Impact of Interplanetary Parameters on Cosmic Rays 27-Day Variation

Rajesh Kumar Mishra[1] and Rekha Agarwal[2]

[2] Information Technology Cell, ICFRE-Tropical Forest Research Institute, P.O.: RFRC, Mandla Road, Jabalpur (M.P.) 482 021, India

[1]Department of Physics, Govt. Science College, Jabalpur (M.P.) 482 001, India

The observed modulation of galactic cosmic ray intensity on time and spatial scales contains information regarding their transport in the heliosphere. We used the data of cosmic ray neutron monitor as well as interplanetary parameters to identify the correlation between their 27-day variations. The 27-day variation of cosmic ray intensity is found to linearly correlated with the interplanetary magnetic field strength (B), the north south component (Bz) of the interplanetary magnetic field vector and the product of the solar wind speed (V) times B (V x B). The cross correlation function of the 27-day cosmic ray variation versus the solar wind speed shows a negative correlation. However, the 27-day variation of cosmic rays is correlated with the variation in both the x- and y- components of interplanetary magnetic field.

Keywords: Sun, interplanetary magnetic field, cosmic ray, anisotropy

Introduction

The Sun, like most other astronomical objects rotates on its axis. Unlike Earth and other solid objects, the entire Sun does not rotate at the same rate. Because the Sun is not solid, but is instead a massive sphere of gas and plasma, different parts of the Sun (depending on the heliolatitudes) rotate at different rates it is called differential rotation. The equator and near equato- rial regions of the Sun rotate on its axis with the period of about 25–26 days, called the Sun’s sidereal period of rotation. For the observer on the Earth this periodicity equals 27–28 days due to the orbital motion of the Earth, called the Sun’s sinusoidal period of rotation. At its poles regions the Sun rotates at rate of about 36 days. The Sun is characterized by solar activity and solar wind (dynamical extension of solar corona) changing in time and having the asymmetrical distributions with the helio-longitudes in general.

Owing to the rotation of the Sun there are observed the periodicity of 25–26 days (sidereal period) among the large range of the quasi-periodic changes of different parameters of solar activity and solar wind as viewed from the arbitrary point of the interplanetary space; the same periodicity as viewed from the Earth equals 27–28 days (sinodial period). It is accepted that the periodicities of solar and geomagnetic activities, solar wind, galactic cosmic rays and other parameters characterizing the solar–terrestrial relationships connected with the Sun’s rotation are called the 27-day variations, instead this periodicity can be slightly different. The changes of amplitudes and range of the 27-day periodicities of different parameters of solar activity and solar wind occur on the background of two long period variations of solar activity: (1) the largest and powerful 11-year solar cycle (sunspot cycle), and (2) the relatively weakly pronounced 22-year solar magnetic cycle. The 11-year cycle (from one minimum to another minimum epoch) shows temporal changes of the level of solar activity (sunspot numbers in general), while the 22-year solar magnetic cycle is associated with the reversal of the Sun's global magnetic field taking place in the maxima epoch of solar activity.

Thus, the 22-year magnetic cycle of the Sun consists of two different polarity periods (from one maximum to another maximum epoch), each lasting 11-years. When the global magnetic field lines are directed outward from the north hemisphere of the Sun and are directed backward to south hemisphere, this 11 year part of the 22-year solar magnetic cycle is called the positive ($A > 0$) magnetic polarity period, while in vice versa case, it is called the negative ($A < 0$) magnetic polarity period of the Sun. Investigation of the 27-day variations of different parameters of solar and geomagnetic activity, solar wind and galactic cosmic rays (GCR) is the fundamental problem in the physics of the heliosphere, solar–terrestrial relationships, magnetosphere and atmosphere of the Earth, and especially in the physics of the space weather [1]. In general lots of papers are devoted to the problem of the 27-day variations of the GCR intensity and anisotropy e.g., [2–5]; a dependence of the 27-day variation of the GCR intensity on the polarity of Sun's global magnetic field is studied in [6–9]. At the same time a relation of the 27-day variation of the GCR anisotropy on the polarity of the Sun's global magnetic field, and on the current sheet's tilt angles are studied in [9–11].

Data and Analysis

We used the hourly averaged cosmic ray counts observed with different neutron monitor. The amplitude of the 27-day variation has been calculated for each detector for every solar rotation during the time interval 1964-2006. We also used hourly avarage values of interplanetary magnetic field and plasma data collected by variety of spacecraft near 1 AU during the same period in order to study their effect upon the 27 day cosmic ray variation. The 27 day averages of each solar rotation have been calculated for interplanetray magnetic field magnitude B, its components in the geocentric solar ecliptic coordinates (Bx, By, Bz), solar wind speed V and their product V x B.

Results and Discussion

The plots for smoothed (13 point averages) of the 27-day averages of of cosmic ray neutron monitor intensity for Moscow and Kiel neutron monitor, IMF magnitude, the IMF components (Bx, By, Bz), solar wind speed (V) and VB is shown in Fig 1-8.

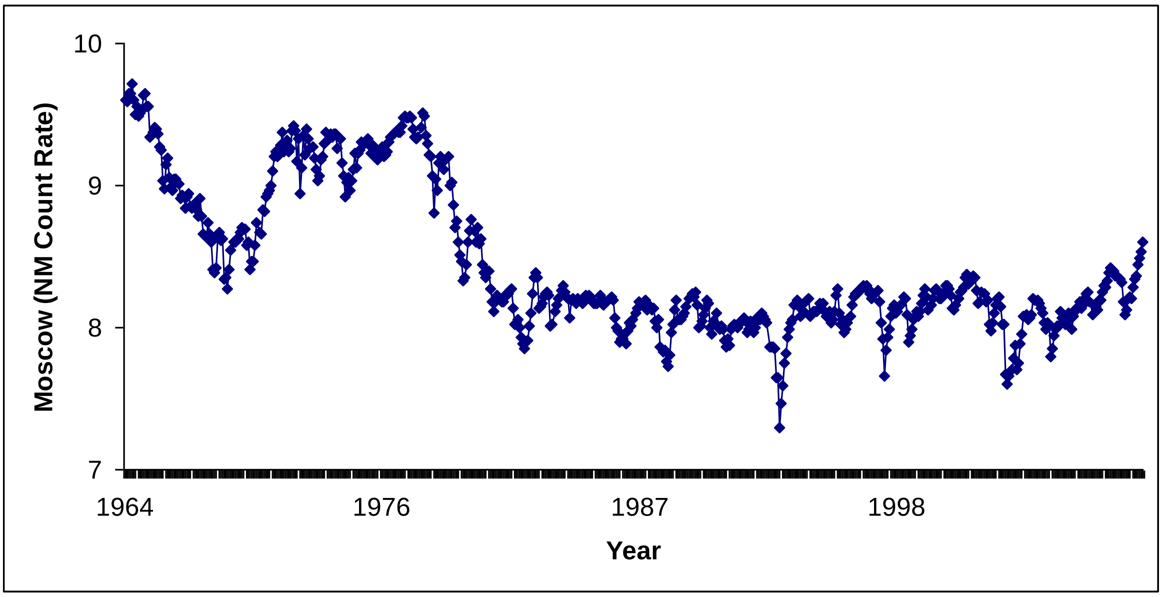

Fig.1: 27 day average of cosmic ray NM count rate for Moscow.

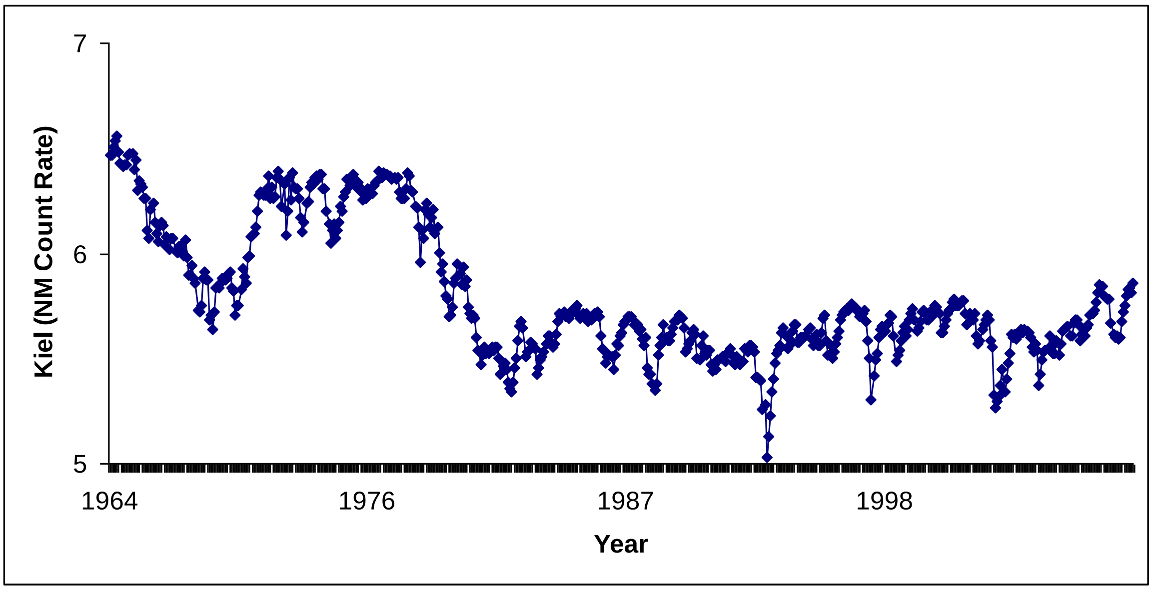

Fig.2: 27 day average of cosmic ray NM count rate for Kiel.

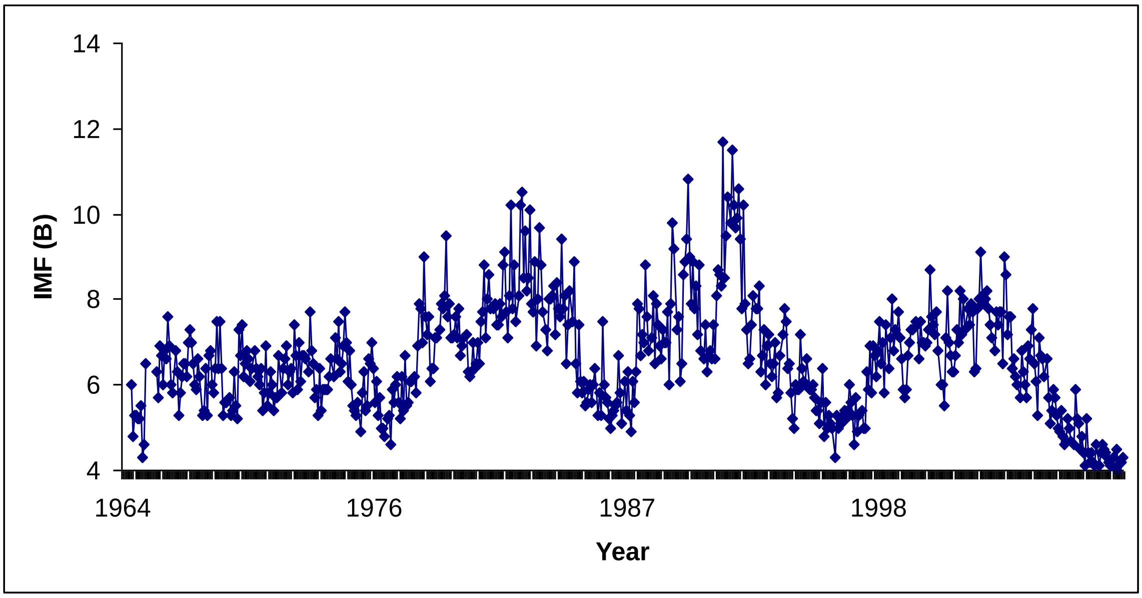

Fig.3 27 day average of IMF (B).

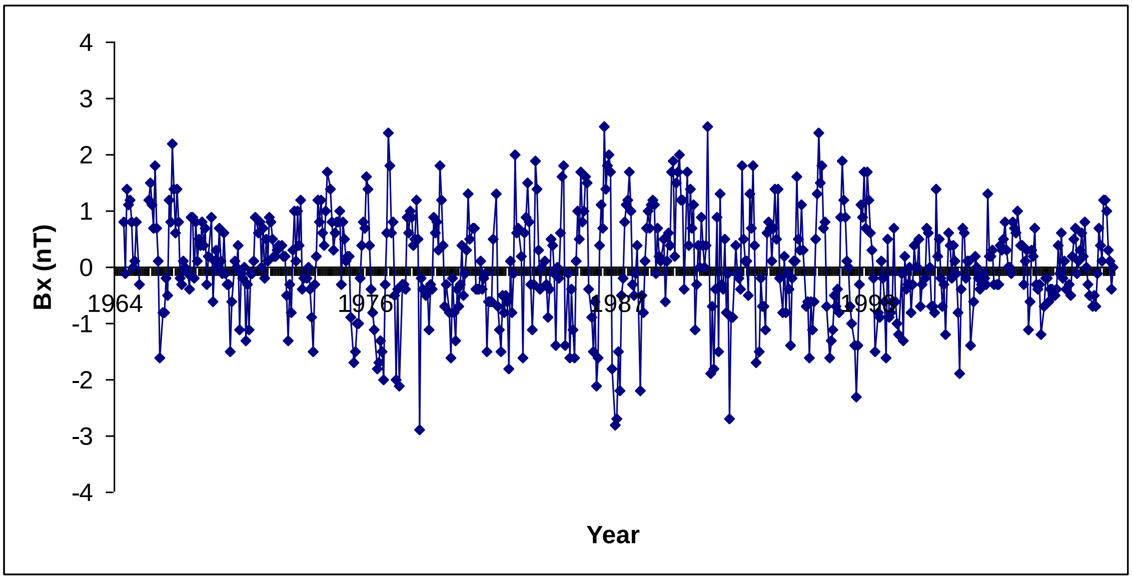

Fig.4: 27 day average of Bx

Is is clearly visible from these plots that cosmic ray intensity exhibits an 11-year solar cycle variation with minima occurring near solar activity minimum and and maxima occurring at solar activity maximum. The interplanetary magnetic field magnitude B and the product VB displays separate solar cycle variation. Their values track the variation in the 27-day cosmic ray intensity.

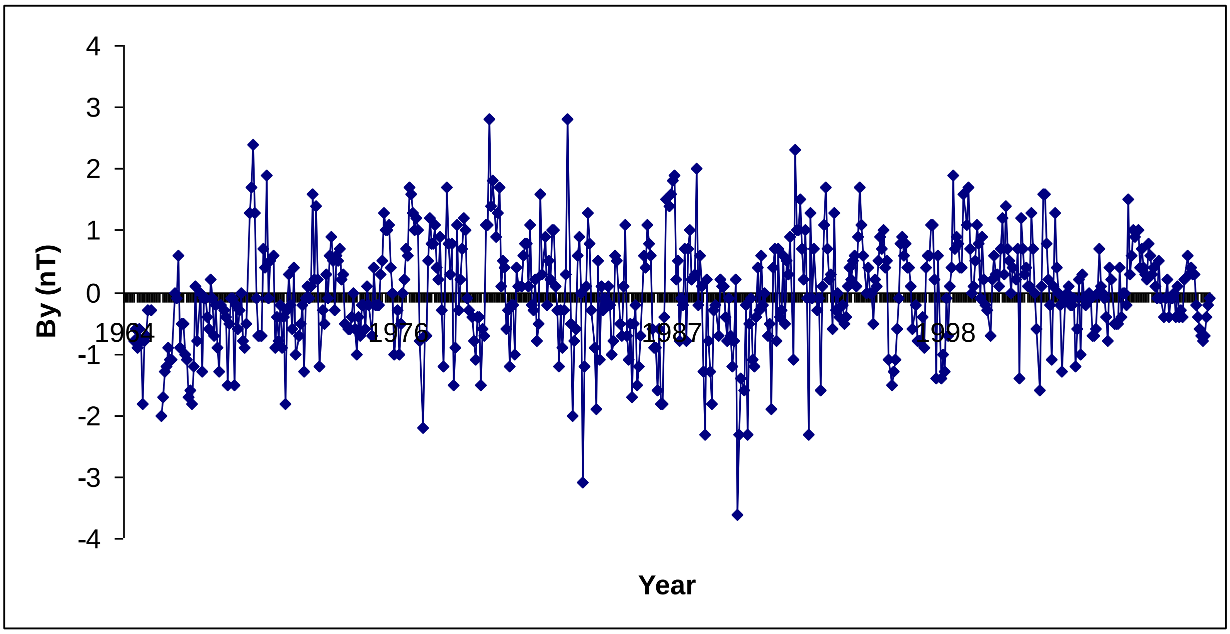

Fig.5: 27 day average of By

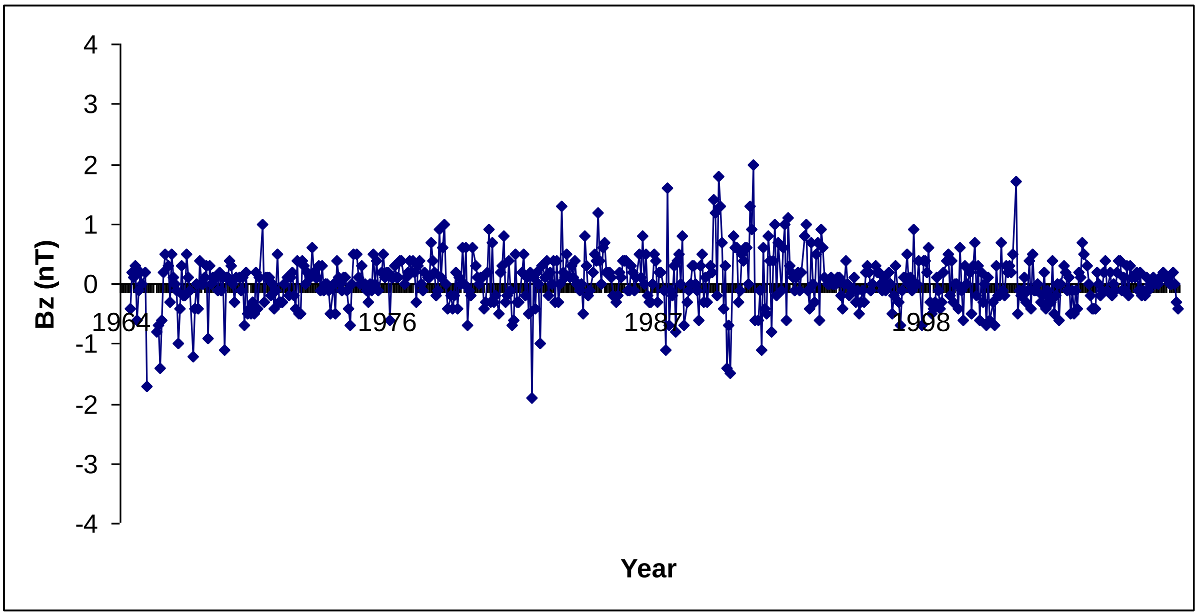

Fig.6: 27 day average of Bz

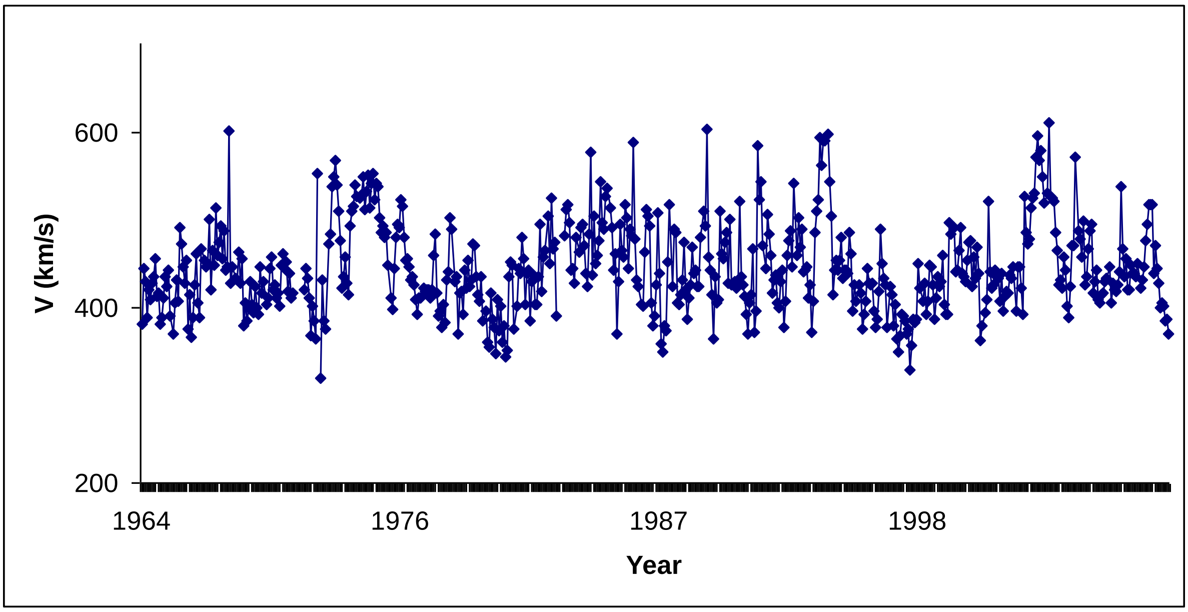

Fig.7: 27 day average solar wind speed

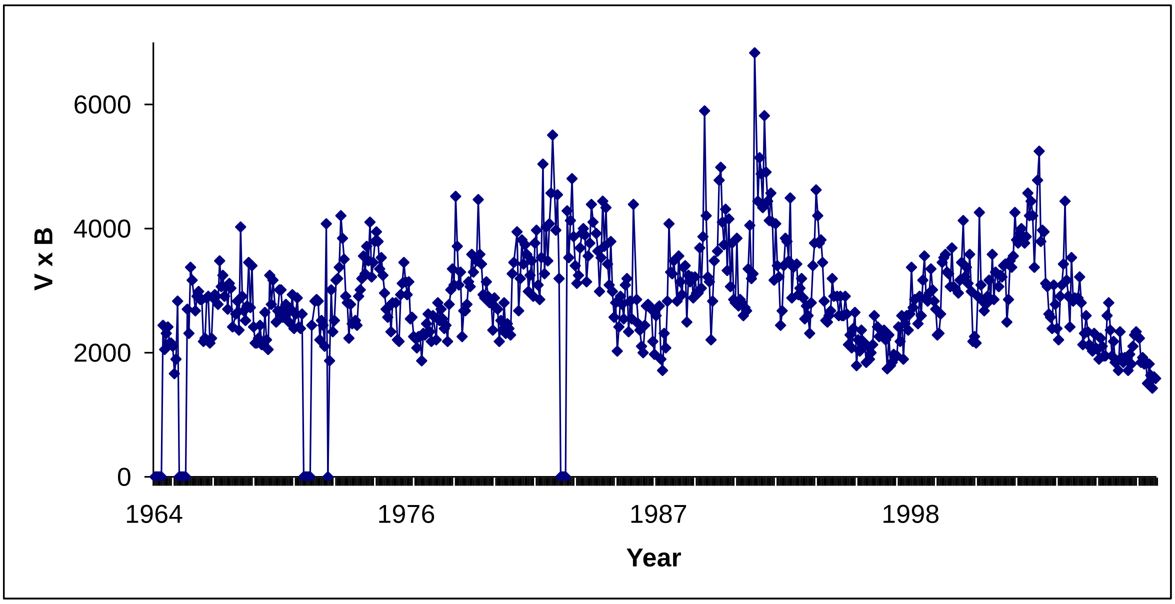

Fig.8: 27 day average of product VB

The values of B and VB are enhanced right after solar activity maximum in 1979and 1989. However the cosmic ray intensity is found to enhanced during 1971-77 at both the neutron monitors.

The Bz component of IMF is also related to to the variation variation in cosmic ray intensity, it reaches the highest value right after solar activity maximum 1991. The other two components (By and Bz) reach their highest values during solar activity minimum.

We have also studied the correlation between the cosmic ray 27-day variation and the IMF and plasma parameters. We plot the cross correlation function (plots not shown here) for both the neutron monitoring stations. We observed that 27-day variation of cosmic ray intensity is linearly correlated with IMF strength with correlation coefficient (r = 0.71), the producr VB (r = 0.63) and the Bz component of IMF with r = 0.49.

We also observe a negative correlation between cosmic ray variation and the solar wind speed with r = 0.72. The other two components (Bx and By) of IMF lags with 5 to 3 years respectively.

Conclusion

In the present study we examined that the effect of the interplanetary parameters upon the 27-day cosmic ray variation during 1964- 2008.The 27-day variation of cosmic ray intensity is found to linearly correlated with the interplanetary magnetic field strength (B), the north south component (Bz) of the interplanetary magnetic field vector and the product of the solar wind speed (V) times B (V x B). The cross correlation function of the 27-day cosmic ray variation versus the solar wind speed shows a negative correlation. However, the 27-day variation of cosmic rays is correlated with the variation in both the x- and y- components of interplanetary magnetic field.

Acknowledgements

The authors are indebted to various experimental groups, in particular, Prof. Margret D. Wilson, Prof. K. Nagashima, Miss. Aoi Inoue and Prof. J. H. King for providing the data.

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