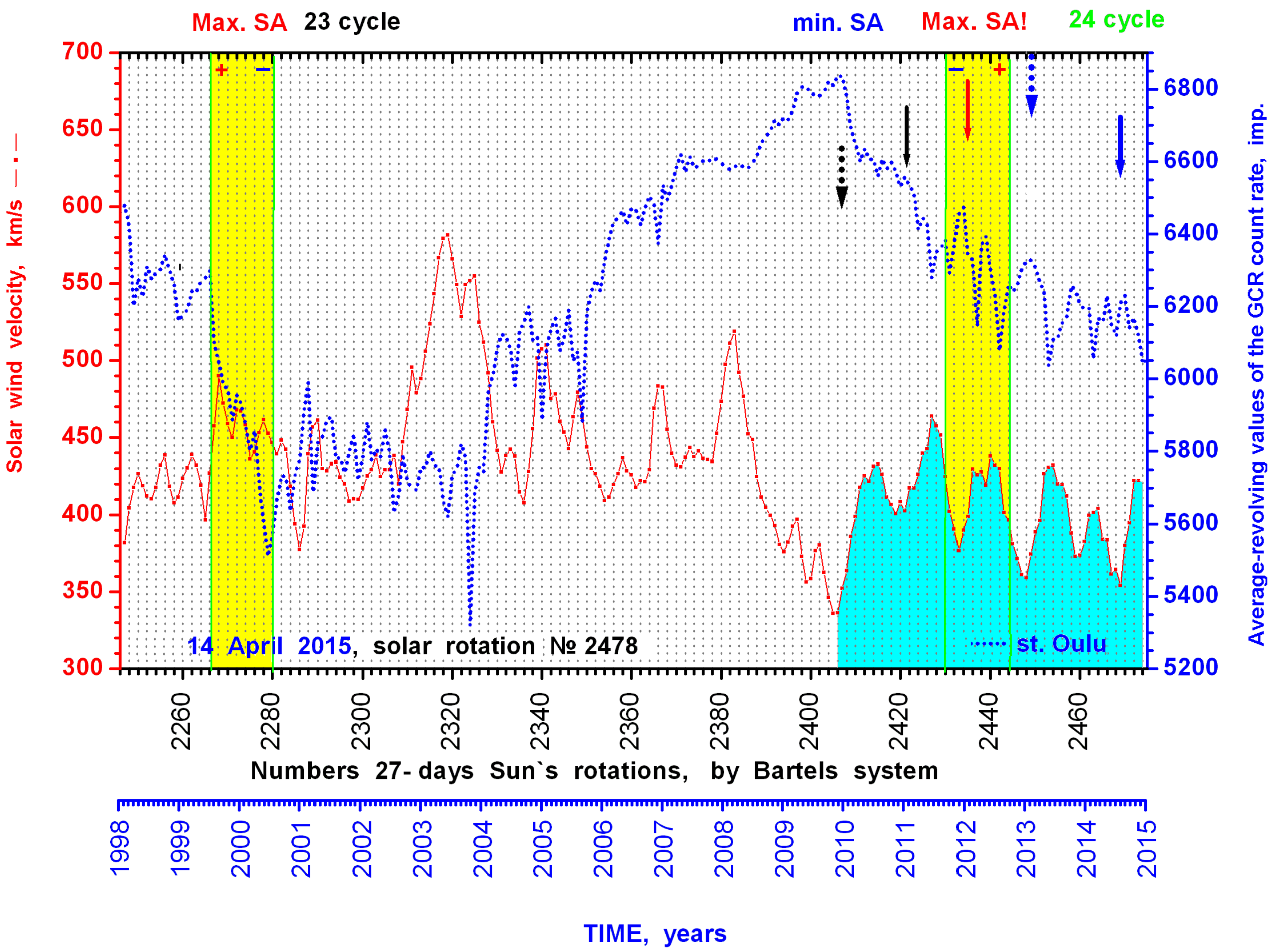


Fig. 3. Comparison of 27-day values of the count rate of cosmic rays in pulses (dashed curve) and solar wind velocity (a continuous curve) by data a space vehicle the ACE /12/, at 23-24 cycles of solar activity: 1997-2014. Precursors in cosmic rays are shown by vertical arrows. All precursors are preceded to global maxima in solar wind **velocity**. Both in fluctuations parameter and in solar wind velocity the **annual** variation is registered.

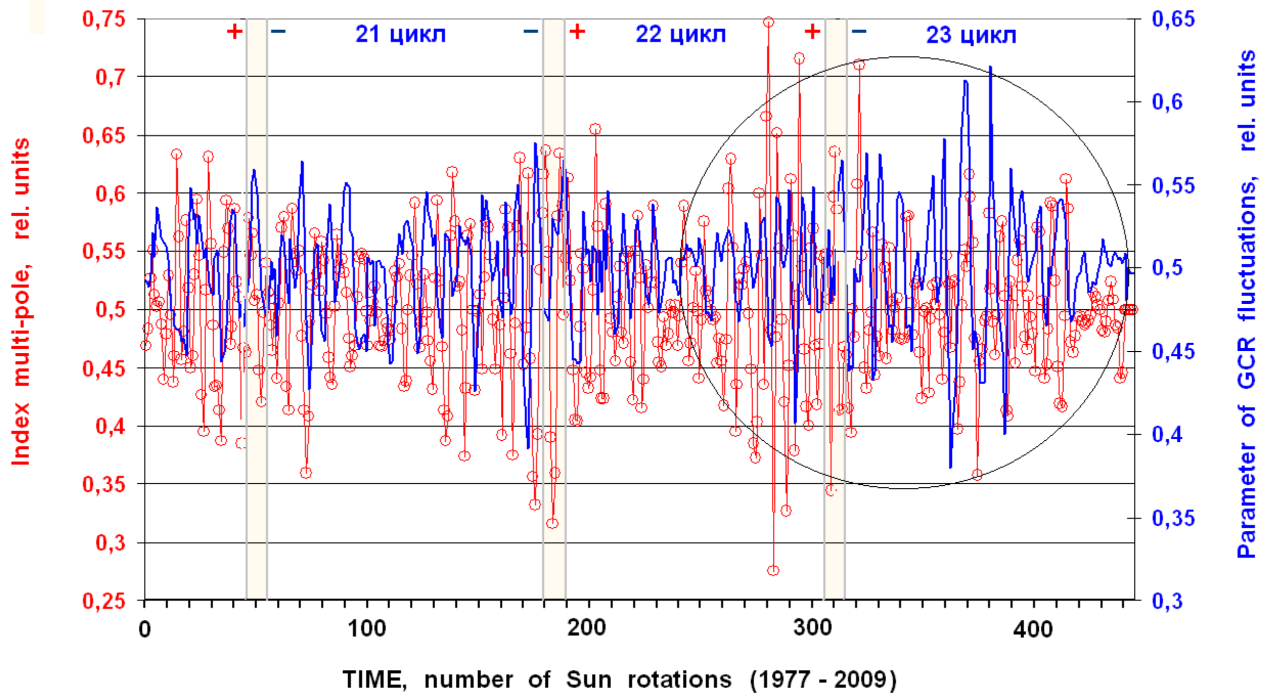


Fig. 4. Multi field index (Sun magnetic field): open mugs - a scale at the left. Cosmic rays fluctuations parameter - a scale on the right (a dark blue curve). On an axis abscissa: time, numbers of solar rotations (with 1977 - 2008). Numbers of cycles, conditionally are shown, the periods of Sun general magnetic field sign change are noted. **Bending** around fluctuations parameter variations and a “multifield index” are reached a maximum, practically, **simultaneously**.

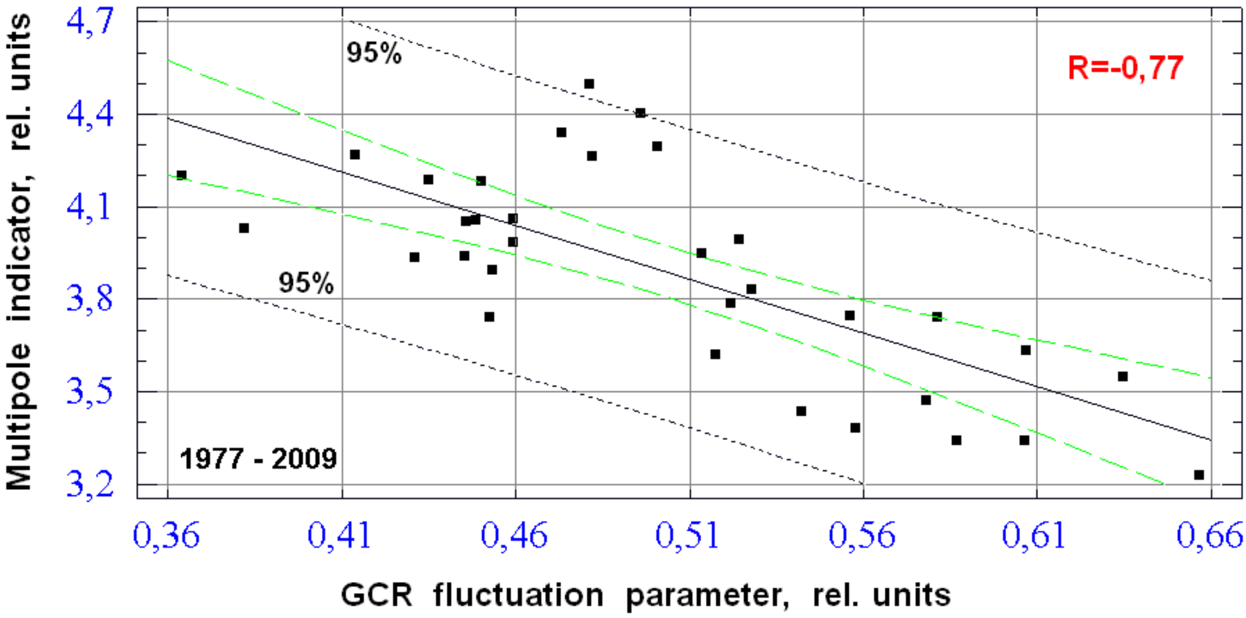


Fig. 5. Estimation of the regression relationship (R = **-0.77**), in **general**, between the average annual values of the "solar multipole" indicator (IZMIRAN) and the cosmic ray fluctuation parameter according to the linear regression model. A 95% significance level is shown.

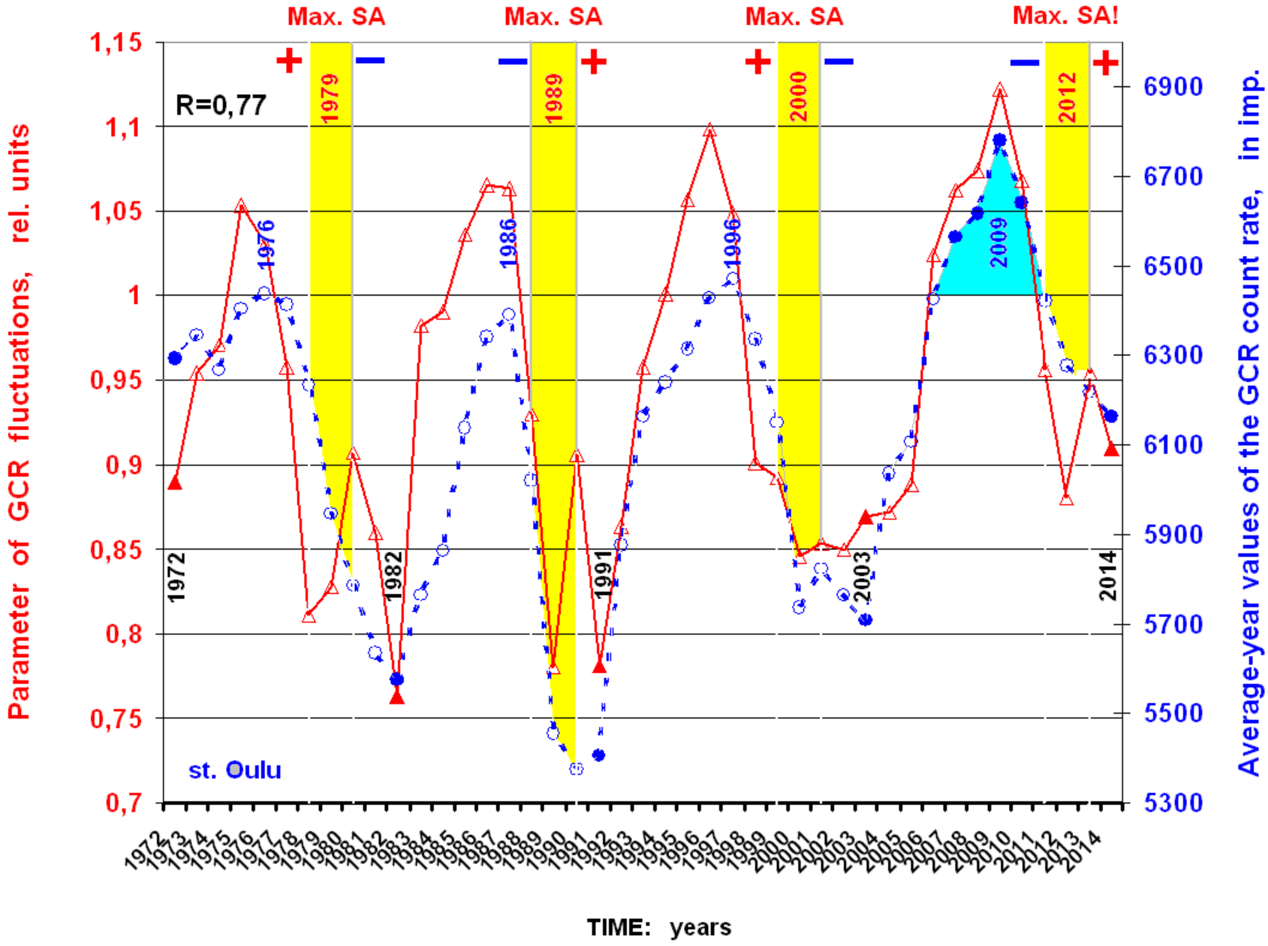


Fig. 6. The dotted curve, the scale on the right is the average annual count rate of cosmic rays in pulses from 1972-2014. Continuous curve, a scale at the left - corresponding fluctuations parameter values calculated for the same period (5 incomplete cycles: 20-24). Conditionally, the periods of Sun general magnetic field change sign and the periods of minima and maxima of Sun activity are shown. **Low** values of fluctuations parameter mean **diagnostics** of the disturbances period. On an abscissa axis: time: years and, accordingly, Sun rotations numbers on Bartels system.

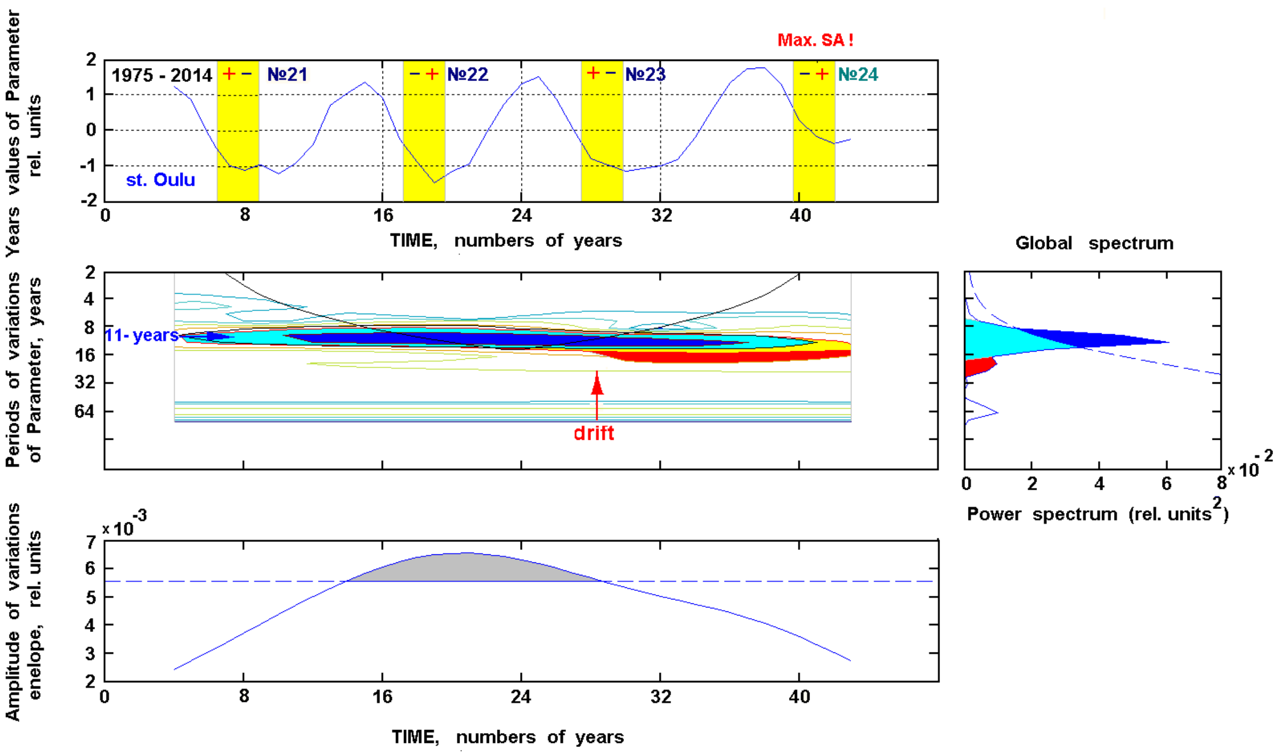


Fig. 7. Above: temporal course of fluctuations parameter for 43 years, about 1972-2014. Below: the amplitude-time-frequency diagram of 11-years variation evolution for the investigated period. On the right: global spectrum, as a whole. Below - bending around amplitudes of variations. The locality of a 11-years variation on the diagram is shown by a horizontal arrow at the left. The vertical arrow is indicated to the **beginning of low-frequency drift** of 23 cycle period. Conditionally, are shown the periods change sign of general magnetic field Sun and, accordingly, numbers cycles.

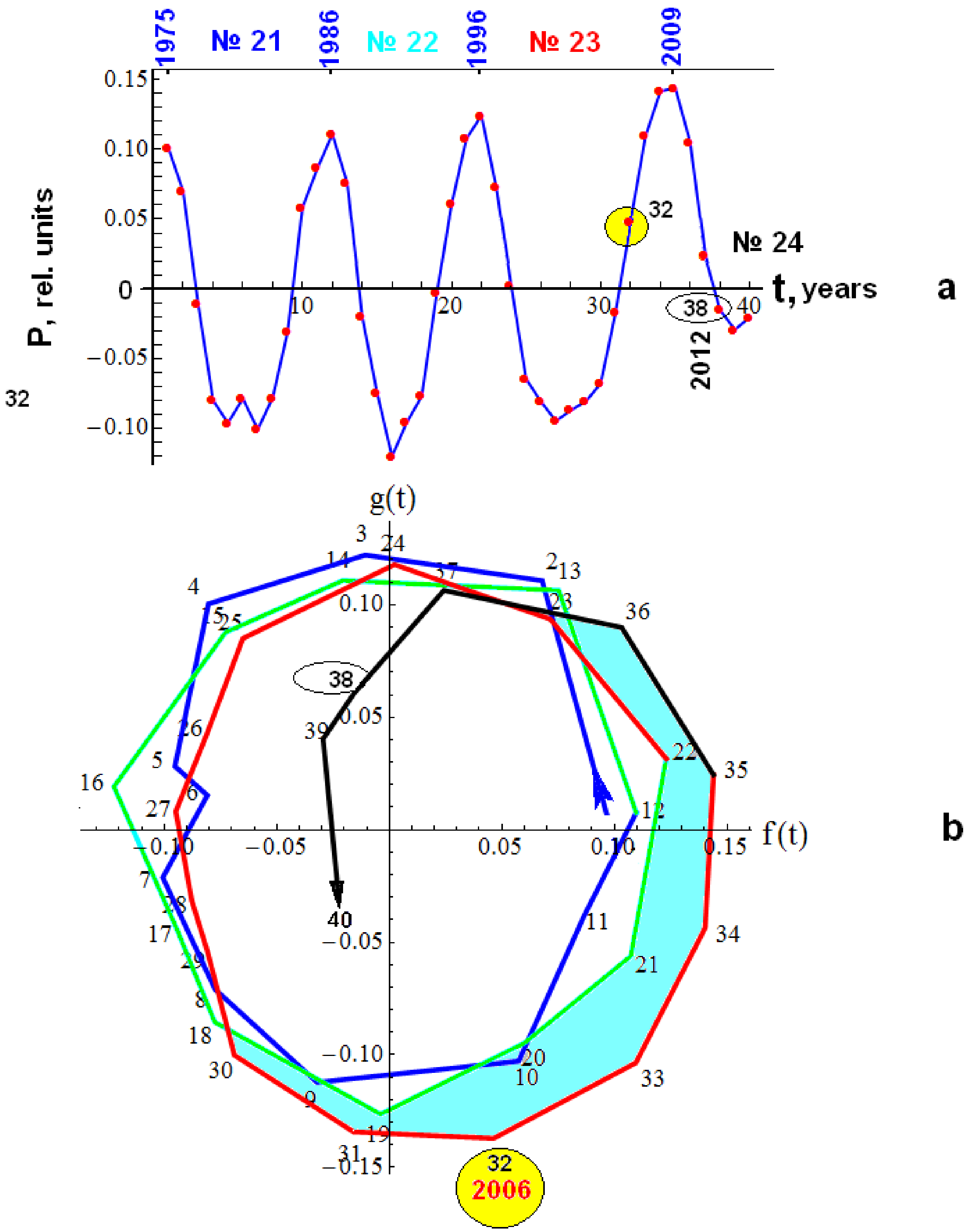


Fig. 8. "Phase portraits" for last 4 incomplete cycles 21-24 (with 1975-2014) calculated us by mid-annual values of fluctuations parameter. Above, a temporal course mid-annual values of fluctuations parameter. Numbers of corresponding cycles are shown. Cycle 23 has the greatest area. The **greatest area** the 23 cycle is **precursor** of not ordinary 11-years cyclicity failure.

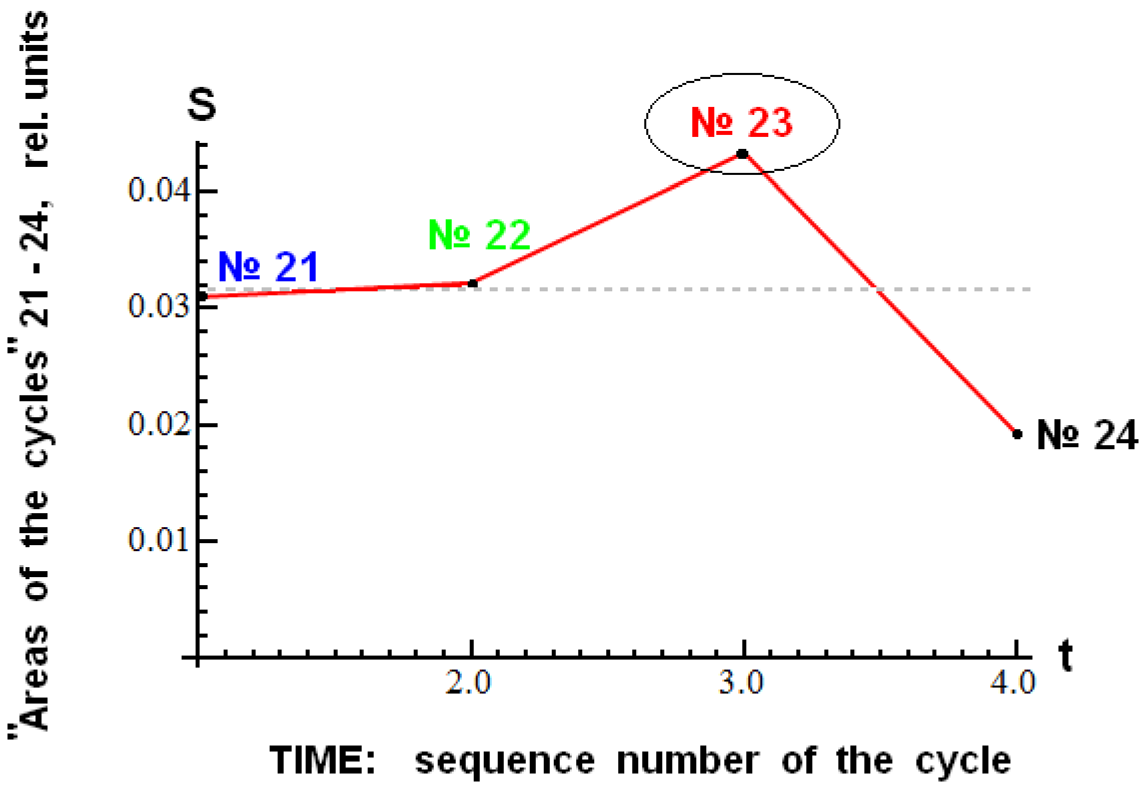


Fig. 9. An estimation of the 11-years cycles areas swept up under curves 21-24 cycles (about 1975-2014) by them to "phase portraits”, calculated on mid-annual fluctuations parameter values. Numbers of cycles are shown. Cycle 23 has the greatest area. The greatest area of cycle 23 is the **precursor** of not ordinary 11-years cyclicity **failure**.

Weibull distribution function:

$$F(x) = 1 - \exp\{-[(x-\theta)/b]^{c}\}$$

where

$\theta < x,\ b > 0,\ c > 0$

b - scale parameter

c - shape parameter

θ - pozition parameter

Distribution function density:

$$f(x) = c/b * [(x-\theta)/b]^{c-1} * \exp\text{^}\{-[(x-\theta)/b]^{c}\}$$

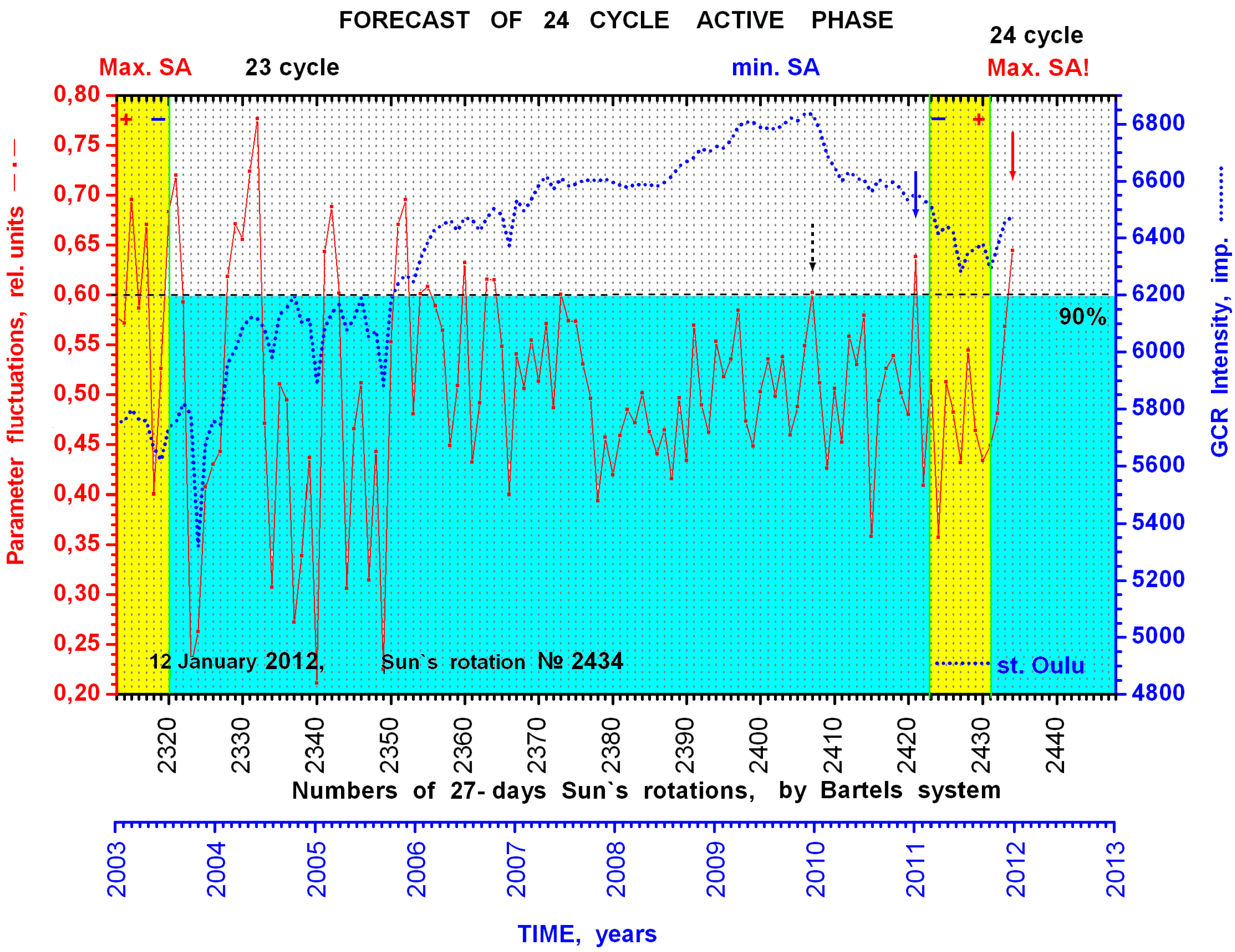
Reliability function:

$$R(x) = 1 - F(x)$$

Hazard function:

$$h(x)=f(x)/R(x)= [c*(x-\theta)^{(c-1)}] / b^{c}$$

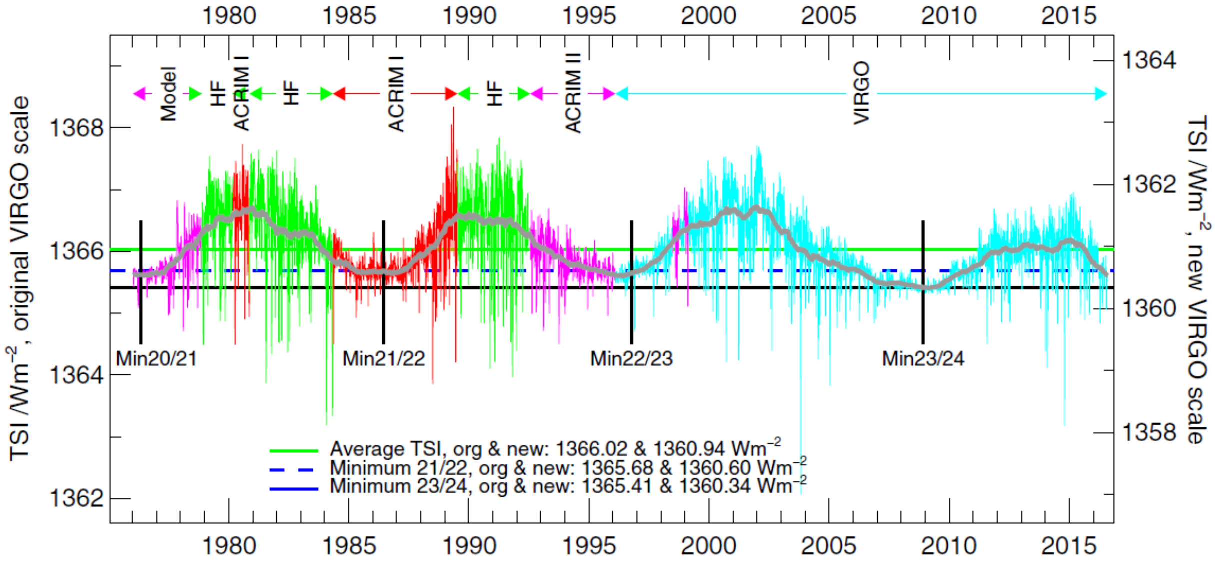
Appendix 1. Mathematical expressions determining the Risk function used in calculating the PARAMETER of cosmic ray fluctuations from the values of the shape parameters (**c**), scale (**b**) and shift (**θ**).



Appendix 2. A dotted curve - are shown (27-days) values of cosmic rays intensity with 1999-**2012**, scale on the right. Continuous curve - corresponding values of fluctuations parameter - a scale at the left. The level of significance (90%) is shown. Precursors: the BEGINNING of cycle 24 is shown by dotted arrow, phase GROWTH of a current cycle - a continuous arrow of black color, a phase of a MAXIMUM 24 cycles - an arrow of **red** color.

	Parameter GCR	Int. GCR	N-Dst	W	Index mp	N-Ey
Parameter GCR	1	0,80	- 0, 85	-0,74	-0,77	-0,76
Int. GCR	0,80	1	- 0,89	- 0,87	-0,68	- 0,67
N-Dst	- 0, 85	- 0,89	1	0,86	0,74	0,83
W	-0,74	- 0,87	0,86	1	0,83	0,59
Index mp	-0,77	-0,68	0,74	0,83	1	0,61
N-Ey	-0,76	- 0,67	0,83	0,59	0,61	1

Appendix 3. The matrix of correlations of the parameter of fluctuations of GCR with the intensity of cosmic rays, solar wind parameters and solar activity indices: with a GCR intensity R = **0.80**; With Wolf numbers R = **-0.74**; with the index of the "electric field of the solar wind" R = **-0.76**. The most value is the anticorrelation of the fluctuation parameter of the GCR with the Dst-variation R = **-0.85**.



Appendix 4. Changes in the relative variation of the solar luminosity, i.e. Changes in the relative variations of the 11-year variability of the "solar constant" for the last 4 cycles (21-24) (http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant) by data of satellite measurements.

Аналитическим сигналом, отображающим вещественный сигнал $s(t)$, называют **обратное преобразование Фурье спектра $S(\omega)$** сигнала $s(t)$ только по **положительным** частотам:

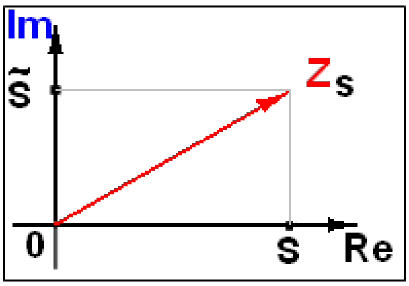
$$z_s(t) = (1/\pi) \int_0^{\infty} S(\omega)\ \exp(j\omega t) = \text{Re}\ z(t) + j\cdot\text{Im}\ z(t)$$

при этом, **реальная** часть аналитического сигнала $z_s(t)$ - равна **самому** сигналу $s(t)$.
мнимая часть аналитического сигнала $z_s(t)$ является **аналитически сопряженной** с его действительной частью Re $z(t)$ = $s(t)$ через преобразование Гильберта:

$\text{Im}\ z(t) = \tilde{s}(t) = \text{TH}[s(t)] = s(t) * hb(t)$, где $hb(t) = 1/(\pi t)$ - оператор **Гильберта**

Таким образом, $z_s(t) = s(t) + j\cdot\tilde{s}(t)$, $\tilde{s}(t) = \frac{1}{\pi}\int_{-\infty}^{\infty}\frac{s(\tau)}{t-\tau}d\tau$

где индексом $\tilde{s}(t)$ **обозначен сигнал, *аналитически сопряженный*** с сигналом $s(t)$.



На комплексной плоскости Аналитический Сигнал отображается **вектором**, **модуль и фазовый угол** которого изменяются от аргумента, а проекция сигнала на вещественную ось равна значению исходного сигнала $s(t)$. **Аналитический сигнал** представляет собой его **новую математическую модель**.

Appendix 5.