THE RELATION OF THE DIURNAL VARIATION TO THE SOLAR ROTATION AND TO THE INTERPLANETARY SECTOR BOUNDARIES

H. Mavromichalaki
Nuclear Physics Lab., Cosmic Ray Group,
University of Athens, Solonos str. 104,
Athens 144, Greece

ABSTRACT

Near the past solar activity minimum a recurrency of the enhanced diurnal variation of Cosmic-ray (C.R.) intensity with period of 27-days has been observed. Particularly, data at Deep River and Athens neutron monitor stations show over 16 solar rotations i.e. from 1 Jan. 1973 to 10 March 1974, two series of 27-days recurrences of the diurnal variation characterized by large amplitudes.

An examination of the direction and the amplitude of the diurnal variation on a 27-day period shows a dependence upon the interplanetary magnetic field (IMF) sector polarity. An enhanced mean amplitude of the diurnal anisotropy correlates with positively directed sectors, while the amplitude of this anisotropy seems to decrease during sector boundaries.

1.- Introduction

The existence of a 27-day recurrence tendency in cosmic-ray intensity has been pointed out by many authors. At first Simpson et al (1952) observing the neutron intensity at Climax in 1951 found the existence of a 27-day periodicity in the intensity from the direct measurements. Later Mori et al (1964) indicated that also the diurnal variation of cosmic-rays reveals a strong 27-day recurrence and gives a strong support for the persistence of the streaming pattern of solar corpuscles in the interplanetary space. Many studies of diurnal vectors on individual days have indicated the presence of a quasi-persistence tendency corresponding to the solar rotation period (Kodama, 1967; Pomerantz and Duggal, 1971; Shatashvilli and Penkratov, 1971; Mori et al, 1975). Recently several workers have concluded that each of the three classical components of the diurnal anisotropy (azimuthal, convective and diffusive) displays a contribution from a 27-day wave (Alaniya et al, 1977).

In the present report recurrence phenomena showing large amplitude in the solar diurnal variation are studied observed by neutron monitor stations over 16 solar rotations at the declining phase of the last solar activity cycle. An analysis of the direction and amplitude of the diurnal anisotropy on a 27-day period shows a dependence upon the IMF sector polarity. Our results are compared with those from spacecraft magnetometers and also with those inferred from ground based magnetograms. It is interesting to note that the daily association of the 27-day diurnal

anisotropy in this period with the IMF direction shows the same pattern with that of the corresponding period of the 19th solar activity cycle.

2.- Data analysis

Neutron monitor data of the Deep River (1.02 GV) and Athens (8.72 GV) stations over the period January 1973 - March 1974 for about 430 consecutive common days were used. The normalized mean daily intensity for the two above referrenced stations over the year 1973 is shown in Figure 1. It is notable the good correlation between the intensities of the two stations. The mean intensity of the time period January 1973 to March 1974 was used for normalization of the pressure-corrected hourly values of cosmic-ray intensity for each station. Also these values were corrected for long-term variations and geomagnetic effects and the amplitude and the direction of the diurnal vectors were obtained for each day.

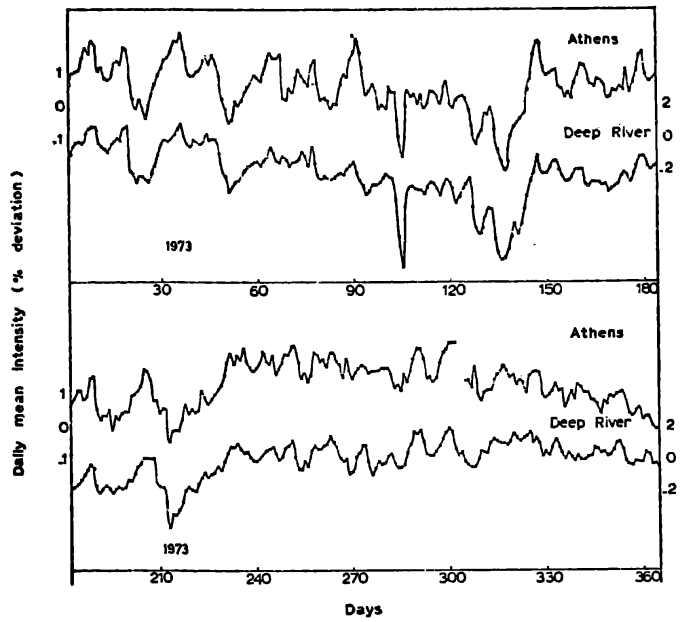

Fig. 1. Normalized mean daily intensity of the Deep River and Athens stations for the year 1973.

In order to examine the correlation of the 27-day daily variation with the sector structure of the IMF, daily values of the IMF polarity at the vicinity of the Earth were used covering the time period 1973-1974. Polarity determinations of the IMF (towards and away the Sun) have been carried out on a daily basis by utilizing the magnetic field data obtained with spacecrafts (Wilcox and Colburn, 1972; Fairfield and Ness, 1974). Also we have used polarities inferred from the geomagnetic field observations given by Svalgaard (1975). These daily values of the IMF polarity are calculated with overlapping measurements of the ground-based magnetograms and in situ measurements from spacecrafts (Mori and Nagashima, 1979).

3.- 27-day diurnal variation and IMF sector structure.

Superposed 27-day variation of the hourly mean intensity over 16 solar rotations (1907-1922) for the Athens station is shown in Figure 2. The rotation No 1907 begins from the first of January 1973. A significant feature of the recurrent daily variations is clearly revealed by two series of large amplitudes of diurnal variations, the one during the solar rotations 1912 through 1915 and the second during the rotations 1916 to 1919.

Mori et al (1975) has observed also remarkable 27-day recurrences of enhanced diurnal variations in the cosmic ray intensity during rotation no 1921 through 1938, which are associated with the sector structure of the IMF.

Further examinations are made to show the responses of the 27-day recurrences of the daily variations to the IMF and the sector boundaries. Figure 3 shows the summation dial of the averaged 27-day variation of the diurnal vectors during solar rotations 1907 through 1922 for the two stations. Examined in detail the mean diurnal phase of Deep River station in each day of the 27-day interval

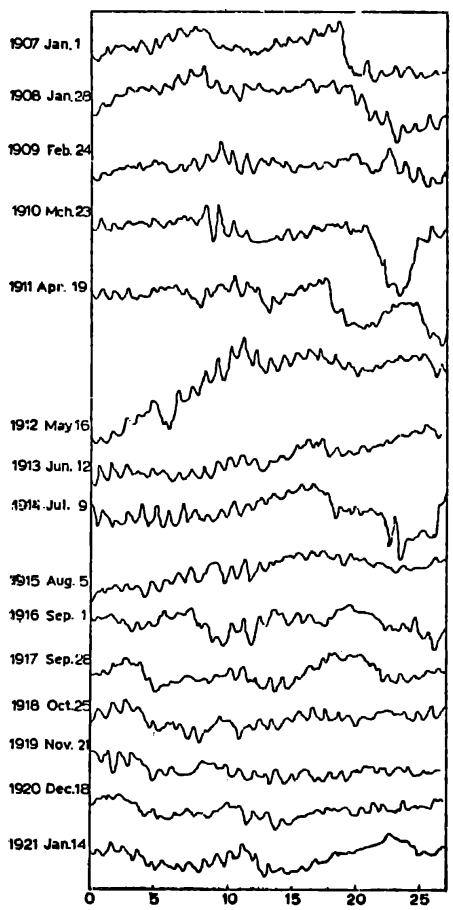

Fig. 3. 27-day variation of the diurnal vectors.

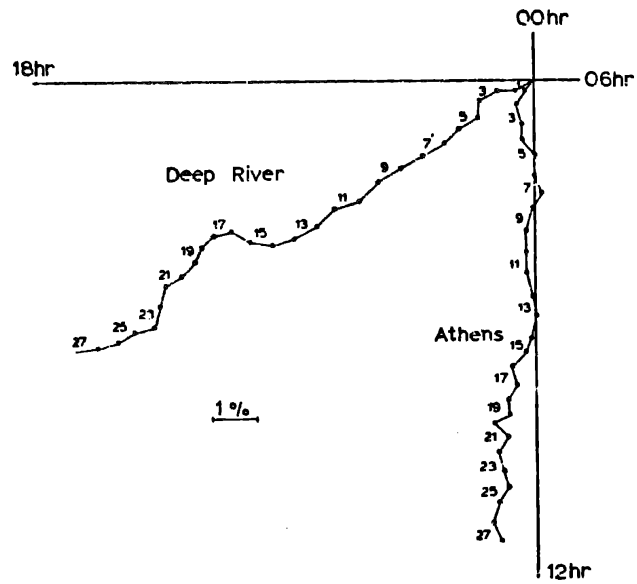

Fig. 2. Hourly values of the cosmic-ray intensity at the Athens station for the solar rotations 1907-1921.

we observed four epochs which are probably corresponded to the sector structure of the IMF. The first epoch situates at around 1st to 4th day, the second at 5th to 15th day, the third at 16th to 21st day and the fourth at 22nd to 27th day (Wilcox and Ness, 1965). It is interest to note that the mean diurnal amplitude of the first and third epoch is appeared to be smaller than that of the other two epochs. Mori et al (1975) and Mavromichalaki (1980) have shown that an enhanced amplitude of the diurnal anisotropy correlates with positively (away) directed sectors.

Indeed comparing our results with the IMF polarity data it is resulted that the first and the third epochs are associated in average with "toward" sectors and the second and the fourth epochs with "away" sectors with some uncertainties in the sector boundaries.

The amplitude of the diurnal vectors seems to be stable in the center of each region and to decrease during sector boundaries. Ryder and Hatton (1968) used Deep River C.R. data for the period Dec. 1963 - Feb. 1964 assumed that a radial streaming exists such that there is a net motion of cosmic-ray particles away from the Sun at

the leading edge of the sector where the diurnal amplitude increase and towards it at the trailing edge of it. Later Bussoletti and Iucci (1970) used also Deep River data in 1965 and 1966 years in which the solar activity is rising, pointed out that there is no steady streaming of C.R. along the lines of IMF at the edges of the magnetic sectors. These discontinuities seen in the amplitude of the diurnal wave at the sector's edge can be explained by diffusion phenomena of C.R. and therefore transverse fluxes of particles which can occur through the lines of IMF.

4.- Discussion and conclusions

In the declining phase of the 20th solar cycle remarkable 27-day recurrences of cosmic-ray diurnal variations characterized by large amplitudes have been observed. It is concluded that the diurnal anisotropy in a 27-day interval might be in close relations with the sector structure of the IMF. It is notable that the morphology of the diurnal variation during this solar cycle connected with the evolving magnetic field in interplanetary space is the same with that of the 19th solar cycle.

The close correlation observed between the C.R. diurnal anisotropy and the IMF follows from the mechanism $(B \times \nabla n)$ where B denotes the IMF and ∇n stands for the C.R. density gradient which is positive in the outer region from the Sun (Swinson, 1969; 1971). Recently Duggal et al (1979) have shown that the particle gradient drift $(B \times \nabla n)$ may play the dominant role in producing the azimuthal 27-day wave. Also Owens et al (1980) have proposed that the component of the corotating C.R. gradient in the ecliptic plane gives rise to a north-south anisotropy and the component of the corotating C.R. gradient perpendicular to the ecliptic gives rise to an anisotropy in the ecliptic seen in the diurnal variation.

Summarizing in this report we propose a method for inferring the sector polarity on a 27-day basis. The method is dependent on the variation of the diurnal anisotropy characteristics in the sector boundaries and in the fact that the mean diurnal anisotropy is larger in the away sectors.

5.- Acknowledgements: Thanks are due to the cosmic-ray Colleaques of Deep River (Canada) for the support with their neutron monitor data. Also thanks are due to Mrs E. Kotridou and Mrs N. Kalyvioti of the Nuclear Physics Lab. of Athens University for technical assistance.

References

Alaniya, M.V. et al, 1977, Proc. 15th Int. Conf. Cosmic Rays 3, 256
Bussoletti, E. and Iucci, N. 1970, Space Plasma Lab.,Univ.of Rome,LPS-70-12
Duggal, S.P. et al, 1979, J. Geophys. Res. 84, 6653
Fairfield, D.H. and Ness, N.F., 1974, J. Geophys. Res. 79, 5089
Kodama, M. 1967, Can. J. Phys. 45, 2733
Mavromichalaki, H., 1980, Astrophys. Space Sci. 68, 137
Mori, S. et al, 1964, Rep. Ionos. Space Res., Japan 18, 275
Mori, S. et al, 1975, Proc. 14th Int. Conf. Cosmic Rays 4, 1463
Mori, S. and Nagashima, K., 1979, Planet. Space Sci. 27, 39
Owens, A.J. et al, 1980, Astrophys. J. 236, 1012
Pomerantz, M.A. and Duggal, S.P., 1971, Space Sci. Rev. 12, 75
Ryder, P. and Hatton, C.J., 1968, Can. J. Phys. 46, S999
Shatashvili, L.K. and Penkratov, A.K., 1971,Proc.12th Int.Conf.Cos.Rays 5,1925
Simpson, J.A. et al, 1952, Phys. Rev. 85, 336
Svalgaard, L., 1975, SUIPR, Rep. No 629 Stanford Univ., Stanford U.S.A.
Swinson, D.B., 1969, J. Geophys. Res. 74, 5591
Swinson, D.B., 1971, J. Geophys. Res. 76, 4217
Wilcox, J.M. and Ness, N.F.,1965, J. Geophys. Res. 70, 5793
Wilcox, J.M. and Colburn, D.S., 1972, J. Geophys. Res. 77, 751