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Recurrent variations in the high-energy cosmic ray intensity

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Abstract: Recurrent variations and their relation to the solar activity and solar wind parameters are investigated on the basis of the cosmic ray intensity data for 4 solar cycles by means of the spectral analysis method. It is found that the temporal change of the power spectrum of 13.5- and 27-day variations repeats the power spectrum change of the number of sunspots and tilt angle of the current sheet. The dependence of 27-day variation on the polarity of general magnetic field of the Sun is not found.

Introduction

The existence of long - lived active regions in the Sun and solar wind of interplanetary space is identified by means of the study recurrent variations of cosmic ray intensity. In recent years, the results of authors using different methods of investigation of 27 - day variations of cosmic rays reduce on the whole to following main conclusion.

Richardson et al. [1] have been explained that recurrent cosmic ray variations are due to the corotating regions of interaction in the interplanetary magnetic field.They obtained and then Gil and Alania [2] confirmed that the 27-day variation amplitude of cosmic rays in the Earths orbit large in the positive polarity epoch of general magnetic field of the Sun ($qA > 0$) that in the negative polarity epoch ($qA < 0$). The observation of this effect contradicts the drift mechanism, as cosmic rays in the positive polarity epoch arrive from the polar regions of the heliosphere and must no sense the current sheet structure [3]. According to Attolini and Galli [4], the period of recurrent oscillations is 28.5 days at the solar activity minimum and 27.5 days at the solar activity maximum. These values correspond to the synodic rotation period of sunspots. Alania, Baranov et al. [5] showed that at $qA < 0$ (1982-1989) temporal changes of 27 - day variation amplitude are consistent with a change of longitudinal asymmetry of sunspot areas and with the tilt angle of current sheet, whereas in the positive polarity epoch $qA > 0$ $(1972 - 1979)$ they correlate with the polar coronal hole area. In the present work, on the assumption that heliophysical characteristics are substantially random, we use analysis methods of stochastic processes, namely, the filtration and spectral analysis to reveal recurrent periods 27-day and 13.5-day variations are analyzed.

Data analysis and discussion

Daily average data of neutron monitors at Climax $(1953 - 2006)$ [6], Mc Murdo $(1964 - 2006)$ [7], ionization chamber ASK-1 at Yakutsk station $(1953 - 2003)$ and also interplanetary magnetic field module $|B|$ [8], numbers of sunspot R_z $(1953 - 2006)$ [9], tilt angle of current sheet HCS $(1976 - 2004)$ [10] are used.

The long-term trend was excluded by the filtration method and the temporal change of 27- day variation of B, HCS, neutron component intensity at Climax and Mc Murdo stations, R_z was obtained. Thereby, the digital nonrecursive narrow-band filters [11] in the form of $y_n = \sum c_k x_{n-k}$, are used, where c_k are coefficients of filter, k is the number of filter coefficients, x are values of initial realization of data, y are values obtained as a result of filtration. The coefficients of a filter associated

with its amplitude-frequency through the inverse Fourier transform:

$$c_k = \frac{1}{2\pi}\int_{-\pi}^{\pi} H(\omega)exp(j\omega k)d\omega \qquad (1)$$

and, vice versa:

$$H(\omega) = \sum_{k=-M}^{M} c_k exp(-j\omega k), \qquad (2)$$

where $\omega = 2\pi\upsilon$, $j = \sqrt{-1}$, for the frequencies $\upsilon_1 < \upsilon < \upsilon_2 = \frac{1}{2\Delta t}$, Δt is digitization step of data.

The temporal change of the 27-day variation is the same for two stations, therefore Fig.1 presents only the results of neutron monitor at Climax station. The bottom panel of Fig.1 is the temporal change of cosmic ray neutron intensity and the number of sunspots. Daily values of the heliospheric current sheet are taken from an ATLAS of computed coronal field synoptic charts [9].

It is seen that temporal changes of 27-day oscillations in the data of HCS, cosmic ray intensity I_{27} and R_z are synchronously intensified in the years of rise and maximum of solar activity and weaken near the solar minimum taking the tilt of pearl oscillations. Inside an envelop of the 11-year change of 27-day variation the number of sunspots, cosmic ray intensity and tilt angle of current sheet, the individual stable oscillations with a duration of 1 to 3 years are observed which can be related to CME, as Forbush-decreases fall into the above periods. It is seen from Fig.1 that the 27-day variation amplitude of the cosmic ray neutron component changes from 0.5 to 2 % from the minimum to maximum of solar activity. It should be noted that we had not found the dependence of 27-day variation on the polarity of general magnetic field of the Sun. However, the tendency to the weak relation of 27-day oscillations of the interplanetary magnetic field module $|B|$ to solar activity.

Fig. 2 presents the results of spectral analysis in the form of spectral estimation values corresponding to the periods of 27 and 13.5 days for the same parameters as in Fig.1 but with addition of hard cosmic ray component (ASK-1). The temporal behaviour of estimations for neutron monitor spectra repeats completely the temporal changes of power

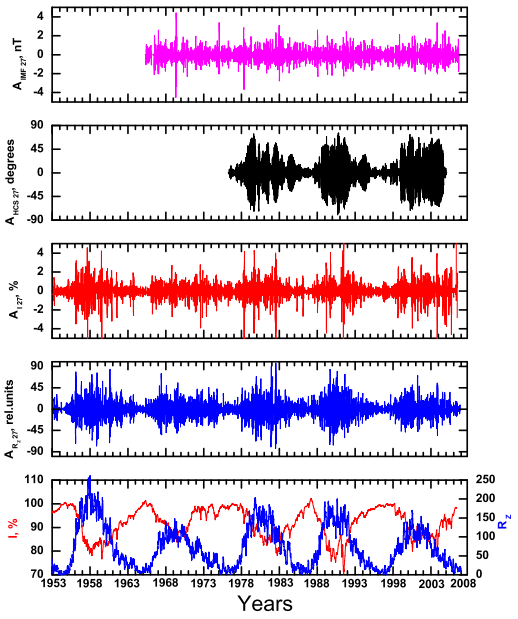

Figure 1: 27- day variation of cosmic ray intensity A_{I27}, interplanetary magnetic field A_{IMF27}, slope angle of current sheet A_{HCS27}, numbers of sunspot A_{R_z27}. The bottom panel is 11 - and 22- year variation of the cosmic ray intensity and sunspots.

spectra for the periods of 27 and 13.5 days of the number of sunspots and tilt angle of current sheet. The closely correlation (0.833 ± 0.029) between corresponding spectral estimations for neutron and hard components but for the neutron component the power is on an order of magnitude higher.

The 27-day oscillation amplitude is significantly higher that for 13.5-day oscillations with the exception of the interplanetary magnetic field intensity. In this case, the spectrum power of 13.5-day oscillations is more than for cosmic ray 27-day variations.

Conclusions

The temporal change of the amplitude of 13.5- and 27-day oscillations repeats the change of the number of sunspots and current sheet slope angle. The

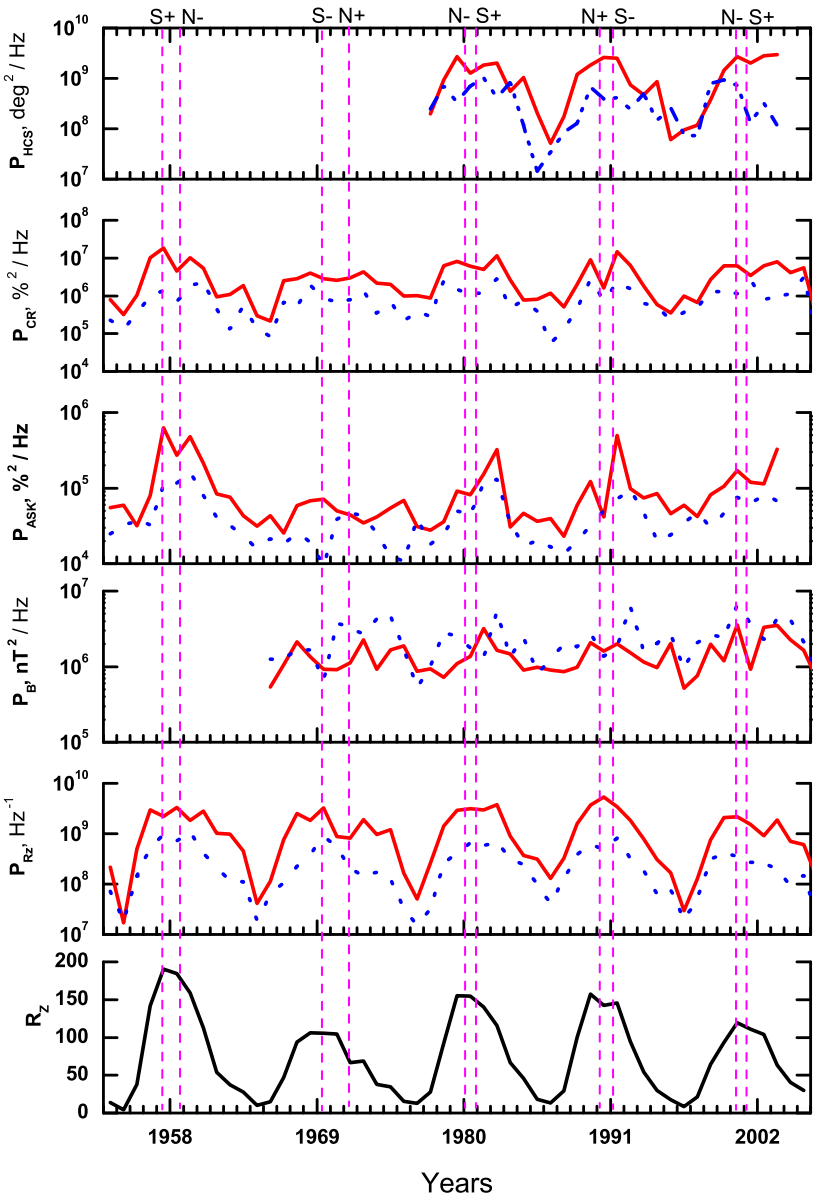

Figure 2: Variations of spectral density for the periods of 13.5 - (dot line) and 27 - (solid line) days. At the bottom panel is the temporal change of the number of sunspots R_z. The vertical dashes lines are moments of sign-change of general magnetic field of the Sun.

amplitude of power spectrum changes of the 13.5-day variation of the magnetic field intensity B is more than for the 27-day wave. No dependence of 27-day variations on the polarity of general magnetic field of the Sun is found.

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References

[1] I.G. Richardson, H.V. Cane, and G. Wibberenz. A 22-year dependence in the size of near-ecliptic corotating cosmic ray depressions during five solar minima. *Journal of geophysical research*, 104: 12549-12561, 1999.

[2] A. Gil, and M.V. Alania. 27-day variations of cosmic rays for the minima epochs of solar activity: Experimental and 3-D drift modeling results. In *International Cosmic Ray Conference 27th, Hamburg, Germany*, 9: 3725-+,2001.

[3] J. Kota, and J.R. Jokipii. Recurrent depressions of galactic cosmic rays in CIRs: 22-year cycle. In *International Cosmic Ray Conference 27th, Hamburg, Germany*, 9: 3577-+, 2001.

[4] M.R. Attolini, S. Cecchini, and M. Galli. On 27-day recurrences in the cosmic rays and the solar corotationion. In *International Cosmic Ray Conference 17th, Paris, France*, 10: 171-+, 1981.

[5] M.V. Alania, D. G. Baranov, A. Gil, M.I. Tyasto, and E.S. Vernova, The asymmetric heliospheres role in the 27-day variations of galactic cosmic rays. In *International Cosmic Ray Conference 27th, Hamburg, Germany*, 9: 3678-+, 2001.

[6] http://www.env.sci.ibaraki.ac.jp/ftp

[7] http://omniweb.gsfc.nasa.gov/ow.html

[8] http://sidc.oma.be/html/sunspot.html

[9] http://wso.stanford.edu/synsource.html

[10] R.V.Hemming, Digital filters, M. Sov. Radio, 1980.