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INFLUENCE OF JUPITER ON COSMIC RAY INTENSITY VARIATIONS

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Abstract

Galactic cosmic ray (GCR) diffusion in interplanetary space depends in a certain way on the degree of regularity of the interplanetary magnetic field (IMF). The sector IMF structure is manifested in inhomogeneous GCR distribution in the heliosphere. In parallel with the usual sectors associated with solar activity, one should take into account the sectors, which are caused by the Jupiter activity. It is known that the Jupiter is a powerful regular source of high-energy electrons (0.2 – 40 MeV), the density of which, on the average, is many times higher than that of solar cosmic rays. The high-energy electrons are systematically registered with the 399-day period in the near-Earth space. According to estimations of the particle energy density their flux is sufficient to decrease the magnetic field in the Jovian sector and can due to corresponding large-scale inhomogeneity in the GKL distribution.

Hereby, we present the evidences that the GCR diffusion is noticeably stronger in the sector where there are Jovian electrons. By data on periodic passage of those sectors near the Earth, we have treated neutron monitor data using the superposed epoch technique. The day of the Earth and Jupiter opposition is taken as a zero epoch. At large statistical data (9925 days) it is found that the GCR intensity in that period increases with an amplitude near 1%. The ground effect is manifested with the period of 399 days and its maximum time is in a certain way shifted relative to the planet opposite moment.

Introduction. Setting a Problem

In the interplanetary space Jupiter is a powerful source of 0.2-40 MeV electrons. As observed in [1, 2], the Jovian particle fluxes, on the average, exceed many times the electron fluxes of solar origin.

According to the paper [3], in the heliosphere the interplanetary magnetic field (IMF) strongly affects the high-energy electron propagation. It is shown, considering this, that in the sector IMF structure the large-scale region of spiral field lines connecting the Sun and Jupiter is distinguished. Below, that IMF sector is called the Jovian sector. The increased contents of particles in it is studied in [4, 5] by 0,1-12 MeV electron measurement data in the near – Earth space.

In [4, 5] the regular dynamics of the Jovian IMF sector over the course of several solar activity cycles has been found. In this paper we continue to study this dynamic factor of the interplanetary medium. The issue of its influence on the propagation of galactic cosmic rays (GCR) in the heliosphere is discussed.

For this purpose, the characteristics of 399-day variation in the GCR intensity are determined by use of the ground-based neutron monitor data. An amplitude is estimated, and its maximum time is associated with the opposition date of the Earth and the Jupiter.

Treatment and Analysis of Experimental Data

Fig.1 (at the top) presents neutron monitor data at Oulu station from October 30, 1973 to December 31, 2000 (9925 daily values). It is seen from Fig.1 that the greatest variations are observed in the secular change and Forbush-decreases. 27-day variations are also of noticeable value. The secular and 27-day variations can be excluded by filtration.

Since the synodic period of Jupiter is 399 days then GCR variations should be forthcoming which is associated with the change of Jupiter position relative to the Earth for the interval of periods more than 27 days (we consider more than 54 days) and less than ≈ 600 days. Fig.1 (at the bottom) shows the filtered GCR intensity values in the interval of periods of 54-600 days from which the seasonal variations have been subtracted. As a result, this curve is 399-day variations and a white noise.

The lower graph (by scale) is shifted relative to the upper graph by 1048 in order to present them as one Figure. The vertical lines in Fig.1 are 399 days. The opposition dates of the Earth and the Jupiter are strongly in the middle between these lines. As seen from Fig.1, in the middle of 399-day separations (nearer to the left edge) the GCR intensity increase is observed (see Fig.1, at the bottom), in 17 of 24 cases (more than 70%), i.e. the effect of GCR intensity increase near opposition moments of Jupiter and the Earth is manifested almost in each event.

Data, treated in such a way, are summarized using the superposed epoch technique near the opposition points (see Fig.2b). As seen from this Figure (in the bottom), in fact there exists the effect of influence of the Jupiter position on the GCR intensity in the vicinity of the Earth.

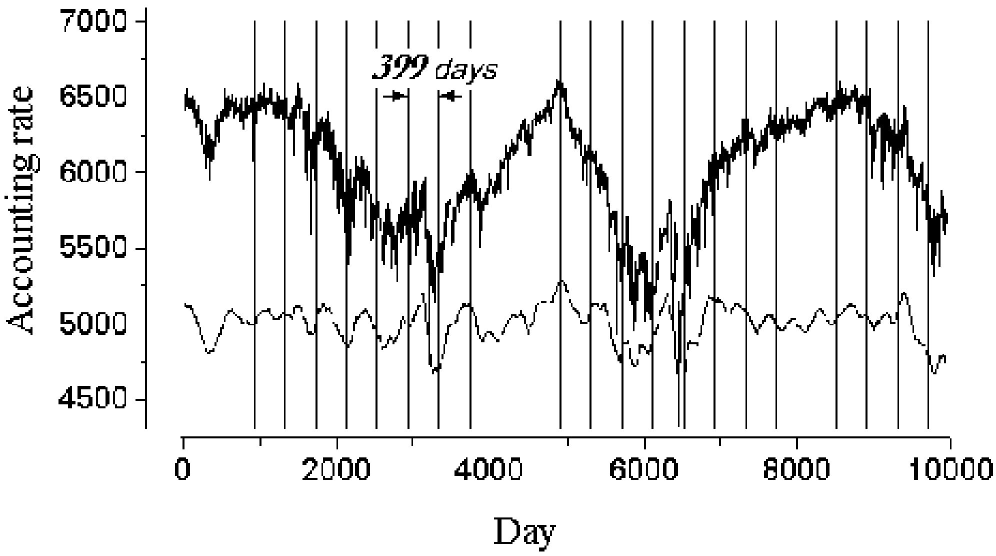

Fig.1 Initial and smoothed neutron monitor data at Oulu station from October 30, 1973 to December 31, 2000

From Fig.2b it follows that there is no pronounced maximum, and there are sloping plateaus with boundaries of –130 and +60 days from the opposition line. A sector (-118°÷+55°) near the opposition corresponds to these values. The amplitude of this effect is found to be the significant value, ~60 units of counts of the neutron monitor at Oulu station (the average value apparatus count is 6048). It corresponds to ~1% of the average count. This value in absolute magnitude is comparable to the small Forbush-decreases. Therefore, the represented variation does not refer to an insignificant class.

Discussion

A possible reason of the discovered GCR effect and the correlation with the Jovian electrons are associated with their appearance in interplanetary space in the following way.

According to [3, 4], the greatest electron concentration near the Earth is registered during its location in an IMF sector with magnetic field lines connecting the Sun with Jupiter (scheme in Fig.2a). By data of [1, 2], the background energy density of these particles is $\sim 10^{-16}$erg·cm^{-3}. The Jovian electrons undergo large fluctuations which can be 10-1000 times greater than background electrons and are of the duration of 1-10 days.

During the synodic period these fluctuations are repeatedly observed (more than ~10 times). The electron energy density inside the Jovian sector can be 10^{-15}-10^{-12} erg·cm^{-3}, that is 10^{-1}-10^{-2} of the IMF energy density. Such variations of density are quite sufficient in order to produce changes of the IMF module and GCR intensity.

Based on cyclic GCR and IMF variations from [5] taking into account the 1:4 sensitivity of particle density to magnetic field changes, we obtain that the detected 1% variation is provided by the 4% variation in the IMF. A typical value of the field of 6γ is to be decreased in the Jovian sector by 0,24γ. This estimation correlates well with the IMF change (upper curve in Fig.2b) obtained after the treatment of King catalogue data.

Thus, according to the above uniform technique, it is not accidentally that the treatment results of IMF observations, energetic electrons and GCR (Fig.2b) are of the close correlation for the distributions in the Jovian sector. The possibility of their relation confirms the physical peculiarity of that sector in the interplanetary space.

In Fig.2a the sector of 120° angular values near the Sun is shown by dashed spiral lines. Here S, E and J correspond to the position of the Sun, the Earth and the Jupiter, respectively. U is the movement direction of the Jupiter relative to the coordinate system with the stationary Sun-Earth line. The lines 1 and 2 are the positions of planets in the opposition and Jupiter at the IMF field line during the maximum ground effect.

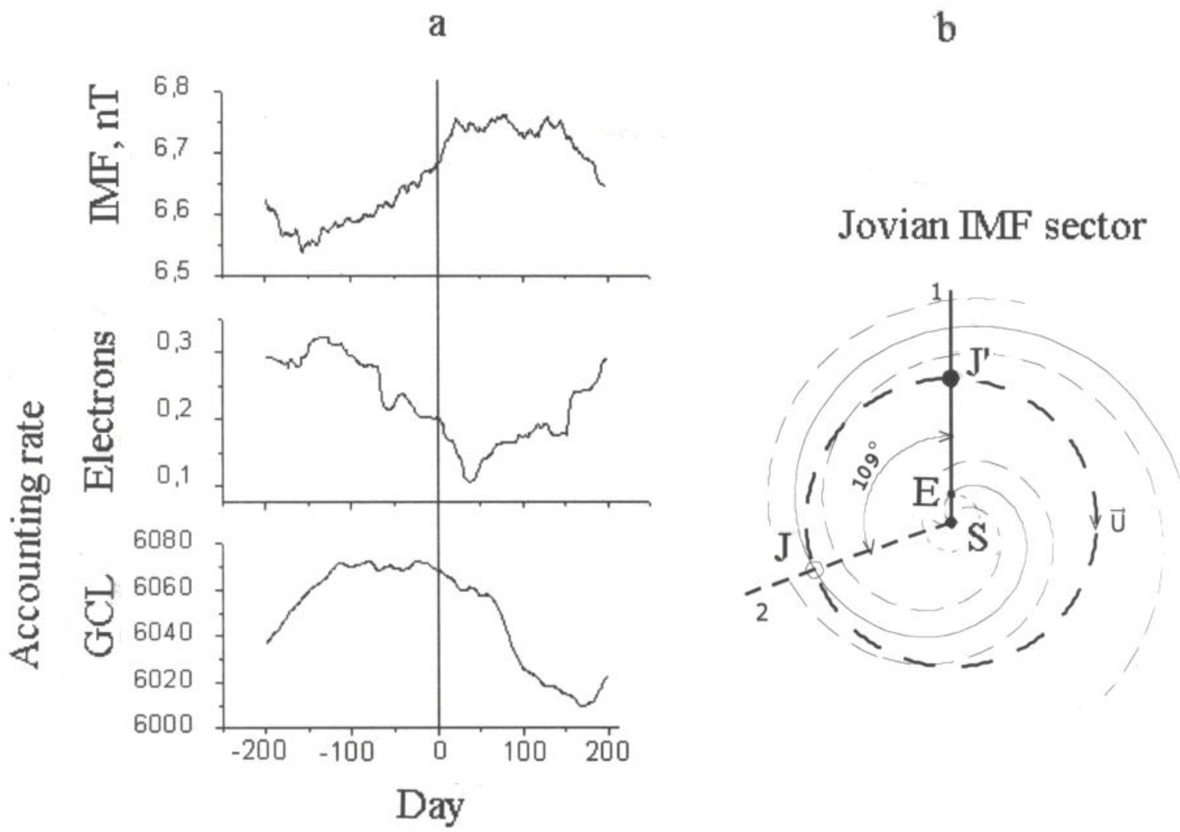

Fig.2. The variations of IMF module, MeV electron density and GCR intensity (b) in the Jovian sector (a).

Summary

The influence of the Jupiter on galactic cosmic rays and the interplanetary magnetic field has been found. During several solar activity cycles there are the regular variations in the GCR intensity and IMF of amplitudes 1% and 4%, respectively, at the time intervals of 399 days equal to the Jupiter synodic period.

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