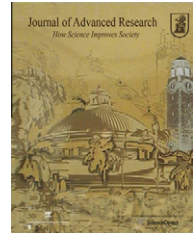




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ORIGINAL ARTICLE

Mid-term periodicities of cosmic ray intensities

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Abstract Galactic cosmic ray intensities (GCRs) observed by five neutron monitors (NMs) have been used to study cosmic ray modulations between 1971 and 2007. The influence of interplanetary magnetic polarity (IMF) states has been studied for the $A < 0$ and $A > 0$ epochs. A comparison of the spectra for both positive IMF polarities indicated different solar origins. The spectra have different power amplitudes and most peaks of different locations. In addition, the differences in the cosmic ray modulations, conditions for solar activity minima and maxima periods are probably associated with the influence of drift effects. The observed differences are related to the 22-year cycle in heliospheric modulations of cosmic rays, leading to the different shapes of CR maxima and the hysteresis effect. Accordingly, drift effects dependent on the polarity of the global solar magnetic field may play a significant role in the observed differences between maxima and minima periods. The drift mechanism is enhanced during periods of low to moderate SA, i.e., around solar cycle minima, during negative polarity periods, when $A < 0$.

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Introduction

Study of the modulation of galactic cosmic rays (GCRs) is important because of its potential for revealing the subtle fea-

tures of energetic charged particle transport in the tangled fields that permeate the heliosphere; as a means of remotely probing the heliosphere; and for learning about the physics of the processes operating on the Sun. The charged particles in the solar wind drag the Sun's magnetic fields with them. While one end of the interplanetary magnetic field (IMF) remains firmly rooted in the photosphere and below, the outer end is extended and stretched out by radial expansion of the solar wind. The Sun's rotation bends this radial pattern into an interplanetary spiral shape within the plane of the Sun's equator. The shape of the IMF depends on the Sun's 11-year of magnetic activity. Near activity minimum, the large-scale global magnetism of the Sun can be described as a simple magnet with north and south poles where large, unipolar coronal holes are located. The northern pole is of one magnetic polarity or direction and the southern pole is of opposite polarity. The negative and positive field lines meet near the solar equator, where a magnetically

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neutral sheet is dragged out into space by the out-flowing wind. The dipole is stretched out at its middle, resulting in two polar monopoles whose magnetic orientation is preserved throughout most of an 11-year activity cycle. The polarity of the Sun's magnetic field reverses during solar activity maximum (i.e., the Sun is directed away during the next cycle, returning to the original direction every 22 yr).

The frequency distribution of the cosmic ray intensity (CRI) oscillations in the low frequency range has been examined [1–8]. The power spectrum displayed significant peaks of varying amplitude within the solar rotation period (and its harmonics) that changed inversely with particle rigidities. The fluctuations of large period (6–11 months) appeared in CRs [5,6,9,10]. The comparison of CR power spectra during four successive solar activity minima has indicated that, at low rigidity particles, the spectrum differences are significantly large between the $A > 0$ and the $A < 0$ epochs. The spectra for even solar maximum years are higher and much harder than those of the odd years. The evolution of cosmic ray intensity is different for odd and even cycles, with different time and shape [11]. Periodicities of several indices were studied [12], displaying periods of wavelengths of 1.3 yr (15.6 months) and 1.7 yr (20.4 months). Short and intermediate term periodicities of galactic cosmic rays intensity recorded by the Oulu neutron monitor station during the period 1996–2008 were examined [13] by the wavelet technique. The study exhibited

a number of short and intermediate term periodicities present between 16 and 500 days in different phases of this cycle.

Previous study of the daily means of the CRI for four NMs, including CI (NM), obtained 1.7 yr, 1.3 yr and 150 d peaks. It was deduced that the 1.7 yr peak contributed strongly in solar cycle 21, and that the 1.3 yr peak was present in the decreasing phase of cycles 20 and 22 [14]. Mavromichalaki et al. [15] studied the power spectral density of CRI for the period 1953–1996 for the CI NM, using three different techniques. They found that several peaks occurred around 1.9, 1.7, 1, 0.75, 0.7, 0.6 and 0.4 yr. The 1.9 yr (~ 2 yr variation) was identified along with the annual and other variations in the neutron monitor data a long time ago.

The aim of this work is to present the power spectra results for the daily averages of the nucleonic intensity recorded by five NMs, which have different cutoff rigidities, over a period up to three solar activity cycles (SACs) in the period 1971–2007. We investigate the observed differences in the CR power spectra related to different rigidities particles, for $A > 0$ and $A < 0$ IMF polarity states, as well as for solar minimum and maximum activity years.

Data and analysis

Daily averages observed by NMs at five locations were recorded, as follows: Calgary ($R_0 = 1.09$ GV; 1971–2007), Kiel

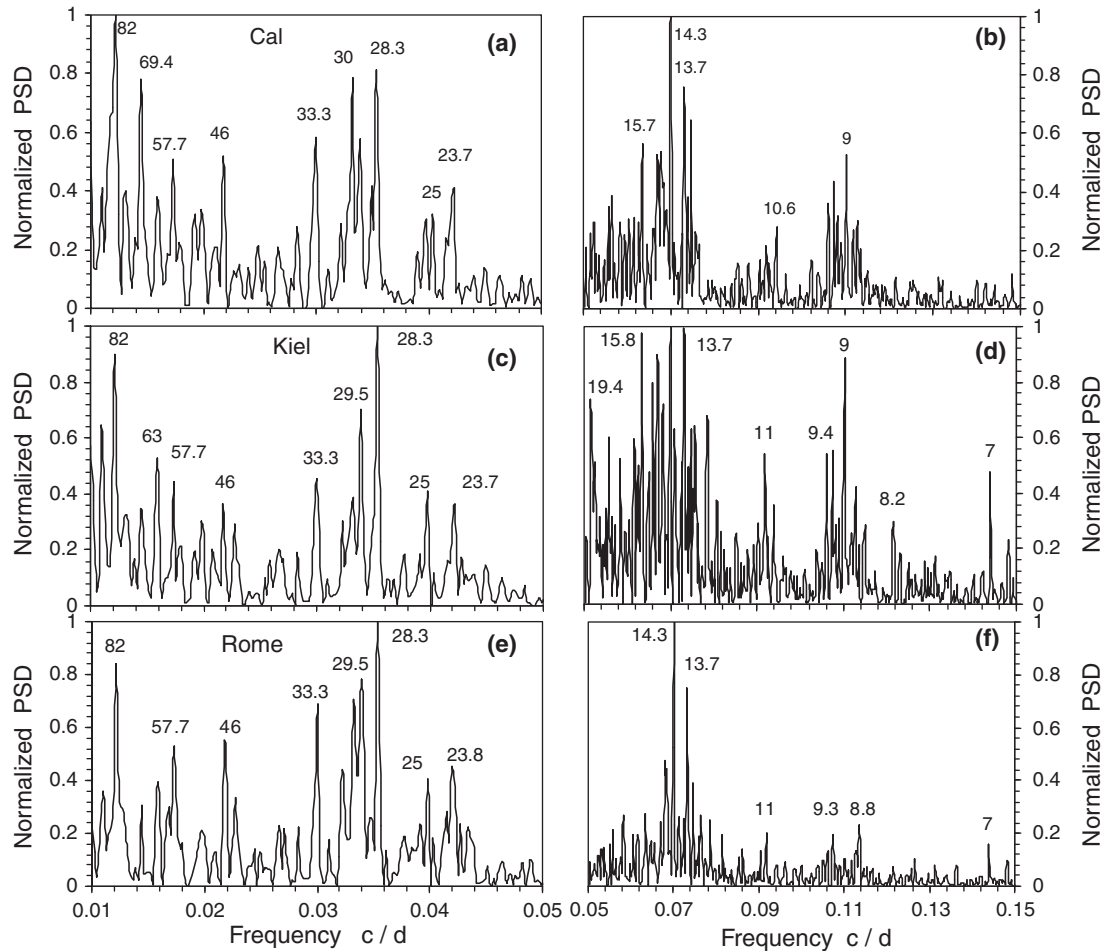


Fig. 1 PSD of: (a & b) Cal, (c & d) Kiel and (e & f) Rome during $A_1 > 0$ (71–80).

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