Sidereal Anisotropies in the Median Rigidity Range 60-600GV in 1978-1983

H.Ueno, Z.Fujii, S.Mori*, S.Yasue* and K.Nagashima
Cosmic Ray Res. Lab., Nagoya Univ., Nagoya 464, Japan
*Depart. of Physics, Shinshu Univ., Matsumoto 390, Japan

1. Introduction

A great many observation has been made of the sidereal time variations of cosmic rays with various detectors in a wide range of rigidities from neutron monitors(effective primary rigidity 10^{10}V), surface and underground muon telescopes to small air shower arrays($10^{13} \sim 10^{14}$V), and much data have been accumlated to explore the nature of the galactic anisotropy, such as its origin and its propagation inside and outside the heliomagnetosphere.

In low rigidity region, the observed sidereal diurnal variations contain not only those of galactic origin but also those of solar and atmospheric origin. The variations of the latter origin are called the spurious sidereal variations, and almost all of them can be eliminated by taking the difference between the variations observed by two component telescopes pointing different directions (cf. Elliot and Dolbear, 1950). This elimination method, however, cannot be applied to the variation arising from the seasonal variation of solar anisotropy. A typical example for this can be seen in the spurious sidereal diurnal variation arising from the solar anisotropy of the 2nd order responsible for the solar semi-diurnal variation(Nagashima and Ueno, 1971).

In the present paper, the observed sidereal variations are corrected for the influence of this spurious variation by a method using the anti-sidereal diurnal variations produced from the same 2nd order anisotropy (Nagashima et al., 1983). It is demonstrated that the corrected variations are a resultant product of two constituents of galactic origin: one is north-south(N-S) symmetric and the other is N-S asymmetric.

2. Data Analysis and Discussions

In the present analysis, we use the data from surface(NAgoya) and underground(Misato and Sakashita) muon telescopes. Hereafter we abbreviate these stations to NAMS by picking up the top letter of the name of the stations. These data cover the rigidity range of 60 to 600GV, and the present work is concerned with 6-year averages of these data in the period of 1978-1983.

In Table 1, 6-year averages of the observed sidereal diurnal variations of NAMS are listed, together with those of the anti-sidereal diurnal variations and are shown in Fig.1 and Fig.2. Also listed in the table are some characteristics of the telescopes(Fujimoto et al., 1984). Errors of the amplitudes are derived from the dispersion of yearly vectors.

The spurious sidereal diurnal variations are produced by various noises such as the atmospheric effects and also transient cosmic ray intensity variations. In the present analysis, these noises can be eliminated statistically by taking 6-year averages and also by introducing the unknown vector common to all directional components at each station in the best fit calculation. The spurious sidereal diurnal variation is also produced from cosmic ray flow perpendicular to the solar equatorial plane. This variation is sector-structure dependent and is called Swinson-type(cf. Swinson, 1969). This variation could

Table 1 6-year averages of observed sidereal diurnal variations of NAMS for 1978-1983, together with those of associated anti-sidereal diurnal variations and also corrected variations for Nagashima's component (see text). Some characteristics of the telescopes are also shown. Errors of the amplitudes are derived from the dispersion of yearly vectors.

		Zenith & Azimuth		Geographic Direction		Median Rigidity	Counting Rate	Amplitude(%) & Phase(hr) of Harmonics of 6 Years Averages 1978-1983					
STATION	TELESCOPE	Z	A	λ	φ	P_{ME}(GV)	×10⁴/hr	Anti-Sidereal 1st		Sidereal 1st		Corrected Sidereal 1st	
NAGOYA 0mwe	V	0°	-	35°N	137°	60	276.0	.034±.008	20.8	.011±.008	16.1	.021±.011	4.4
	N	30°	0°	65°N	"	66	125.0	.037±.008	19.5	.018±.007	14.5	.018±.010	3.3
	E	"	90°	30°N	172°	67	120.0	.026±.008	19.7	.002±.008	3.8	.026±.009	3.2
	S	"	180°	5°N	137°	64	123.0	.014±.009	21.3	.009±.008	4.2	.022±.011	4.5
	W	"	270°	30°N	102°	63	126.0	.035±.007	22.3	.016±.007	18.7	.018±.011	5.0
MISATO 34mwe	V	0°	-	36°N	138°	145	28.0	.032±.007	21.9	.028±.007	19.0	.012±.008	0.9
	N	33°	39°	57°N	177°	155	10.7	.033±.007	19.5	.030±.007	15.8	.007±.009	21.9
	E	"	129°	12°N	164°	143	14.2	.012±.007	21.7	.018±.008	21.9	.018±.008	0.3
	S	"	219°	9°N	117°	155	10.7	.025±.005	23.6	.019±.007	23.9	.022±.008	4.6
	W	"	309°	51°N	95°	156	9.8	.037±.006	23.3	.025±.006	19.5	.012±.007	5.1
SAKASHITA 80mwe	V	0°	-	36°N	138°	331	39.0	.032±.004	23.0	.017±.004	22.9	.028±.004	4.2
	N	41°	346°	73°N	104°	401	6.2	.023±.004	22.6	.008±.004	17.6	.015±.005	6.4
	E	"	76°	35°N	188°	384	7.6	.021±.004	21.2	.021±.004	22.6	.029±.003	1.5
	S	"	166°	5°S	147°	387	6.7	.018±.004	1.3	.054±.004	2.6	.056±.005	3.8
	W	"	256°	18°N	96°	444	5.6	.019±.004	2.2	.040±.005	3.8	.045±.004	5.4
	NN	60°	346°	77°N	26°	595	2.4	.002±.004	6.4	.002±.004	13.2	.004±.006	13.5
	SS	"	166°	23°S	151°	540	2.7	.015±.005	8.1	.086±.005	2.6	.072±.006	2.4

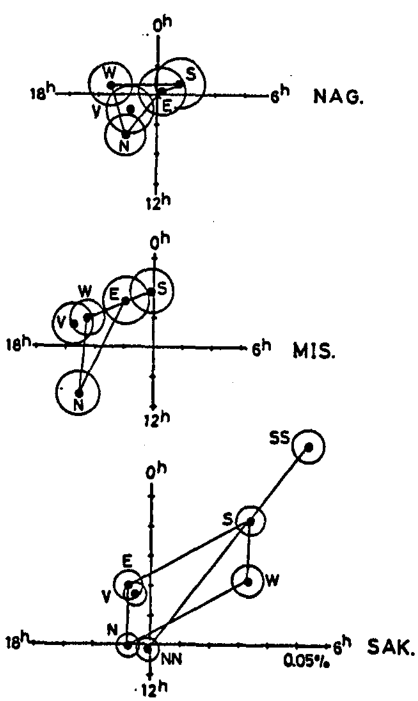

Fig.1 6-year averages of observed sidereal diurnal variations of NAMS telescopes at Nagoya (NAG), Misato (MIS) and Sakashita (SAK) for 1978-1983.

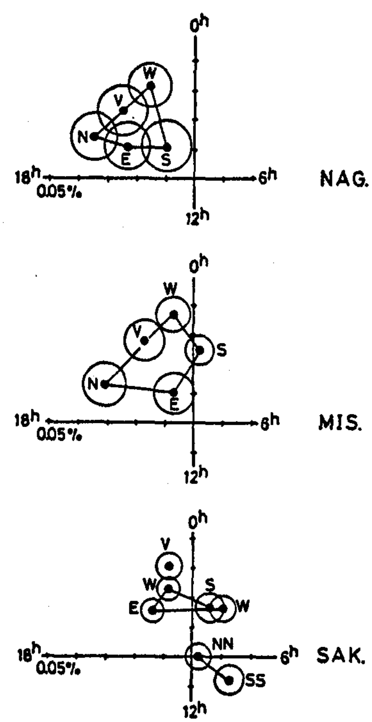

Fig.2 6-year averages of observed anti-sidereal diurnal variations of NAMS telescopes for 1978-1983.

be canceled by taking averages of the all period due to almost equal appearance of the toward and away sectors.

Spurious sidereal diurnal variation is also produced by a systematic annual variation of the solar diurnal variation arising from a solar diurnal variation caused by a stationary anisotropy responsible for the solar semi-diurnal variation(Nagashima and Ueno, 1971). According to the recent study(Nagashima et al., 1983), the spurious variation can be eliminated by multiplying the observed anti-sidereal diurnal variation by 0.947, rotating the vector counterclockwise by 68°, and subtracting it from the observed sidereal diurnal vector.

The corrected sidereal diurnal variations of NAMS are also listed in Table 1 and are shown in Fig.3. As is seen in the figure, the corrected sidereal diurnal variations at Sakashita station are statistically significant, while the variations at Misato and Nagoya stations are comparable with the corresponding dispersion errors. As the counting rates at Misato and Nagoya are large, the large errors are supposed to be caused by the scattering of year-to-year vectors mainly due to the insufficient correction for transient solar diurnal variations. On the other hand, the relative configuration of the vectors of each station seems to be reasonable from the standpoint of geometrical setting of the component telescopes. This implies that real errors may be smaller than the dispersion errors, and in this respect it is worthwhile examining the rigidity dependence of the corrected sidereal diurnal variations including those of the two stations.

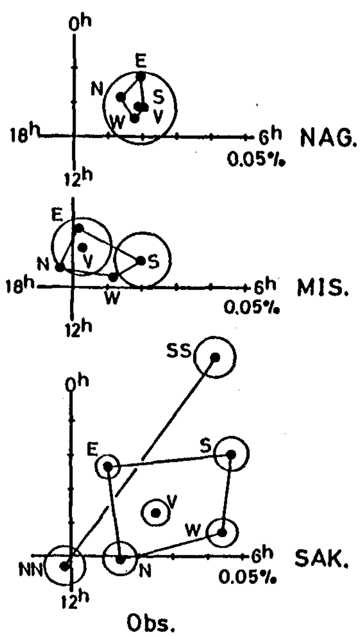

Fig.3 6-year averages of corrected sidereal diurnal variations of NAMS telescopes for 1978-1983.

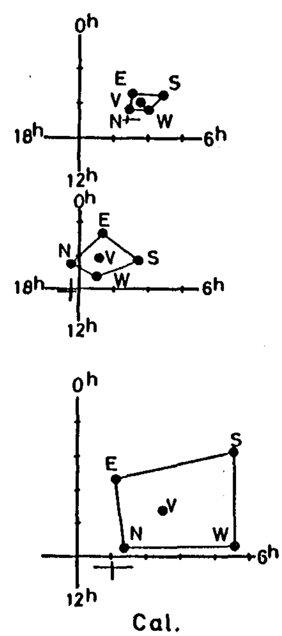

Fig.4 Best fit case of corrected sidereal diurnal variations of NAMS telescopes for 1978-1983. The cross marks are the common vector for each station calculated by the least squares method.

In order to derive the anisotropy, we assume the following in the best fit method as

1) two terms of N-S symmetric and N-S asymmetric types are assumed in the anisotropy for a better fitness between the observed and the expected variations,
2) from the observed fact that the amplitudes are larger for the deeper underground stations, we reasonably assume the low cutoff rigidity P_L in the flat rigidity spectrum, and
3) the unknown vectors are introduced to eliminate the spurious noises as mentioned above.

Tentative results using coupling coefficients given by Fujimoto et al. (1984) are obtained;

N-S symmetric term (P_1^1-type)
the amplitude 0.079+0.007%, the phase 3.5hr and P_L=200GV

N-S asymmetric term (P_2^1-type)
the amplitude 0.035+0.007%, the phase 14.9hr and P_L=200GV

In the present calculation, SS-component at Sakashita station is not included because of larger risidual error probably due to some heliospheric effect which occurs in sidereal semi-diurnal variations (Fujii et al., 1984). The calculated variations in the best fit case are shown in Fig.4.

3. Summary

1. The correction for the spurious sidereal variation using the anti-sidereal variation is indispensable to the study of sidereal anisotropy in low rigidity region.
2. Galactic sidereal anisotropy can be explained better with two terms of N-S symmetric and N-S asymmetric types than the usual uni-directional anisotropy only.

References

Elliot,H. and Dolbear,D.W.N. (1950) Proc. Phys. Soc. A, 63, 137.
Fujii,Z. et al. (1984) Proc. Int. Symp. CR Mod. Morioka, 364.
Fujimoto,K. et al. (1984) Rep. CR Res. Lab., Nagoya Univ., No.9.
Nagashima,K. and Ueno,H. (1971) Rep. Ionos. Space Res. Japan, 25, 212.
Nagashima,K. et al. (1983) Nuovo Cimento, 6C, 550.
Swinson,D.B. (1969) J. Geophys. Res., 74, 5591.