Nature of Arrhythmia in the Cyclicity Activity of Sun

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The question of further development of the new 25th cycle remains relevant. CR data (https://cosmicrays.oulu.fi/) indicate a sharp and deep ($\approx$20%) decrease in CR intensity at the end of the 24th cycle, comparable to ... cycle 21 in the early 80s (1982). Most likely, the 11-year cyclicity of the Sun is restored, possibly at a level above average. Obviously, this indicates a LOCAL nature of the failure in cycles 23-24. The previously established conservatism or invariance of the binary relationship "amplitude-duration" of the 11-year cycle is violated in the two previous cycles 23 and 24. The maximum area ("*energy content*" or *luminosity* - "*solar constant*") occurs in cycle 23, with a subsequent significant decrease in energy content - luminosity of cycle 24. Nevertheless, the INVARIANT with the characteristic scale of the duration of the "physical" 22-year cycle is preserved. In this case, after a local failure of the 11-year cyclicity in the 23-24 cycles, the 11-year cyclicity in the new 25 cycle should be restored!

GJSFR-A Classification: **LCC: QB529, QB506**

NATUREOFARRHYTHMIAINTHECYCLICITYACTIVITYOFSUN

Strictly as per the compliance and regulations of:

Nature of Arrhythmia in the Cyclicity Activity of Sun

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It is important to note that the Lorenz system (according to G.V. Kuklin et al.) is capable of describing various stages of the system's evolution: from the emergence of convection - the appearance of self-oscillations (11-year cyclicity) when the critical temperature value is exceeded, to the disappearance of self-oscillations (entering to the *chaotic* regime of the "*strange attractor*") when the temperature decreases. As it happened during the "*Maunder* minimum", essentially - a parametric "*phase catastrophe*". There are, obviously - extremal cases.

There is also an intermediate situation or ARRHYTHMIA in the cyclic activity of the Sun: a "local" failure, when the invariant of the 22-year cycle is preserved (modern cycles 23-24 and 19-20) and a "*global*" failure, when the invariant of the 22-year cycle is violated ("*Dalton* minimum" and "*Gleissberg* minimum"). At the same time, both the emergence and violation of cyclicity are organically linked by a common approach to the cyclic activity of the Sun as a mechanism for regulating energy. In this, in our opinion, lies the nature of solar cyclicity, 11-year and 22-year: solar cyclicity is nothing other than a self-oscillating mechanism of "release" - regulation of energy (in the convective zone) of the Sun, *stabilizing* its temperature

I. Introduction

The situation in the solar wind during the period of maximum solar activity, when the probability of sporadic phenomena (flares, shock waves, etc.) is high, can be defined as "crisis". And therefore it is quite natural to apply the concept of crisis phenomena to describe the process as a whole, namely, to use the "Theory of Continuous Media Failure" or "Reliability Theory". In this case, the *highest* moments of the distribution function are used in the analysis. More precisely, the generalized three-parameter Weibull-Gnedenko distribution is used [1] (Appendix 1). To calculate the PROBABILITY of achieving the critical value of the cosmic ray (CR) count rate, it is necessary to estimate the shape parameter "c" of the Weibull-Gnedenko empirical distribution, which determines the degree of DEVIATION of the approximating function of the empirical histogram from the normal distribution.

The approximating function of the empirical (integral) histogram of the CR count rate is found by the least squares method. The average values of the CR count rate for each bin interval of the empirical distribution function (integral histogram) will be grouped in the vicinity of the fitted straight line, but in a new coordinate grid (after the procedure of double logarithmization and substitution of variables). In this case, the tangent of the slope of the straight line fitted by the least squares method and the free term give the relationships necessary for estimating the sought-after shape and scale parameters. The shape parameter "c" is the *key* parameter: when it reaches a *critical* value, the parameter value is determined as a *predictor* of entering a critical, essentially transient, regime. The scale parameter is determined by the average value of the empirical histogram of the CR count rate distribution.

Thus, the procedure for extracting a useful precursor signal from a noise-like signal is reduced to finding the Risk function (by definition, the CR fluctuation PARAMETER) of the Weibull-Gnedenko distribution describing the experimental (integrated) histograms of five-minute CR count rate values. This allows extracting a useful predictor signal from Gaussian noise: Gaussian noise is contained, simply put, in the "linear" part of the Risk function, and the desired predictor signal is in the

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nonlinear part. The desired, nonlinear component of the predictor signal is formed when the calculated probability of the CRITICAL value of the analyzed variable (CR fluctuation parameter) is exceeded, i.e. when P>Pcr.

II. Method

A test calculation of the Risk function, when a whole series of the most extreme events of solar cycle 23 (October 2003) was observed – Appendix 2. The calculation was carried out for 7 solar rotations: first, for 5 rotations 2318-2322 preceding the extreme events on rotations 2323-2324, and then directly during the specified active phase of the solar cycle. From the calculation results it follows that significant (P>0.5) values of the maximum of the Risk function – *predictor*, were detected in July-August 2003 (rotations *2320-2321*). In this regard, the time interval falling on rotations 2320-2321 during which the predictors were detected is defined as - the *transitional* regime to the *extreme* active phase of the solar cycle in October-November 2003 (rotations 2323-2324). Thus, we can conclude that the ideology of *crisis* situations, in this case, has proven itself to be successful.

An example of calculating the Risk function on a smaller (*semi-diurnal*) scale of averaging the count rate and the corresponding values of the CR fluctuation parameter is shown in Fig. 1. In the *complete absence* of spots on the visible hemisphere of the Sun, on January *1*, 2008, a CR *predictor* from a "behind-the-limb" source was registered. According to data from the Stereo-A spacecraft, on December 31, 2008, two large C8-class X-ray flares were observed on the side of the Sun invisible from Earth. Both flares were accompanied by a coronal mass ejection (CME). A possible source of these X-ray flares could be active region (AR) № 978. This was the only source observed during the previous solar rotation (https://spaceweather.com/archive.php?day=01&month=01&year=2008&view=view), which reappeared on the eastern limb of the Sun only on January *2*. 2008. The decrease in the CR count rate began from 4.I.2008 to 5.I.2008. The clearly expressed *low*, in fact - the MARKER of the shock wave, i.e. - the *diagnostic* value of the CR fluctuation parameter registered from *4*.I.2008 to *5*.I.2008 (Fig. 1) definitely indicates the registration of the shock wave at the specified time. Thus, the proposed approach shows a fairly *high* efficiency both on the 27-day averaging scale and on a smaller, semi-daily averaging scale.

III. Results

At Figure 2 shows the results of calculating the CR fluctuation parameter for the previous 24th and the beginning of the new 25th cycle. A clearly expressed increase in activity was observed in July 2023: *medium-term predictors* were registered on rotations No. 2590,

2592 and *2597*. Of greatest interest is the precursor on rotation *2597* (4-31.01.2024). Taking into account the forecast lead time $\Delta\tau=2$ (±1 rotation) of the Sun's rotations, an increase in activity should be expected on rotation *2599* (±1 rotation), i.e. in *February-April* 2024. Rotation No. 2599 corresponds to the penultimate (bottom right) point of the CR fluctuation parameter - a *diagnostic* or *marker* in red. From this it follows that the indicator of the beginning of the maximum of the new 25th cycle can be considered rotations No. *2599* (*March* 2024).

Indeed, starting from the 3rd ten-day period of February 2024, large X-ray flares of class *X*1.8 (02/21/2024), *X*1.7 and *X*6.3 (02/22/2024) were registered in AO 3590. Before AR 3590 left for the solar hemisphere invisible from Earth, on February 28-29 https://spaceweather.com/images2024/28feb24/filament _CME.gif a flare of a long and complex structure of class M was observed, accompanied by a series of CME.

The *beginning* of the maximum of the 25th solar cycle from late April to May, which began in the 3rd ten-day period of *February* 2024, is becoming more active: this was manifested in the increased activity of both hemispheres of the Sun simultaneously. An illustration of this is the appearance of so-called (https://spaceweather.com/images2024/05may24/acticity_teal.gif) "*sympathetic*" flares. First, "paired" - in the northern and southern hemispheres), and then serial (https://spaceweather.com/images2024/06may24/m4p5 _anim_opt.gif) events registered on the entire visible hemisphere of the Sun *simultaneously*!

Thus, in the first ten-day period of May, a "paired" (in the form of 2 semi-diurnal values) *predictor* in the CR fluctuation parameter for May *5-6*, 2024 was obtained (Fig. 3). The specified predictor was obtained at the beginning of the day on May 6, and already on the 2nd day - May *8*, according to the ACE spacecraft (USA), an increase in the flux of low-energy protons in a wide energy range began - "*storm*" particles Appendix 3, which usually *precede* the arrival of shock waves in the Earth's orbit. The high power of this event is most likely due to the *cumulative* effect [2] (Appendix 4), according to foreign terminology: "*cannibal* effect" [3].

High solar activity in May 2024 continued in October-November. This follows from the results of the subsequent *medium-term* forecast (Fig. 4). The "double" *predictor* is registered on rotations No. *2602-2603* in May-June 2024. Indeed, after $\Delta\tau=2(\pm1$ rotation) of the Sun's rotations, starting in *August* (rotation No. *2605*) 2024, a long and deep *decline* in the CR intensity began. This is also indicated by the relatively *low* (markers), *diagnostic* average-rotation values of the fluctuation parameter on the extreme rotations No. *2607-2608*.

The medium-term forecast is confirmed by the results of *operative* monitoring (Fig. 5). Indeed, the

"double" values of the CR fluctuation parameter from October *4* to *5* and from October *8* to *9*, 2024 exceed the "cosmic noise" region, thus being predictors of shock waves. On the contrary, the extremely *low* values of the CR fluctuation parameter on October *5-6* and October *10-11* are MARKERS of the registration of shocks in the Earth's orbit, which is confirmed by the results of modeling in the *NOAA* Space Weather Prediction Center (Appendix 5-6). It follows that in October-November 2024 (rotations *2607-2608*) the MAXIMUM of the new 25th cycle is registered!

IV. The Nature of Arrhythmia of Solar Cyclicity

Earlier, in [4], it was established that the higher the cycle amplitude at the maximum, the shorter the duration of the polarity reversal process, after the completion of which the CR restoration begins. And, conversely, the lower the cycle amplitude, the longer the polarity reversal phase. The *inverse* dependence of the field inversion process duration on the cycle amplitude revealed by the CR indicates the possible presence of the Invariant of the binary relationship of the 11-year cycle characteristics "amplitude-duration".

We analyzed the relationship between variations in the amplitude and duration of the solar cycle using the language of phase portraits on a complex phase plane using an analytical signal - Fig. 6. The area of the "phase portrait" has the dimension of ACTION, with the dimension of "energy x time" (a "*phase volume*"). In this sense, for a fixed (in time) cycle, its area is a characteristic of *energy-capacity*, the change in which from cycle to cycle can be traced, for example, by the change in the relative variation in the solar *luminosity*, i.e. by the relative variation (https://www.sws.bom.gov.au/Educational/2/1/12) 11-year variability of the "*solar constant*".

Below is an estimate of the *areas* of the phase portraits of solar cycles 21-24, i.e. the characteristics of their *energy-capacity*. The analysis was carried out using the average-annual values of the CR fluctuation parameter. The areas of cycles 21 and 22 are practically identical (Fig. 7). The constancy (invariance) of the area, as a characteristic of energy-capacity, indicates the conservatism or constancy of the area of the 11-year cycle in time (*time symmetry*) during two consecutive cycles 21 and 22. Conservatism or invariance (in the sense of the binary relationship "amplitude-duration") is violated for the two subsequent cycles 23 and 24.

Violation of the conservatism of the system means the presence of 11-year cycles with different *energy-capacity*, i.e. with different *areas*. This is observed in cycles 23 and 24. The maximum area occurs in cycle 23, with a subsequent clear decline in area in cycle 24, starting in 2006 (Fig. 7). It is noteworthy that the relative variation in solar luminosity, as a possible characteristic of the energy intensity of the cycle, also began to decrease in cycle 24, in fact, starting in the same 2006. https://www.sws.bom.gov.au/Educational/2/1/12.

On the other hand, averaging the areas of *pairs* of adjacent 11-year cycles (starting with 21) preserves the invariance of the areas of pairs of 11-year cycles: 21-22 and 23-24, i.e. the *invariance* of the areas of adjacent 22-year cycles or their energy-capacities is *preserved*. This means conservatism (time symmetry) of the dynamic system (the Sun) in a broad sense, i.e. the presence of an INVARIANT with a characteristic scale of the duration of the *22*-year cycle. In this case, after a failure of the 11-year cyclicity in the 23-24 cycles, the 11-year cyclicity of solar activity in the next 25 cycle should be *restored*!

In turn, this should mean the fulfillment of the following physical criterion: the level of CR *background radiation* in the minimum of the current cycle 25 should be significantly *lower* than the level of background radiation in the minimum of the previous 24 cycle [5]. In turn, this will mean the fulfillment of the Gnevyshev-Olya rule. This is exactly the situation we observe now if we compare the CR count rate *minima* in 2014 and 2024 (in *yellow ovals* in Fig. 2 and Fig. 4). In this case, the value of the current data for 2024 is difficult to overestimate. Their comparison with similar data for 2014 indicates that the failure of the 11-year cyclicity in cycles 23-24 can be confidently attributed to a *local* failure.

The conclusion about the local nature of the failure in cycles 23-24 is confirmed by the data https://www.sidc.be/SILSO/dayssnplot of flare activity, as well as by the data of subsequent CR monitoring. Indeed, the CR data indicate a sharp and deep (≈20%) *decrease* in the GCR intensity at the *end* of current cycle (Fig. 4), comparable only, as minimum, with cycle … *21* in the early 80s (1982): https://cosmicrays.oulu.fi/. In fig. 8 shows the results of calculating the "phase portraits" of four solar cycles No. 19-22 calculated from the average annual values of Wolf numbers [6]. At the top is the time course of the average annual values of Wolf numbers. The numbers of the corresponding cycles are shown. Cycle *19* has the largest area. The *largest* area of the *19* cycle is a *predictor* of a LOCAL failure of the 11-year cyclicity in the 19-20th cycles, which occurred in the modern era - the era of the "Space Era". Then, in the 21-22nd cycles, the cyclicity of solar activity is *restored*.

It is important to note that the Lorenz system (according to G.V. Kuklin et al. [7]) is capable of describing various stages of the system's evolution: from the emergence of convection - the appearance of self-oscillations (11-year cyclicity) when the critical temperature value is exceeded, to the disappearance of self-oscillations (entering to the *chaotic* regime of the "*strange attractor*") when the temperature decreases. As it happened during the "*Maunder* minimum", essentially

a parametric "*phase catastrophe*". There are, obviously - extremal cases.

There is also an intermediate situation or ARRHYTHMIA in the cyclic activity of the Sun: a "*local*" failure, when the invariant of the 22-year cycle is preserved (modern cycles *23-24* and *19-20*) and a "*global*" failure, when the invariant of the 22-year cycle is violated ("*Dalton* minimum" – Fig. 9) and "*Gleissberg* minimum"). At the same time, both the emergence and violation of cyclicity are organically linked by a common approach to the cyclic activity of the Sun as a mechanism for regulating energy. In this, in our opinion, lies the nature of solar cyclicity, 11-year and 22-year: solar cyclicity is nothing other than a self-oscillating mechanism of "release" - *regulation* of energy (in the convective zone) of the Sun, *stabilizing* its temperature.

V. CONCLUSIONS

– In the parameter of CR fluctuations, a predictor to the beginning of the maximum of the new 25th solar activity cycle was obtained. Taking into account the value of the forecast lead time $\Delta\tau=2(\pm1$ rotation) of the Sun's rotations, the beginning of the maximum of the 25th cycle was *predicted* for the *2597*-th rotation (±1 rotation), i.e. in *February-April* 2024. The indicator - marker of the *beginning* of the maximum of the new 25th cycle is a significantly *low* value of the CR fluctuation parameter on the rotation No. *2599*, in *March* 2024.

– This is confirmed by the results of the operative forecast on May *5-6*, as well as October *4-5* and 7-8, 2024, the registration of "*storm*" particles (*preceding* the arrival of shock waves to the Earth's orbit) and the *fact* of the passage of shock waves of the Earth's orbit by the registration of the *marker* - an extremely *low*, *diagnostic* value in the CR fluctuation parameter on May *10-11*, as well as *5-6* and 10-11, October 2024.

– The failure in the 23-24 cycles can be confidently attributed to a LOCAL failure, i.e. the 11-year cyclicity of solar activity, begin from the 25th cycle, should be *restore*!

– ARRHYTHMIA in the cyclic activity of the Sun: a "*local*" failure, when the invariant of the 22-year cycle is preserved (modern cycles *23-24* and *19-20* and a "*global*" failure, when the invariant of the 22-year cycle is violated ("*Dalton* minimum" and "*Gleissberg* minimum").

– The nature of solar cyclicity (11-year and 22-year) from the standpoint of the INVARIANT of the 22nd cycle: solar cyclicity is nothing more than a self-oscillating mechanism of "release" - *regulating* the energy (in the convective zone) of the Sun, *stabilizing* its temperature.

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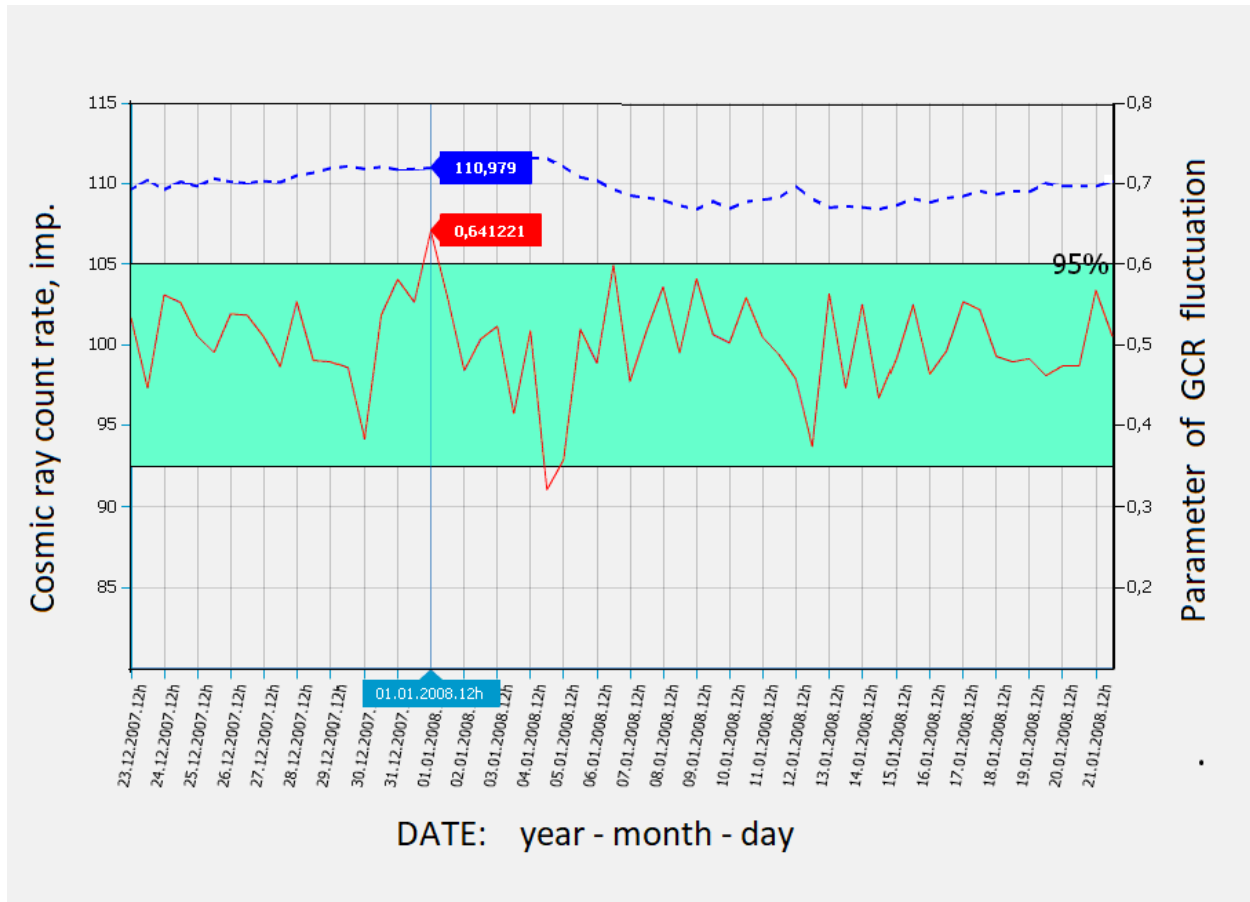
Fig. 1: TEST – calculation of *predictor* in CR during the appearance on the visible hemisphere of the Sun as the *only* source of activity. Results of calculation of the CR fluctuation parameter from December 2007 to January 2008 have been obtained using the Cyber-FORSHOCK *robotic expert system*. The scale on the right corresponds to the values of probability or parameter of fluctuations shown by the(solid curve; the scale on the left corresponds to the count rate in the pulses per 5 minutes (averaged over 12 hours) by data of the neutron monitor at the Oulu station (Finland) shown by the dotted curve. The parameter values placed in the interval: 0.35<P<0.60 - the "cosmic noise" region. On the lower scale the date and time are plotted.

MIDDLE-TERM COSMIC RAY MONITORING
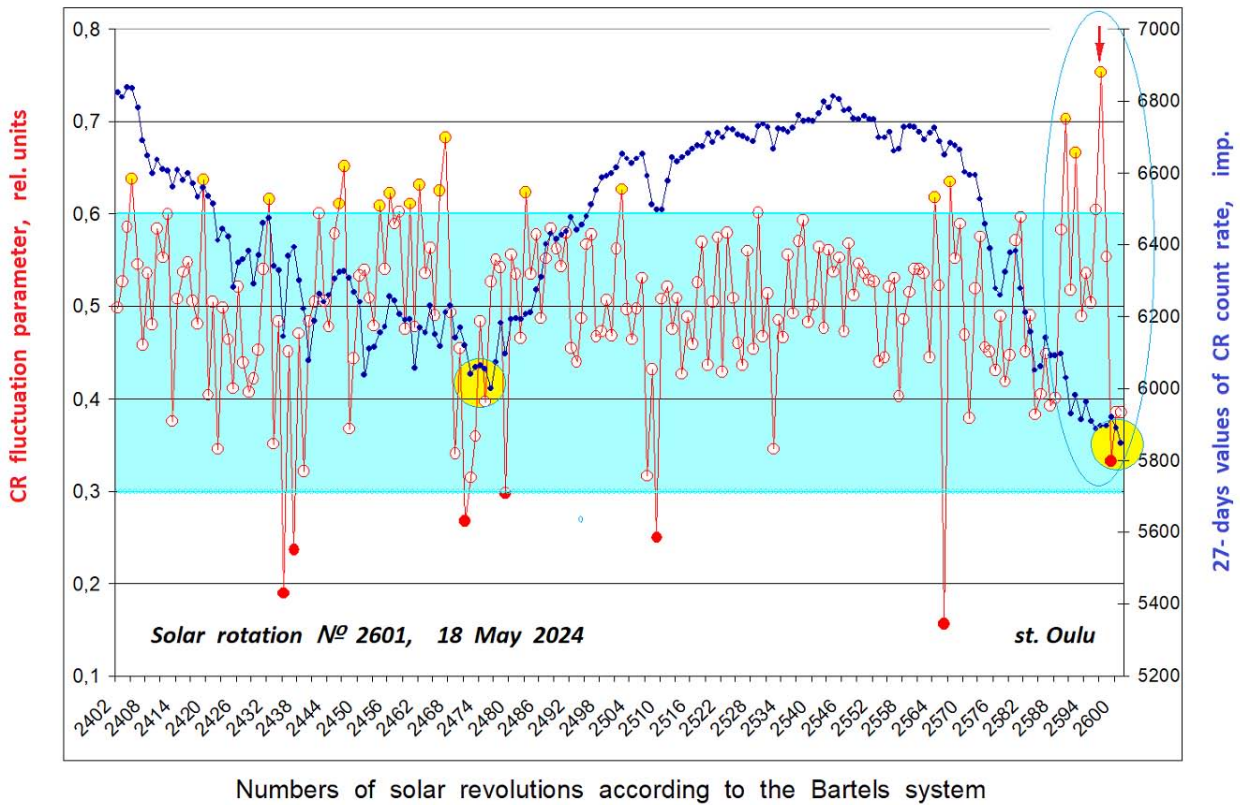
Fig. 2: Cosmic ray count rate at the Oulu (Finland) in pulses per 5 minutes averaged over 7776 points of 5-min values during each solar rotation shown by the blue dotted curve, scale on the right. 27-day values of the CR fluctuation parameter in relative units shown by the red solid curve, scale on the left. The 90% significance level is shown. The CR fluctuation parameter values exceeding the "cosmic noise" area (shown by green) are precursors of the increase of solar activity. The *precursor* of the beginning of the 25th cycle maximum (the late on the right, shown by the vertical red arrow) - is registered on the № 2597 rotation. And, on the contrary, a sufficiently low value of the CR fluctuation parameter (the penultimate point in red, the № 2599 rotation, *March* 2024) is defined as - a MARKER of the *beginning* of the new 25th cycle maximum.
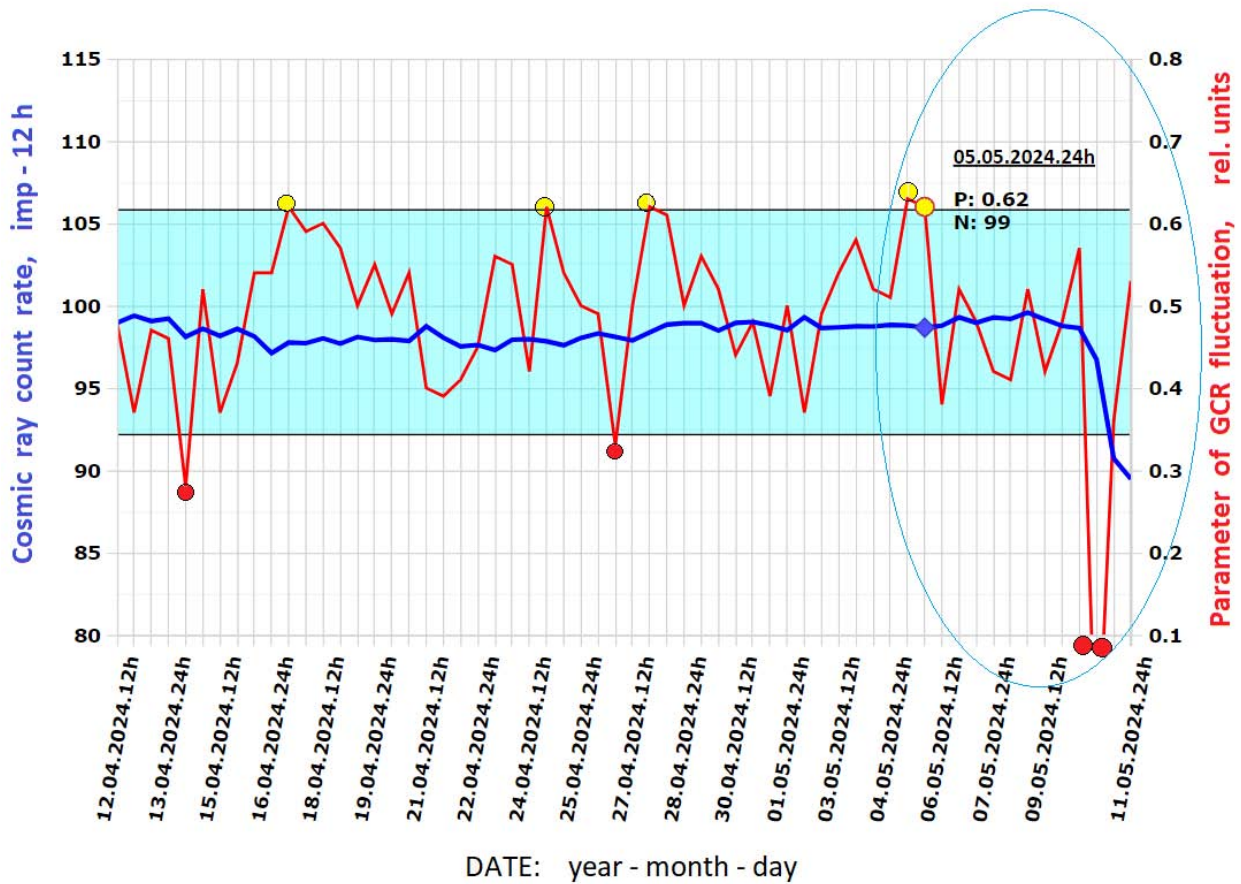
Fig. 3: Results of operational monitoring of cosmic rays in April-May 2024. The scale on the right (the red curve) corresponds to the values of the CR fluctuation parameter; the scale on the left (the blue curve) corresponds to the count rate in pulses per 5 minutes (averaged over 12 hours) by the neutron monitor data from the Oulu (Finland). The parameter values in the interval of 0.35<P<0.60 are the "cosmic noise" area (shown in green). On the lower scale the date and time are plotted. The "paired" values of the CR fluctuation parameter from 5 to 6 May, 2024 exceed the "cosmic noise" region and, therefore, the "paired" parameter of CR fluctuations is a *predictor* of shock. On the contrary, the extremely *low* values of the CR fluctuation parameter from 10 to 11 May are a *marker* of shock registration at the Earth's orbit.

MIDDLE-TERM COSMIC RAY MONITORING
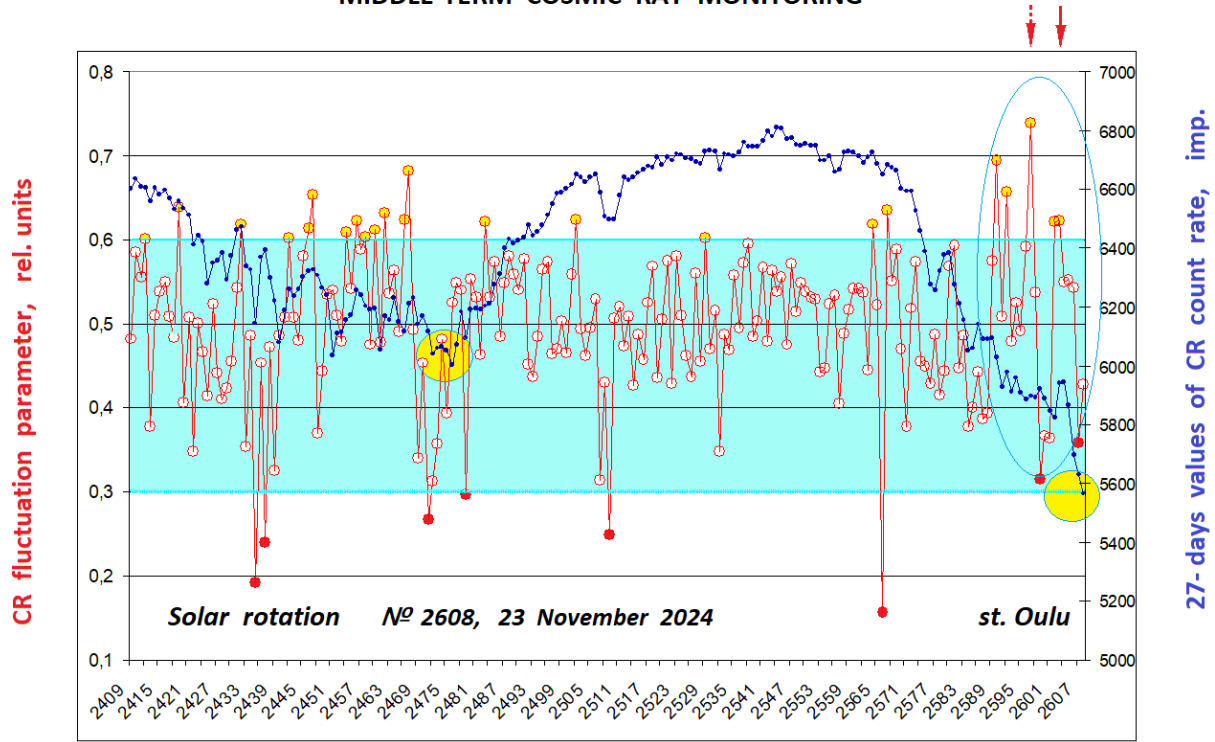
Fig. 4: Cosmic ray count rate at Oulu station (Finland) in pulses per 5 minutes, averaged over 7776 points of 5-min values during each solar rotation - blue dotted curve, scale on the right for the time interval starting from the 2409-2608 rotation. 27-day values of the CR fluctuation parameter in relative units - solid red curve, scale on the left. 90% significance level is shown. CR fluctuation parameter values exeeding the "cosmic noise" region (shown in green) are harbingers of increased solar activity. The precursor of the beginning of the maximum of the 25th cycle - the one on the far right (shown by the vertical arrow - dotted red line) is registered on the rotation № 2597. The subsequent "double" precursor is registered on rotations № 2602-2603 in *May-June* 2024. On the contrary, a fairly *low - diagnostic* value of the CR fluctuation parameter (the penultimate point in red, rotation № 2599, *March* 2024, as well as on the last two rotations 2607-2608), is defined as - a *marker* of the MAXIMUM of the new 25th cycle.
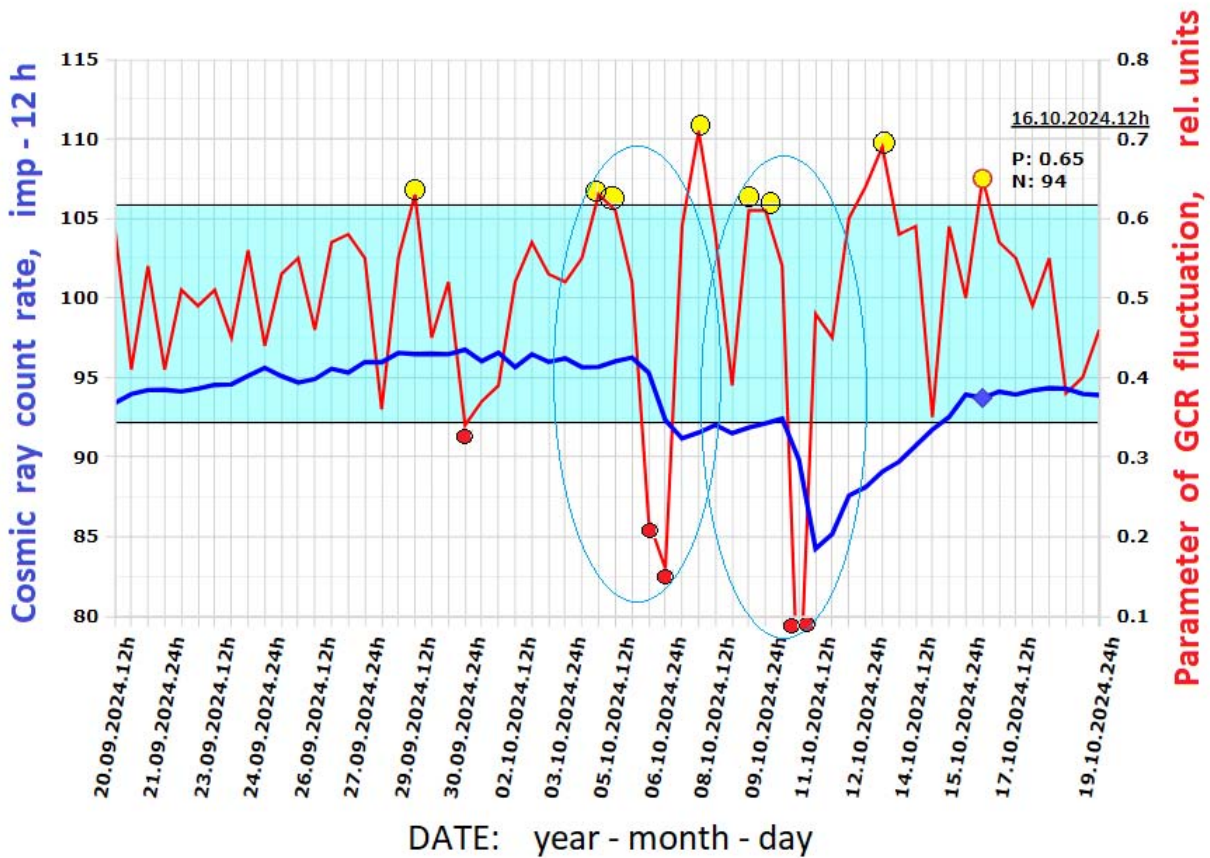
Fig. 5: Results of operative monitoring in September - October 2024. Along the ordinate axis: the scale on the right (red curve) – values of the CR fluctuation parameter; the scale on the left (blue curve) – count rate in pulses per 5 minutes (averaged over 12 hours) according to data from the neutron monitor of the Oulu station (Finland). The parameter values included in the interval: $0.35<P<0.60$ – the "cosmic noise" region (shown in green). Along the abscissa axis – date: year – month – day – hour. The "double" values of the CR fluctuation parameter from October *4* to *5* and from October *8* to *9* of this year exceed the "cosmic noise" region and, therefore, the "*double*" parameter of CR fluctuations is a *predictor* of shock. On the contrary, the extremely *low* values of the CR fluctuation parameter from *5-6* and *10-11* October are MARKERS of the registration of shocks in the Earth's orbit.
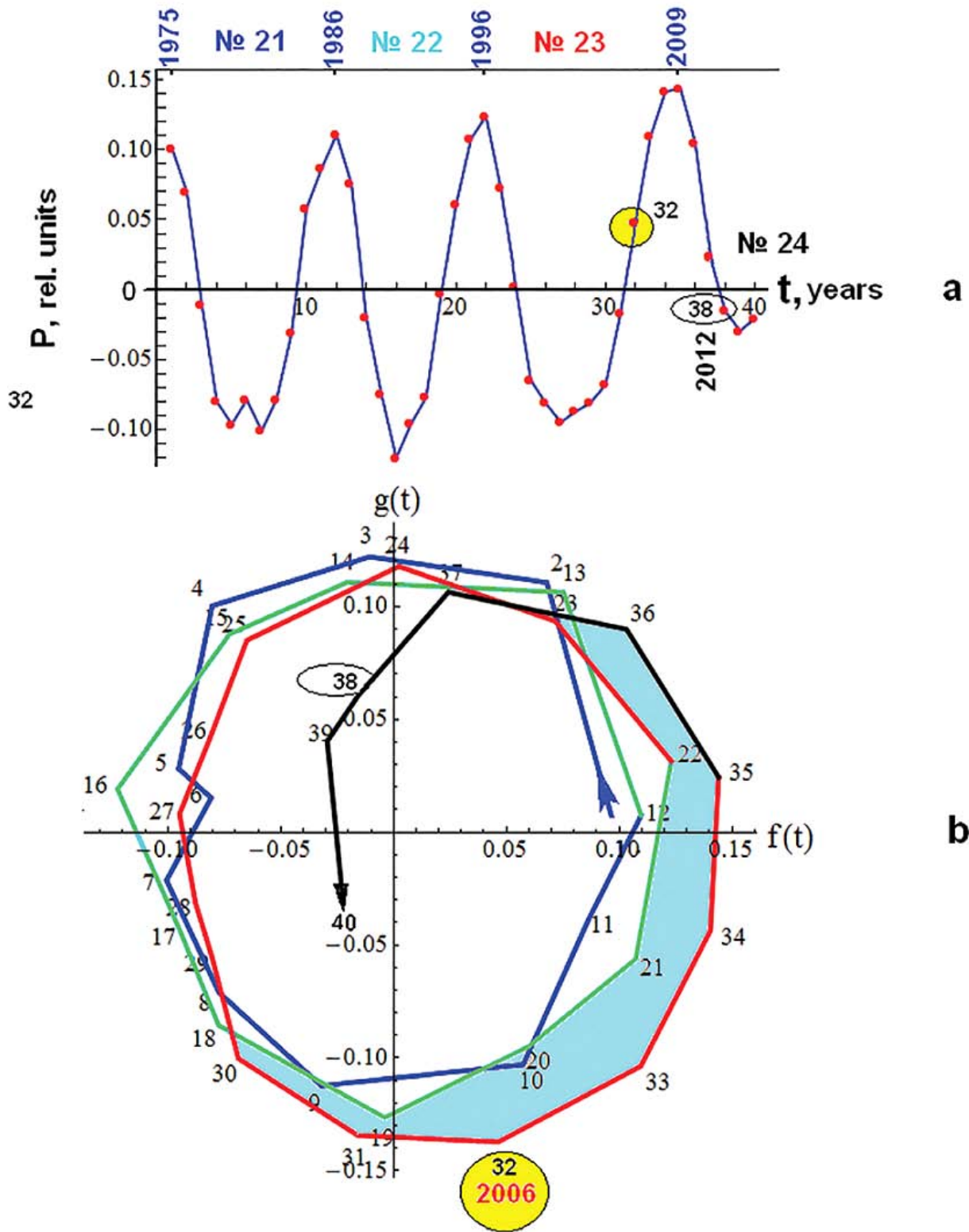
Fig. 6: "Phase portraits" of the last 4 cycles No. 21-24 (for 1975-2014) calculated by the annual average values of the cosmic ray fluctuation parameter. At the top there is the time dependence of the annual average values of the cosmic ray fluctuation parameter. The numbers of the corresponding cycles are shown. The 23rd cycle has the largest area. The *largest* area of the 23rd cycle is a precursor of an extraordinary disruption of the 11-year cyclicity, i. e. a *predictor* of the LOCAL failure of the 24th cycle.
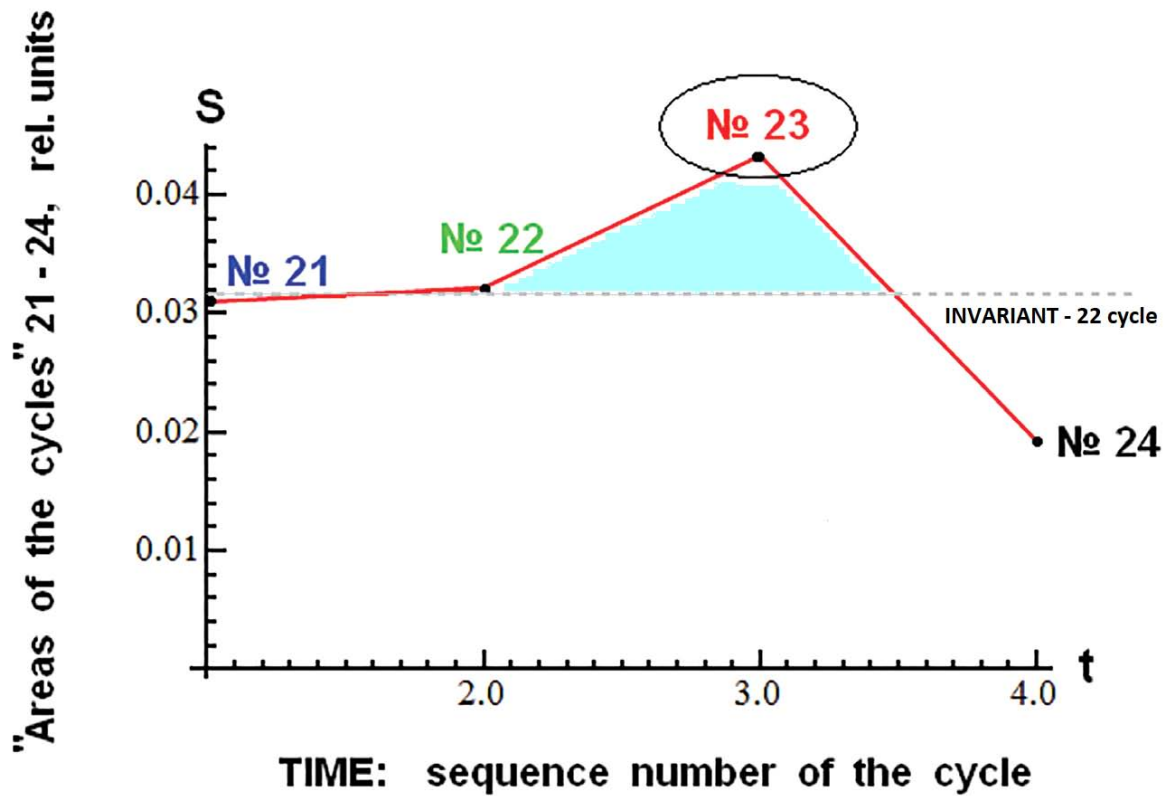
Fig. 7: Estimation of the areas swept under the curves of the 21-24 cycles of 11-year duration (for 1975-2014) by their "phase portraits" calculated by the annual average values of the CR fluctuation parameter. The horizontal line (shown by dots) represents the level of constancy of the average value of the areas of pairs of the adjacent 11-year cycles, i. e. the INVARIANT level of the 22-year cycle. The 23rd cycle has the largest area. The *largest* area of the 23rd cycle is a *predictor* of LOCAL failure of the 11-year cyclicity.
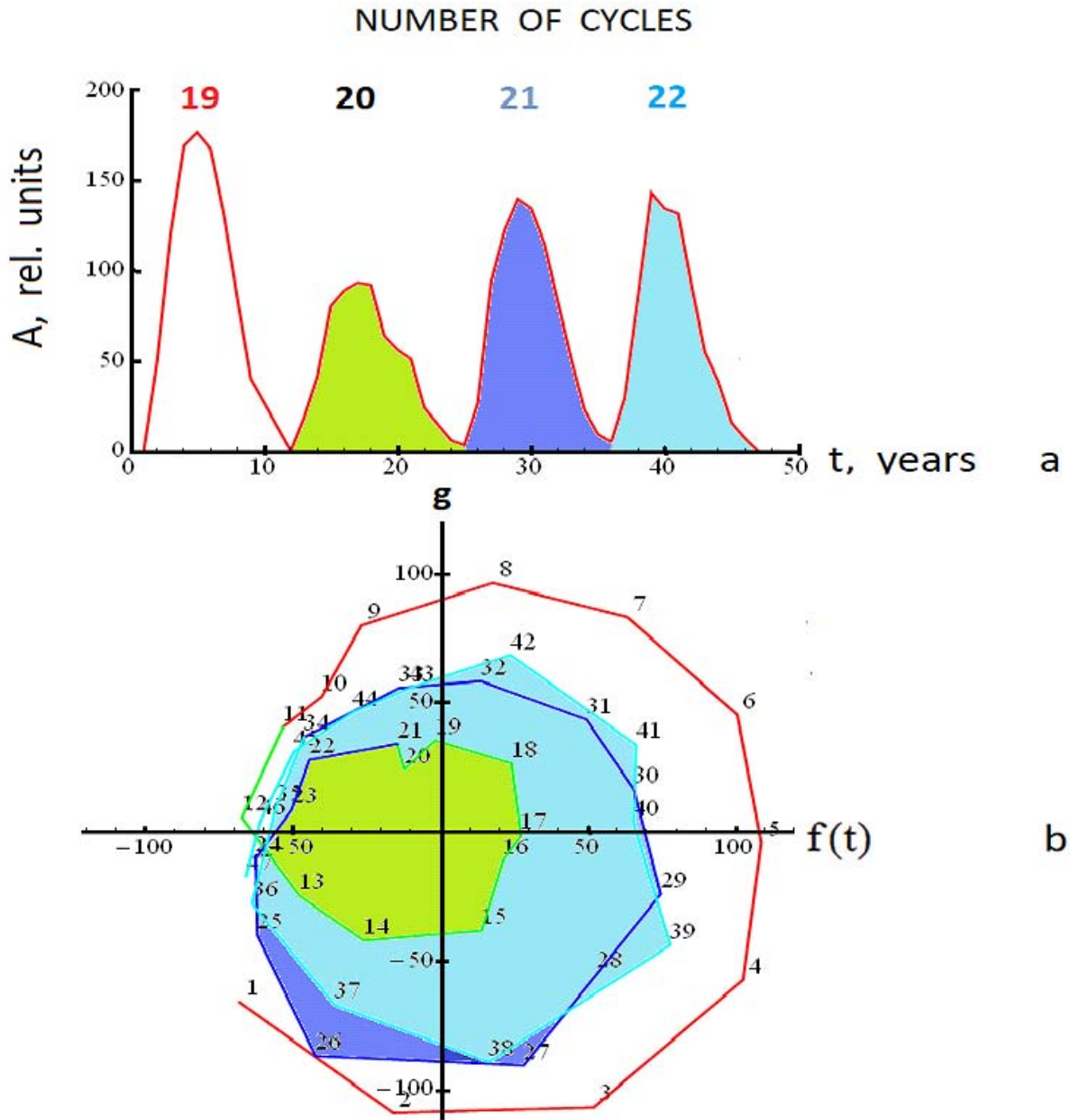
Fig. 8: "Phase portraits" of the 4 cycles № 19-22, calculated by the annual average values of number Wolf. At the top there is the time dependence of the annual average values of number Wolf. The numbers of the corresponding cycles are shown. The 19 cycle has the largest area. The *largest* area of the 19 cycle is a precursor of a non-ordinary disruption of the 11-year cyclicity, i. e. a *predictor* of the LOCAL failure non-ordinary disruption of the 19-20 cycles.

NUMBER OF CYCLES
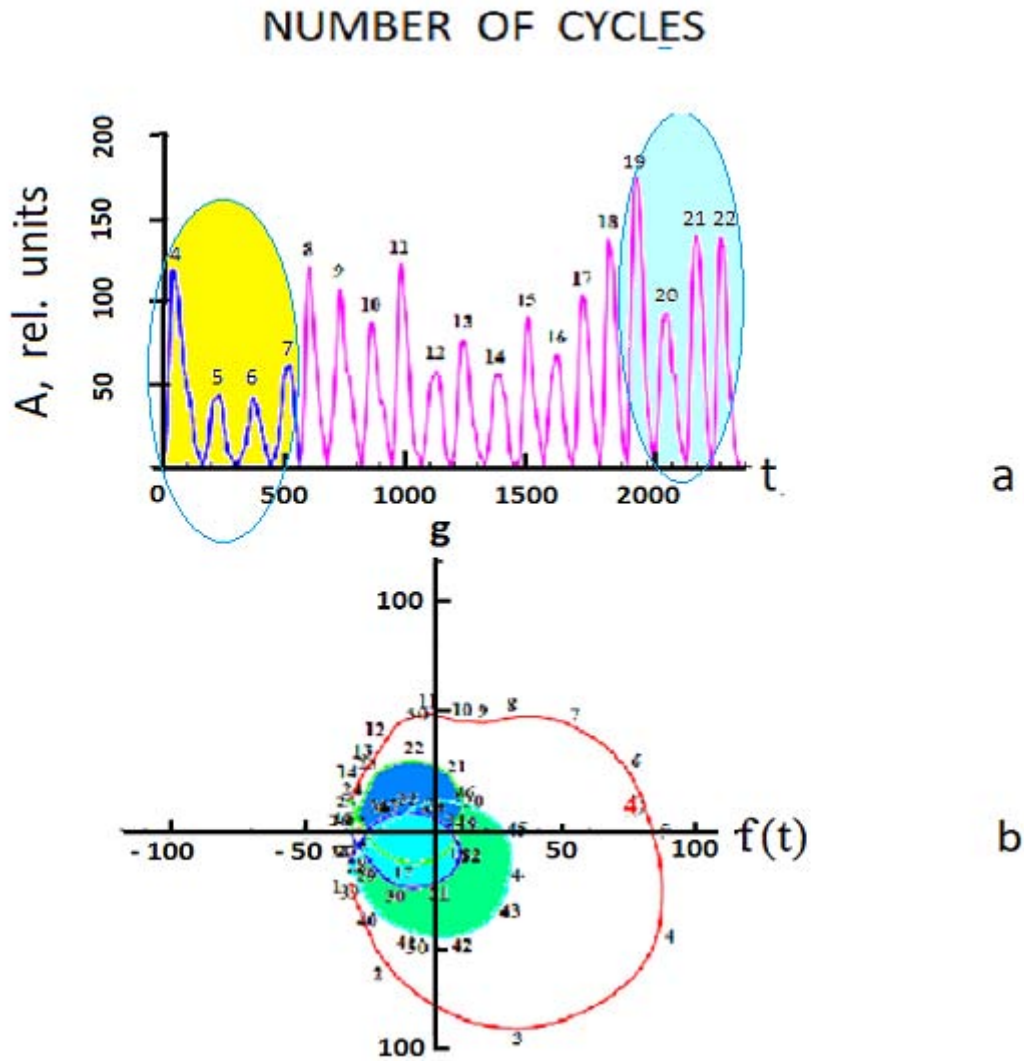
Fig. 9: "Phase portraits" of the 4 cycles No. **4-7** calculated by the annual average values of number Wolf during the "*DALTON* minimum". At the top there is the time dependence of the annual average values of number Wolf. The numbers of the corresponding cycles are shown. The 4 cycle has the largest area. The *largest* area of the 4 cycle is a *predictor* of essentially - a *GLOBAL failure*, when was the INVARIANT of the 22-year cycle is *violated*.

Weibull distribution function:

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

where

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

b — scale parameter

c — shape parameter

θ — pozition parameter

Distribution function density:

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

Reliability function:

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

Hazard function:

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


h(t)

Pre - Crisis

h(t)=const

t

h(c)

0,5

5

2
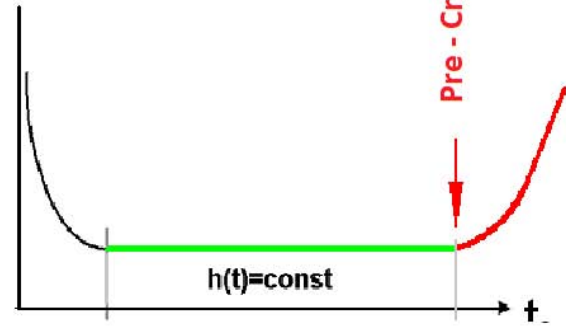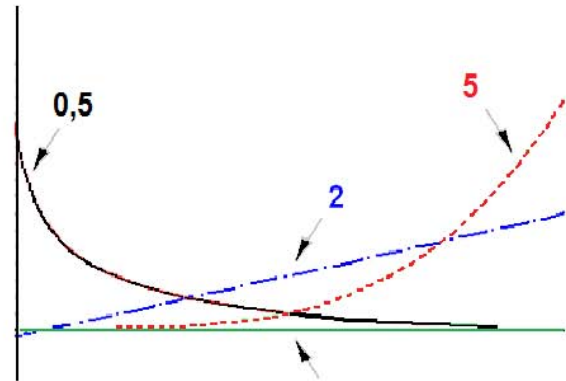
Appendix 1: Mathematical expressions (and corresponding function graphs) used to calculate the CR fluctuation PARAMETER based on the parameter values of the shape (c), scale (b) and shift (Ө). The rapidly decreasing value of the Risk function at the value of shape parameter c=0.5 corresponds to the "break-in" period of a complex dynamic system. The horizontal line of the Risk function (green) corresponds to the "normal" operation mode of the system. The value of parameter of the shape c>3 and higher (c=5) is the reaching of *pre-crisis* state of the dynamic system (a mode before the pre-catastrophe) shown by the red section of Risk function curve.

**DYNAMICS OF RISK FUNCTIONS**
on Sun rotations: 2318 - 2324
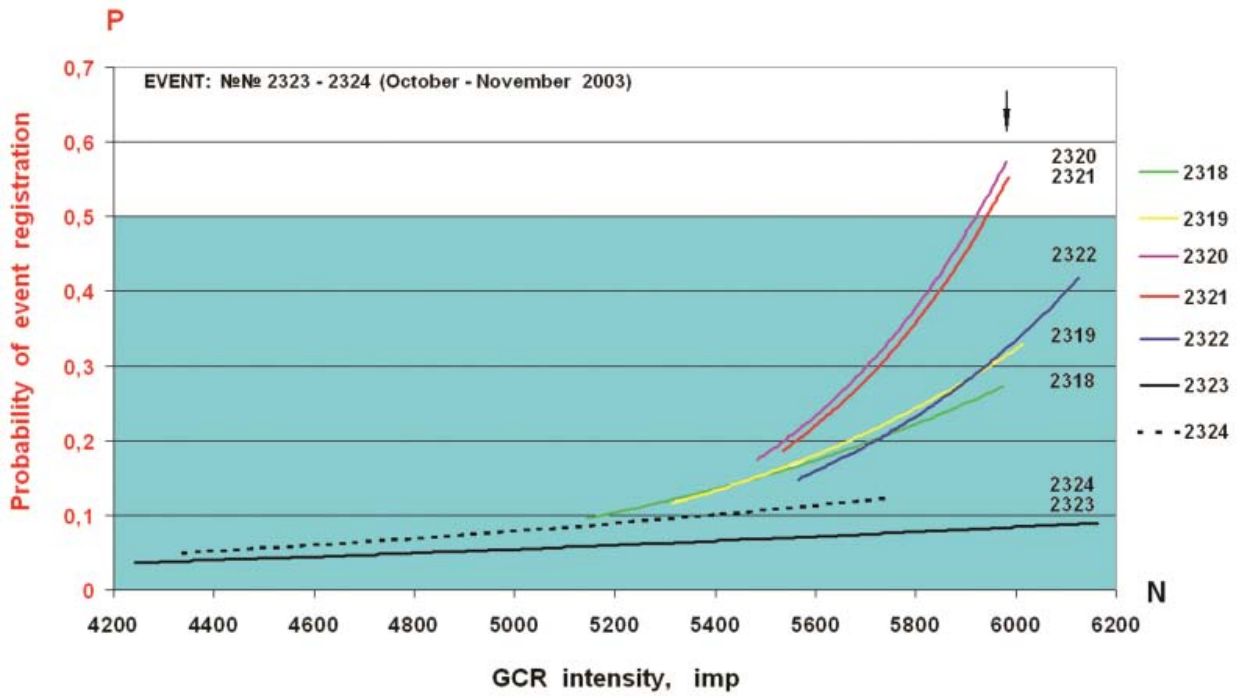
Appendix 2: The calculation of parameter fluctuations CR (function RISK) was carried out for 7 solar rotations: first, for 5 rotations 2318-2322 *preceding* the *extreme* events on rotations *2323-2324*, and then directly during the specified active phase of the solar cycle. From the calculation results it follows that significant ($P>0.5$) values of the maximum of the Risk function – *predictor*, were detected in July-August 2003 (rotations 2320-2321).
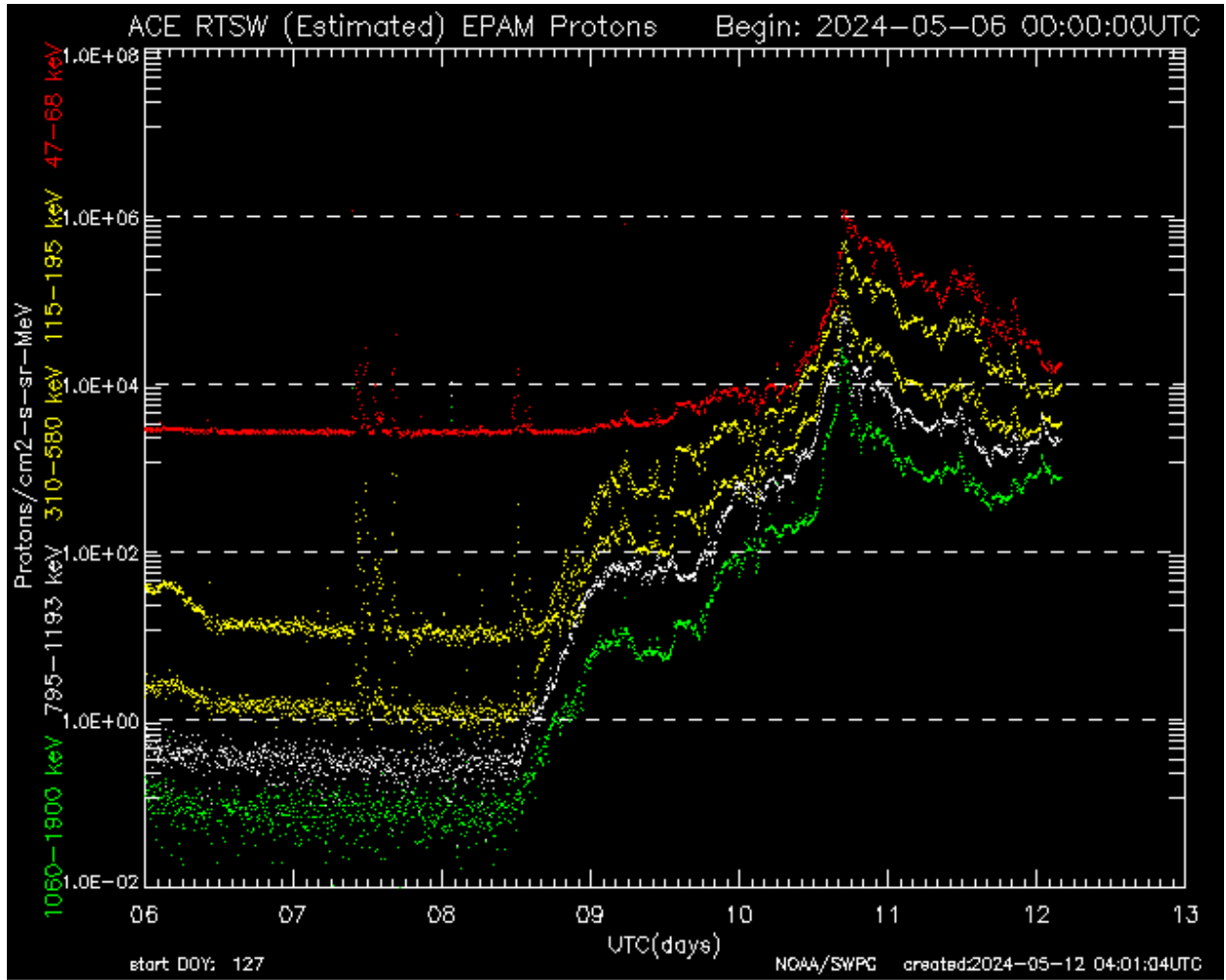
Appendix 3: Fluxes of "storm" particles with the energy $\varepsilon \approx$ 50-2000 keV by the data from the ACE spacecraft for May 6-12, 2024
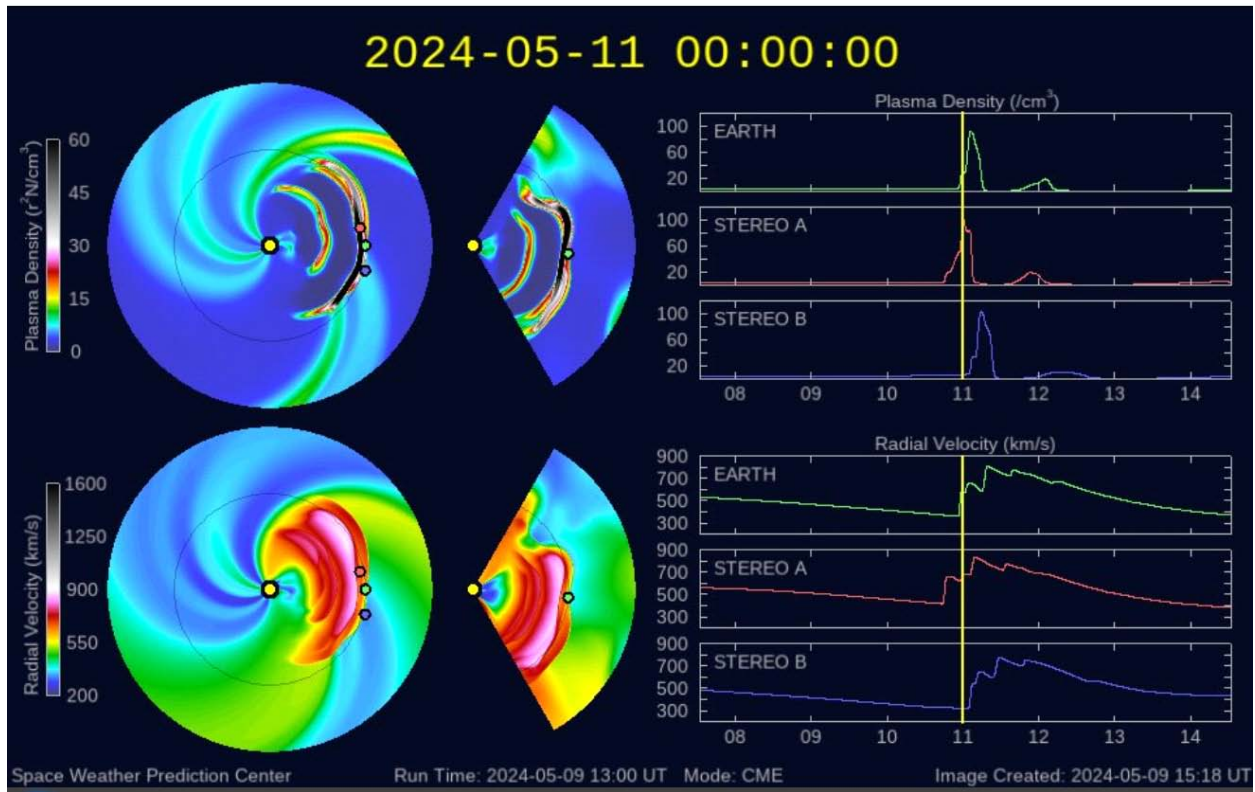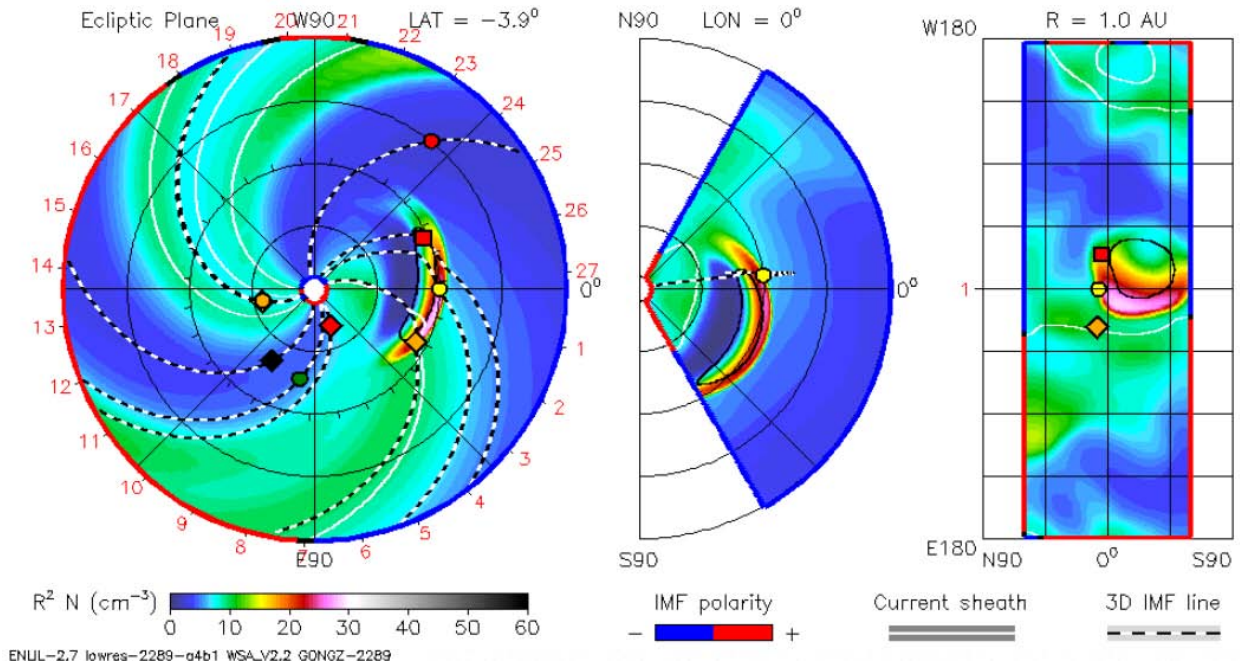
Appendix 4: Results of simulation of the situation on May 8-11, 2024 at the NOAA Space Weather Prediction Center. The shock wave crosses the Earth's orbit for May 10-11 that confirms the presence of marker in the CR. The marker is the extremely low diagnostic value of the CR fluctuation parameter. The simulation results are a good illustration of *cumulative* effect ("*cannibal effect*" according to foreign terminology) of the shock interaction.

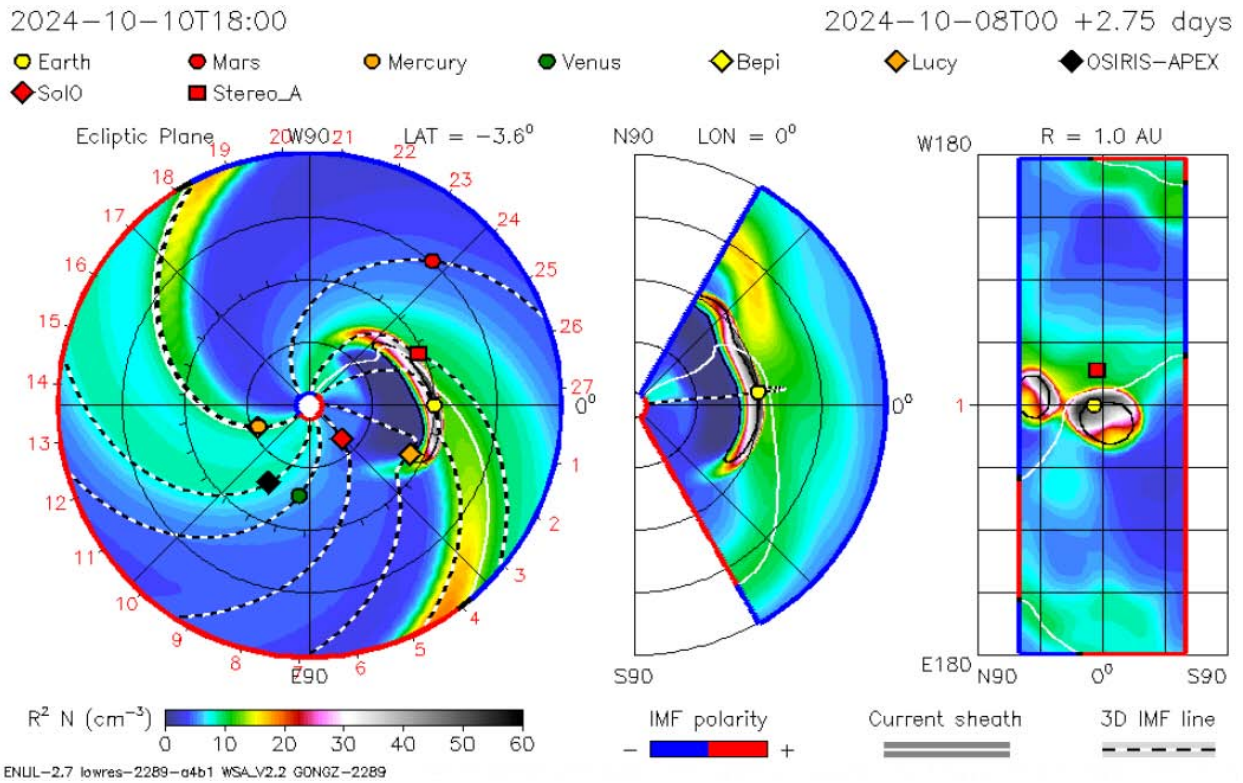*Appendix 5:* Results of simulation of the situation on *October 4-6*, 2024 at the *NOAA Space Weather Prediction Center*. The shock wave crosses the Earth's orbit for *October 5-6* that confirms the presence of marker in the CR. The *marker* is the extremely *low* diagnostic value of the CR fluctuation parameter.

Appendix 6: Results of simulation of the situation on *October 8-11*, 2024 at the *NOAA Space Weather Prediction Center*. The shock wave crosses the Earth's orbit for *October 10-11* that confirms the presence of marker in the CR. The *marker* is the extremely *low* diagnostic value of the CR fluctuation parameter