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COSMIC RAY SIDEREAL DIURNAL VARIATION OF GALACTIC ORIGIN OBSERVED BY NEUTRON MONITORS

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ABSTRACT

Cosmic ray sidereal diurnal variations observed by neutron monitors are analyzed for the period 1961-1978, by adding 134 station-years data to the previous paper (Nagashima et al., 1983). Also the dependence of the sidereal variations on Sun's polar magnetic field polarity is examined for two periods; the period of negative polarity in the northern region, 1961-1969 and the period of positive polarity, 1970-1978. It is obtained that for the former period, the amplitude A=0.0203±0.0020% and the phase ϕ=6.1±0.4 h LST and for the latter period, A=0.0207± 0.0020% and ϕ=8.6±0.4 h LST, respectively.

1. Introduction

In the previous paper (Nagashima et al., 1983; hereafter referred to as Paper I), we presented the analyzed results of the cosmic ray sidereal diurnal variations observed by neutron monitors, by using 620 station-years data from a worldwide network for the period 1958-1979. It was shown that the sidereal variations averaged over the above period for the Northern Hemisphere are significantly different from the corresponding variations in the Southern Hemisphere. Both difference and average between two hemispheres were analyzed. The results were interpreted on a theoretical basis of the three-dimensional anisotropy and its annual modulation model (Nagashima and Ueno, 1971; Nagashima et al., 1972a, b) that the former (difference) can be identified with the spurious sidereal diurnal variation arising from annual modulation of 2nd order anisotropy in space responsible for the solar semi-diurnal variation. And the latter could be regarded as being due to uni-directional galactic anisotropy (see detail, Paper I). In the present work, we analyze the neutron monitor data by adding 134 station-years to the previous ones, in the same manner as in Paper I for the period 1961-1978.

Cini-Castagnoli et al. (1975) pointed out the association of the sidereal diurnal variations at deep underground stations in the northern hemisphere with changing Sun's polar magnetic field polarity. For the period of negative polarity in the northern region, the observed sidereal vectors were around 20 h LST, while for the period of positive polarity, the vectors were observed at $\sim$3 h LST. Very recently, Nagashima et al. (1984) pursued this problem in detail, and demonstrated that Cini-Castagnoli et al.'s finding is not real, but virtual even for the deep underground observations (rigidity region $\lesssim$500 GV) due to modulation with the spurious sidereal diurnal variation of solar origin, based on the three-dimensional anisotropy and its annual modulation. In the present analysis, we examine the dependence of the sidereal variations on Sun's polar magnetic field polarity for two periods; for the negative period in the northern region (1961-1969) and for the positive period (1970-1978).

2.Analysis

The data used in the present analysis are those of neutron monitors from a worldwide network for the period 1961-1978. The total amount of data in the Northern and Southern Hemispheres are respectively 544 and 142 station-years by adding 134 station-years to them. The added data are mostly concentrated on 1974 to 1977.

The analysis is made in the same manner as in Paper I. The top panel of Fig. 1 show the first harmonics of the observed daily variations for Northen (N) and Southern (S) Hemispheres and are; for the (N), the amplitude A=0.0123±0.0019% and the phase ϕ=9.0±0.3 h LST and for the (S), A=0.0286±0.0037% and ϕ=6.7±0.4 h LST, respectively.

Fig. 1 shows their difference first harmonics (N-S)/2 and average (N+S)/2 for two Hemispheres; for (N-S)/2, A=0.0099±0.0014% and ϕ=17.3±0.5 h LST and for (N+S)/2 A=0.0196±0.0014% and ϕ=7.4±0.3 h LST, respectively. For comparision, the corresponding expected variations are shown for flat rigidity spectrum with an upper cut-off rigidity of 300 GV. The present results reconfirm the previous results and support the conclusion in Paper I.

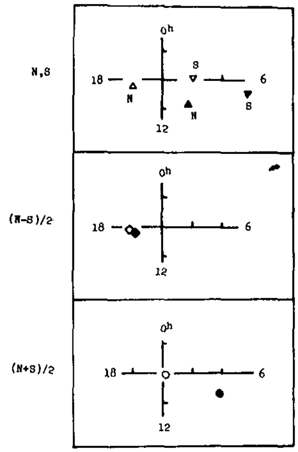

Fig. 1 The first haronic of observed sidereal daily variations for the Northern (N) and Southern (S) Hemispheres, together with their difference (N-S)/2 and their average (N+S)/2 with solid marks. The corresponding expected variations are also shown with open marks.

In order to examine the dependence of the sidereal diurnal variation on Sun's polar magnetic field polarity in neutron monitor rigidity region, we separate the variations into two groups according to Sun's polar field polarity; the negative period showing toward field polarity in the northern region (1961-1969) and the positive period showing away field polarity (1970-1978). The number of data used and their average cut-off rigidities are tabulated in Table 1. These are not necessarily balanced for both hemispheres, but we regard them almost conjugate with respect to the north-south. The sidereal diurnal variations of all the station-years for N

Table 1 Number of data and average cut-off rigidity.

	Negative period (1961-1969)		Positive period (1970-1978)	
	Station-years	Cut-off (GV)	Station-years	Cut-off (GV)
Northern Hemisphere	253	2.86	291	3.66
Southern Hemisphere	78	4.07	64	3.68

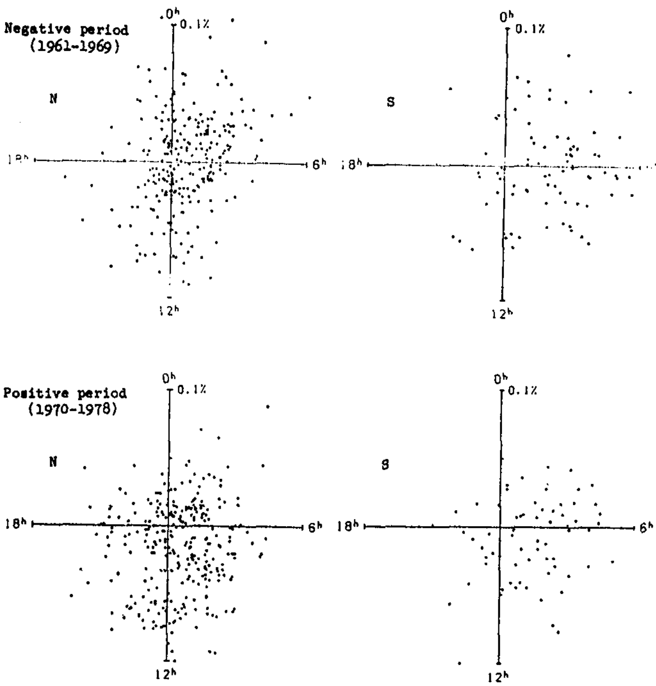

Fig. 2 Sidereal diurnal variations of all the station-years for N and S for two periods; negative (1961-1969) and positive (1970-1978) periods.

and S for two periods are shown in Fig. 2. In the figure, the distributions of variations of N are different from those of S for both periods

Fig. 3 shows the mean vectors for N and S for these two periods, N_1 and S_1 for the negative period (1961-1969) and N_2 and S_2 for the positive period (1970-1978), respectively. The numerical values; their averages and each dispersions are tabulated in Table 2. In the vectors with a notation (N+S)/2 expresses the variation common to both hemispheres of north-south symmetric type. This could be regarded as being due to uni-directional galactic anisotropy as has been discussed in Paper I, and is shown Fig. 4. It is obtained that for the negative period, the

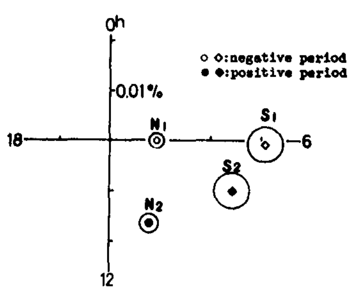

Fig. 3 Averaged sidereal diurnal variations for N and S for two periods; ○◇ with figure 1 for negative period (1961-1969) and ●◆ with figure 2 for positive period (1970-1978).

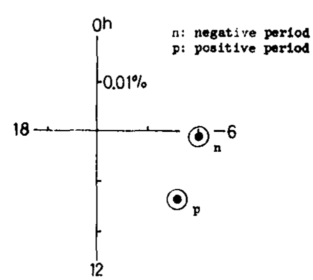

Fig. 4 Sidereal diurnal variations (N+S)/2 for two periods; negative (n) and positive (p) period.

	Negative period (1961-1969)		Positive period (1970-1978)	
	Amp.(%)×10^{-4}	Phase(h)	Amp.(%)×10^{-4}	Phase(h)
N	94 (16)	6.0 (0.6)	182 (19)	10.3 (0.4)
S	312 (36)	6.2 (0.4)	261 (36)	7.5 (0.5)
(N+S)/2	203 (20)	6.1 (0.4)	207 (20)	8.6 (0.4)

Table 2 Observed sidereal diurnal variations for N and S for two periods. Also (N+S)/2 is shown. Figures in the parentheses express the dispersions.

amplitude A=0.0203±0.0020% and the phase ϕ=6.1±0.4 h LST and for the positive period, A=0.0207±0.0020% and ϕ=8.6±0.4 h LST. It is noteworthy that the present averages are exceptionally significant from the statistical point of view.

3.Discussion and Conclusion

The present results of the sidereal diurnal variation, (N+S)/2, common to both hemispheres are statistically significant for two periods; the negative (1961-1969) and the positive (1970-1978) period of Sun's polar magnetic field as shown in Fig. 4. In these variations, the spurious sidereal variations may be eliminated by taking a long-term average. And also the spurious sidereal diurnal variation caused by annual modulation of the solar diurnal variation produced from a stationary anisotropy responsible for the solar semi-diurnal variation (Nagashima, 1984), can be eliminated due to its north-south asymmetric nature.

Also as shown in Fig. 4, the sidereal diurnal variations for these two periods are significantly different from each other (several times larger than the dispersion error). On the other hand, a recent work of Nagashima et al. (1984) demonstrated that the sidereal diurnal variations observed at deep underground stations in both hemispheres almost coincide with each other, after correcting for the annual modulation effect of the solar diurnal variation for the negative and positive period mentioned above. And they showed that these resultant variations are stationary throught the periods 1958-1983, regardless of Sun's polar magnetic field polarity reversal. The present result msy somewhat contradict their conclusion, which may be due to rather larger errors in underground data.

As far as these two periods and the neutron energy regions are concerned, a clear phase difference between two periods; negative and positive periods, was obtained. A further analysis is necessary to derive a definite conclusion.

4.Acknowledgements

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