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Effect of Solar Magnetic Field Reversal by Dynamics of Cosmic Ray Scintillation

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Abstract

Dynamics of GCR intensity scintillations is best manifested during a *decay* of the large-scale magnetic field at the completion stage of a *reversal* of the solar magnetic field which is accompanied by a *growth* of the number of shocks, Forbush-decreases and an index of their energy spectrum.

1 Introduction:

An aim of the work is to study transitional turbulence regimes of solar wind plasma in the 11-year cycle of solar activity by means of the investigation of GCR intensity fluctuations in the 10^{-4} -$2{\cdot}10^{-3}$ Hz range. To study a variability of power spectra of cosmic ray fluctuations the GCR spectral–time scintillation index was introduced (Kozlov and Tugolukov, 1992). By definition, the rise of the scintillation index points to the simultaneous increase of the frequency and the amplitude of fluctuations and, on the contrary, the decrease of the index indicates on their simultaneous decrease.

2 Results:

The Forbush-effect structure is not reduced to the two-step one. In a number of the most powerful events, for example in March 1991, the complex structure of the Forbush-effect is observed. In June 1991 the *multi-step* Forbush-effect structure was registered. In Fig. 1 the example of the continuous calculation of the spectral-time scintillation index (a solid line) for the period from April 6 to June 16, 1991 is presented. The horizontal dashed line is the two-side 95% significance level. In that period two Forbush-decreases were registered: on April 24-27 with the amplitude A=5% and on May 28 – June 13 with the complete profile of GCR intensity (a dashed line). A maximum of the envelope of GCR scintillation index variations is preceded to Forbush-effects in both cases, i.e. the envelope of index variations describes the macrostructure of the Forbush-effect and variations of the index reflect its fine structure. It is more visually seen in the detailed comparison of scintillation index variations with the multi-step profile of the GCR intensity (Fig. 1). The scintillation index rises at the increase phase of intensity (pre-increases) reaching a maximum *before* the beginning of the local decrease. As a rule, the minimum value of the scintillation index was registered at the local GCR intensity minimum. It is practically preserved for all local decreases registered, on the average, with the sequence interval $T\approx 4$ days. Only such a “phasing” of the scintillation index and GCR intensity at a stage of similar pre-increases and decreases permits to conserve the stability of the phase shift between the scintillation index and the GCR intensity. Thus, the dynamics of GCR scintillation index variations revealed earlier for the isolated Forbush-decreases is conserved both for complex structure Forbush-effects, on the whole, and for elements of its fine structure. A similarity of dynamics in the “large” and the “small” is the *hierarchical self-similarity* or the scale invariance of the fluctuation spectrum dynamics during the Forbush-effect with the profile of any complexity. Taking account for the above results we study further a character of the structure of GCR intensity decreases for the large averaging intervals. Below we present the results of the spectral-time analysis of fluctuations by 5-min neutron monitor data at Tixie station for the solar activity (SA) cycle of 1980-1991. Fig. 2 presents the graphs of 27-day values of GCR intensity (a dashed line, the scale on the right) and the spectral scintillation index (solid line). The local deep minimum in 1982 (and 1991) is caused by the contribution of a series of powerful Forbush-effects registered usually at the branches of SA declining and it is accompanied by maximum geomagnetic activity in the cycle. The *envelope* of 27-day values of the scintillation index describes the *macrostructure* of the GCR intensity profile, and variations of the scintillation index – its fine structure (caused by seasonal variations of the heliospheric current sheet geoefficiency).

3 Discussion:

As to the origin of the sharp and extreme large decreases of the GCR intensity at declining branches of the 11-year cycle (Fig. 2), the question remains unsolved to this day. Attempts to explain them by the modulation by "magnetic barriers" (CMIR, LMIR, GMIR etc., (Burlaga et al., 1993, Le Roux and Podgieter, 1993) formed far in interplanetary medium are inconsistent. On the other hand, the long-term increases of solar wind speed have been detected, associated evidently, with fundamental variations of the coronal field of the Sun. It was supported that they caused extreme disturbances in 1982 and 1991 (Gasis, 1996). A decay of the large-scale magnetic field of the Sun beginning with the moment of a reversal of the magnetic field in 1971, 1981 and 1990, is , most likely, a source of such increases of the solar wind speed. Namely in 1972, 1982 and 1991 there were the maximum sporadic activity of the Sun, the maximum value of the intensity module and power spectrum of IMF, the most intense variations of an angle of inclination of the heliospheric current sheet and variability of Bz-component, the growth of the number of powerful Forbush-effects and magnetic storms and also the maximum angular size of the radius of the Sun. A totality of these factors allows to suggest that, beginning with an end of a reversal of the magnetic field of the Sun, in the time interval $\tau = t_{max} + (2\pm1$ year), the transitional process of decay of the 11-year cycle took place which was finished by the rapid and extreme large decrease of the GCR intensity at the declining branch of the cycle. Earlier it was noted (Vitinsky et al., 1986), for example, that "*the traditional reference of 11-year cycle onset from an minimum epoch was formal and had no physical foundation. It is more correctly to take the moment of end of a reversal of the general magnetic field of the Sun as the onset of the 11-year cycle. It is also confirmed by the Ohl's conclusion that the onset of the new 11-year cycle take place in the depths of old one (in a traditional sense)* ". Thus, the onset of the new cycle had to be regarded as the time of ***end of the transition process of the current 11-year cycle decay,*** after that the *latent phase* of new cycle begins (Kozlov, 1999).

4 Conclusion:

Dynamics of GCR intensity scintillations is best manifested during a *decay* of the large-scale magnetic field at the completion stage of a *reversal* of the solar magnetic field, which is accompanied by a *growth* of the number of shocks, Forbush-decreases and an index of their energy spectrum.

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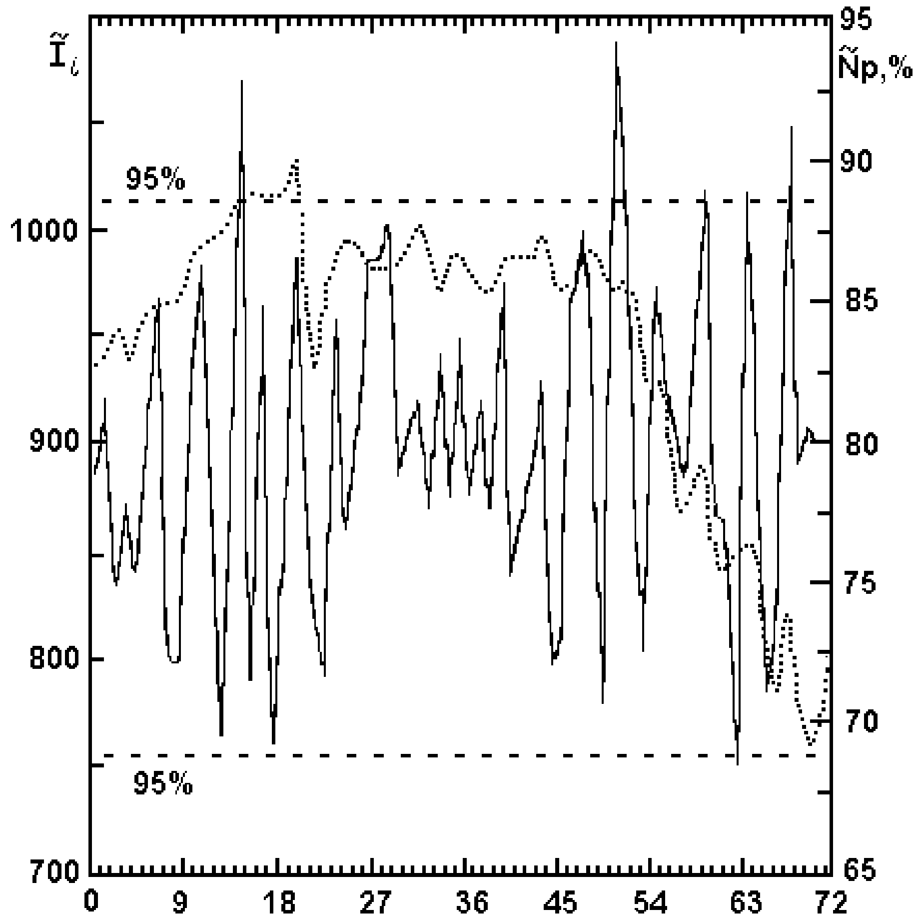

Fig. 1 Oscillations of the scintillation index I_i (solid curve) and GCR intensity variations N_p (dotted curve) for the period from April 6 to June 16, 1991. The dashed line is the two-side 95% significance level for the scintillation index. The abscissa axis – the time in days.

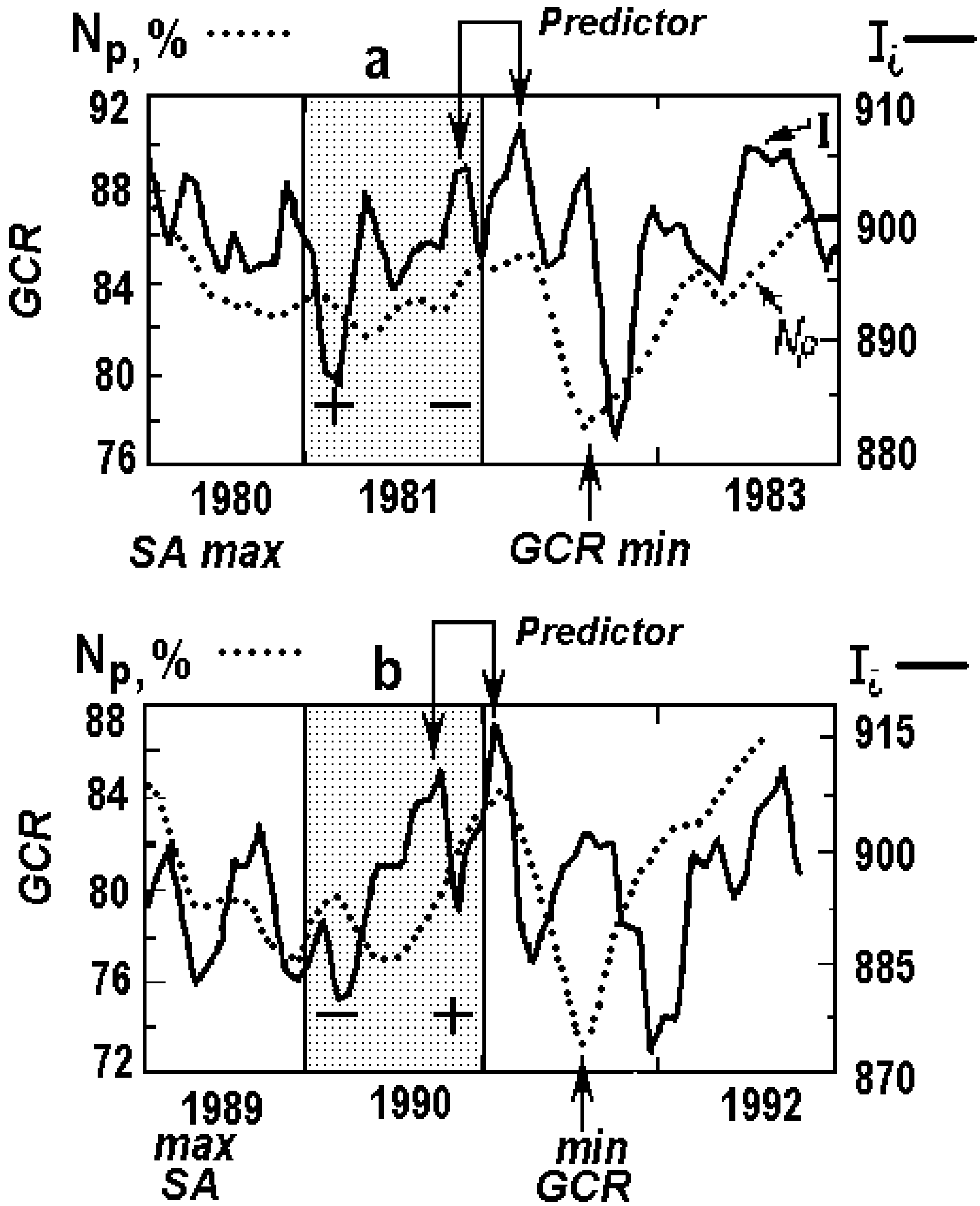

Fig. 2. Dynamics of variations of the scintillation index I_i (solid curve, the scale on the right) during sharp and extremely large decreases of GCR intensity N_p (dotted curve, the scale on the left) at declining branches of the 11-year cycle in 1980-1983 and 1989-1992. The abscissa axis – the time in years. The cross-hatched section – the period of the *reversal* of the magnetic field of the Sun for 21 and 22 cycles. Double arrows – a *predictor* of global decreases of the GCR intensity in 1982 and 1991.