SH.3.2.17

Sun Cycles as Interchange of Low-dimension Attractors in Haotic Dynamics of Solar Activity

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Abstract

The scale-invariant character (a scaling) of the cosmic ray scintillation dynamics observed during GCR intensity decreases of different scales is proved by the *monofractal* dependence of the correlation dimension of a process with the explicitly express plateau: d=2.5±0.1. The scaling of GCR scintillation dynamics reflects the hierarchically self-similarity, i. e. a fractal structure of GCR intensity decreases at the geoeffective phase of the 11-year solar cycle. The "*window of order*" in the chaotic, on the whole, dynamics of solar activity correspond to the *low-dimension attractor*, and the ***interchange*** of "windows of order" is manifested as solar ***cycles***.

1 Introduction:

An aim of the work is to estimate quantitatively scaling features of the GCR fluctuation dynamics at different phases of the 11-year solar cycle. Earlier the dynamics of GCR scintillation index variations for isolated Forbush-decreases has been established. Besides, the analogous dynamics is conserved both for events of the complex structure on the whole, and for elements of the structure. Such a dynamics is also conserved during the sharp and extremely large decrease of the GCR intensity at the descending phase of the 11-year cycle and for a long (several years) global GCR intensity decrease at the ascending phase of solar activity. A similarity of dynamics in the "large" and the "small" is, essentially, a hierarchical self-similarity, *scaling*, of GCR fluctuation spectrum dynamics (Kozlov and Markov, 1997). The quantitative estimation of scaling features of a process is reached by using special analysis methods (Grassberger and Procaccia, 1983).

2 Results:

To exclude spatial effects and to increase the signal/noise ratio in analyzed data, the hourly values of the scintillation index were first averaged over 1 day and further over 27 days. Then scintillation index variations were subject to a test procedure to the normal distribution. It was established that the zero hypothesis about the normal distribution of mean-rotational values of the scintillation index over the solar activity (SA) cycle does not hold. The exception is only a sampling for 1984 – 1987, i.e. for the period close to the minimum of SA (the significance level is P=90%). At both descending phase of the 11-year SA cycle in 1980-1983 and 1989-1992 the *normal distribution hypothesis is unsuitable*. At the bottom of Figure the calculation results of the correlative dimension d(n) for the Poisson process (a dashed line) are presented. The solid lines are the calculation by using the GCR scintillation index for the descending phase. In both cases the curve flattens out at d≈2.5. A plateau effect is more expressive at the descending phase for 1989 – 1992.

The fact that dynamics of scintillation index variations in this period is of more expressed is no surprise, as an amplitude of GCR intensity decrease in 1991 is significantly greater than in 1982. Near the minimum of SA (1984 - 1987) a plateau is erosion and the dependence d(n) is typical rather for the chaotic process, that is confirmed by test results of the scintillation index to the normal distribution in the minimum epoch (at level P=90%).

3 Discussion:

It is known that amount of the coronal mass ejection (CME), which are a solar source of shock waves and magnetic clouds, rises during a decay of large-scale magnetic fields at the descending SA phase (Lindsay et al., 1994, Luhman et al., 1994). A finite value of the correlative dimension of GCR scintillation index variations at SA decay branches (see Figure) in that case is the correlative dimension of nonstationary disturbances dominating at the decay phase of the large-scale magnetic field of the Sun. As shown by Zeleny and Milovanov (1994), as the magnetic clouds move away from the Sun they will interact nonlinearly. As a result, the large-scale fractal structures (superclasters) are formed consisting of magnetic clouds just as magnetic clouds consist of magnetic force tubes. Thus superclasters are monofractal objects (Zeleny and Milovanov, 1994). The clasterization effect of CME- events at the SA descending phase has been cited Webb (1995). Moreover, Burlaga and Ness (1991) established that the largest decreases of GCR intensity in 1991 are rather determined (monofractal) objects than statistical clasters, that confirms our results.

At the "latent phase" (Kozlov, 1999) of new SA cycle (1984 - 1987) a plateau is *erosion*, and the dependence d(n) is rather characteristic for a chaotic process (Figure). It is obvious that erosion plateau and the monotonic increase of the dimension point to the chaotization of process as is evident from the turbulence structure evolution according to the universal scenario by Feigenbaum (1978). There are the inverse dependence between the fractal dimension and the fluctuation spectrum index (Kudela and Venkatesan, 1995). The increase of the dimension and, correspondingly, the decrease of the fluctuation spectrum index point to the recovery of small-scale IMF inhomogeneities near the minimum of SA.

The recovery of small-scale inhomogeneities will make worse modulation features of the magnetic field (Kuzmin, 1968), that will manifest as the decrease of the GCR intensity modulation depth. This is consistent with a deficit of the number of Forbush-effects in the minimum epoch (Morishita et al., 1990) and also with small modulation depth of the GCR intensity by recurrent disturbances dominating in the above period (Badruddin, 1993).

Thus, a behavior of solar activity and, more exactly, GCR scintillation index variations in the 11-year cycle even if is described the low-dimension attractor then only at the geoeffective decay phase of the 11-year cycle. The output to the plateau of the dependence d(n) at the same value d=2.5 for different cycles points to just this. Near the SA minimum epoch the process becomes essentially chaotic.

In the light of obtained results, the "*window of order*" in the chaotic, on the whole, bifurcation diagram of turbulence evolution by the universal scenario of Feigenbaum (1978), correspond to the *low-dimension attractor*, and the ***interchange*** of "windows of order" in the chaotic dynamics of solar activity is manifested as solar ***cycles*** (Kozlov, 1999). The detection of the low-dimensional attractor in the chaotic dynamics of solar activity by the GCR scintillation index is evidence of the *principal* possibility for the forecast of the periods of maximum sporadic activity of the Sun, mainly, at the decay phase of the 11-year cycle (Kozlov, 1999). Namely the decay phase as most geoeffective is of interest for the forecast of catastrophic manifestations of geophysical activity.

4 Conclusion:

The behavior of solar activity and, more exactly, GCR scintillation index variations in the 11-year cycle even if is described the low-dimension attractor then only at the geoeffective decay phase of the 11-year cycle. Explicitly express plateau of the dependence d(n) at the same value d=2.5 for different cycles points to just this (near to the SA minimum epoch the process becomes essentially chaotic). In the light of obtained results, the "window of order" in the chaotic, on the whole, dynamics of solar activity corresponds to the low-dimension attractor, and the ***consequence*** of "windows of order" in the chaotic dynamics of solar activity is manifested as solar ***cycles***.

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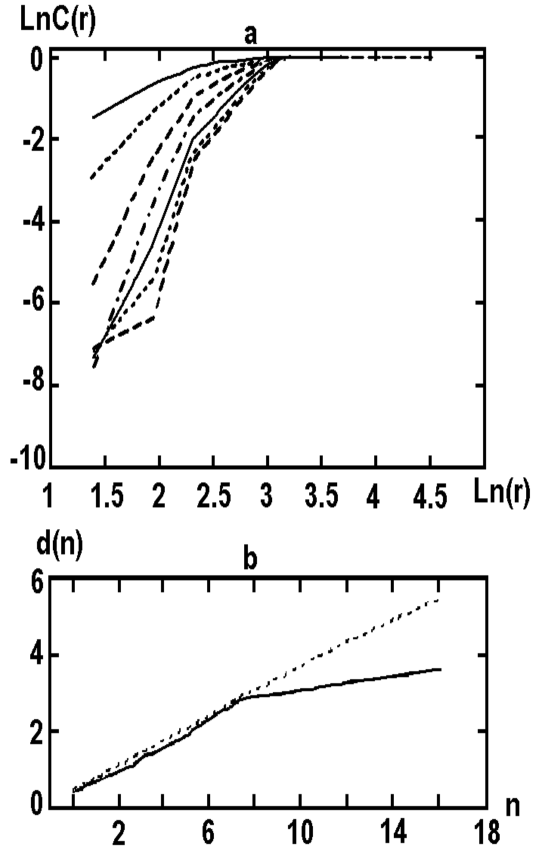

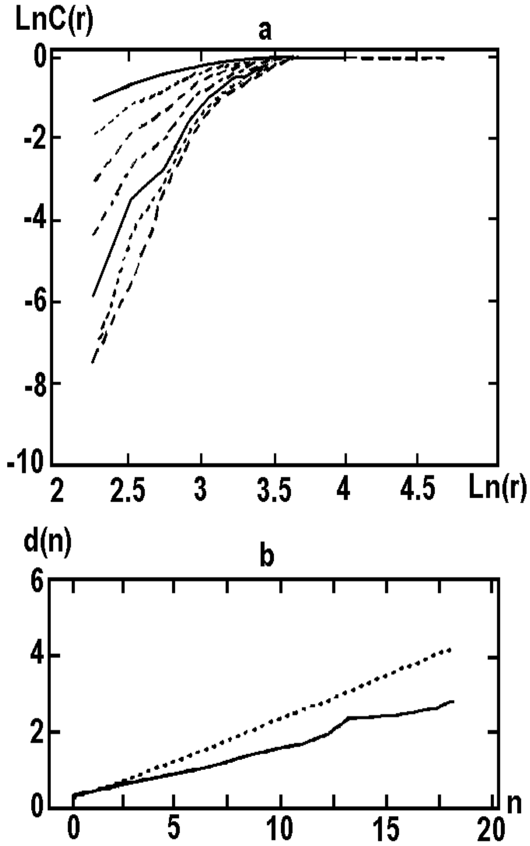

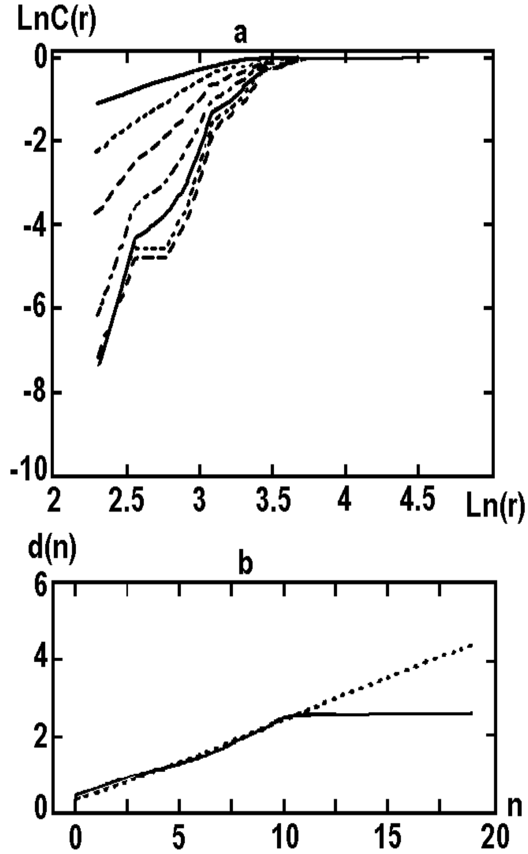

The calculation results of integral correlative functions C(r) at the log-log scale and dependence d(r) for 1980-1983, for 1984-1987 (on the right) and 1989-1992 (below).