BQ7900189

Sidereal Anisotropy of Small Air Showers Observed at Mt. Norikura.

K. Nagashima, S. Sakakibara, K. Fujimoto, Z. Fujii, H. Ueno and I. Kondo*.

Cosmic Ray Research Laboratory, Nagoya University, Nagoya, Japan.
*Cosmic Ray Laboratory, University of Tokyo, Tanashi, Tokyo, Japan.

Abstract

Observation of small air showers has been continued from August 1970, using a part of the multidirectional cosmic ray telescope at Mt. Norikura. Most significant result obtained from this observation was a sidereal diurnal anisotropy of amplitude 0.051 ± 0.004 % with maximum at 1.0 ± 0.5 h, which showed a persistent trend over six years.

Based on the results of the observation together with those obtained by Gombosi et al and Fenton et al., a tentative model of sidereal anisotropies is presented.

1. Observed Results

Observation of small air showers were continued from August 1970, utilizing a part of the multidirectional cosmic ray telescope at Mt. Norikura (2770 m, $\lambda=36^{\circ}$N, $\phi=137.5^{\circ}$E).[1] This observation was carried out in order to derive information about the anisotropy of primary cosmic ray intensity in the energy region of 10^{12} - 10^{14} eV. Most remarkable result obtained from the observation over six years, was a sidereal diurnal anisotropy having an amplitude of 0.051 ± 0.004 % with time of maximum at 1.0 ± 0.5 h sidereal time. As seen from the summation dial shown in Fig. 1a, this anisotropy showed a persistent trend over 6 years.

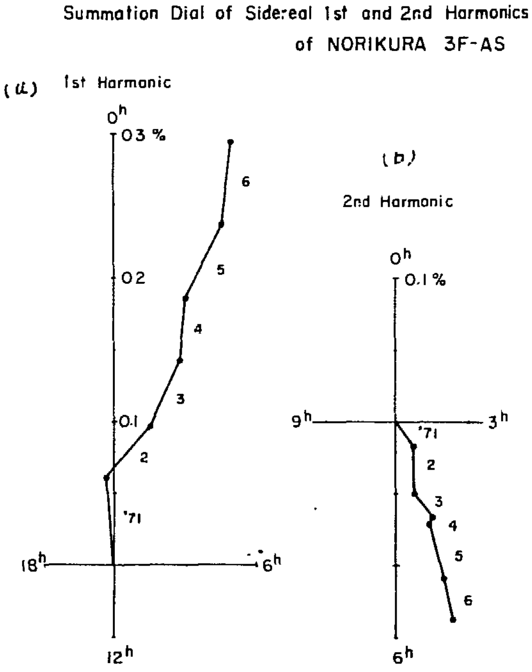

Fig. 1.

A sidereal semi-diurnal anisotropy showing similar persistent trend in the same period as shown in Fig. 1b is also obtained. It has an amplitude of 0.026 ± 0.004 % and time of maximum at 5.5 ± 0.3 h.

Two independent results about the sidereal anisotropy in the same energy region were reported. One from air shower observation at Peak Musala by Gombosi et al[2], and another from underground observation at Poatina by Fenton et. al[3]. Together with two other results of *4F* air showers and the directional air showers at Mt. Norikura, all the results are consistent with each other as shown in Fig. 2.

2. Compton-Getting Effect and Galactic Loss-Cone Model

The observed results described in the previous section strongly suggest the existence of sidereal anisotropy in 10^{12} - 10^{14} eV region. Especially the constancy of the sidereal vectors for *3F* observation through one half of a solar cycle indicates no influence of solar modulation on these observations. Further, the fact that the observed phase of the anisotropy is ~1 hr. sidereal time suggests that this is not due to the sidereal anisotropy of solar origin which has the eigen phase of 6 or 18 hr.

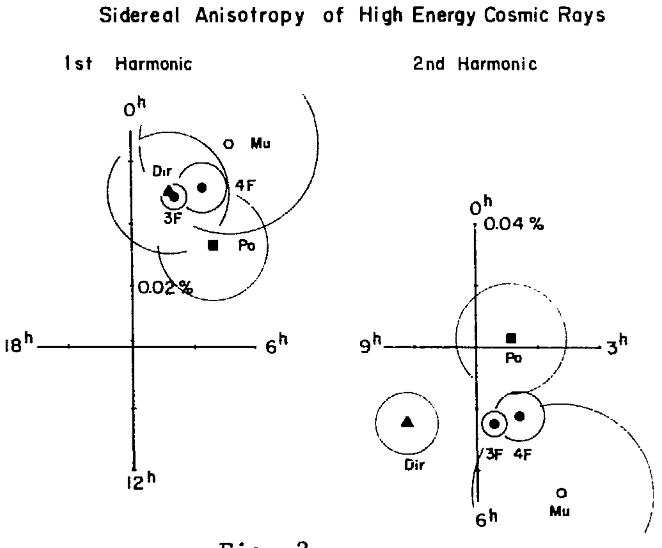

Fig. 2.

There are two kinds of relative motion of the solar system in the Galaxy which might produce the Compton-Getting effect. One is the proper motion of the solar system relative to the local stars in the direction of 18 hr. right ascension, with speed of ~20 km/sec. Another is the motion of the solar system relative to the intersteller gaseous matter which constitutes the spiral arm in the direction of 4.0~4.7 hr. right ascension with speed of 20~30 km/sec. (Fujimoto[4], Roberts[5], cf. Table I). Cosmic ray anisotropies produced by these two relative motions are estimated and the observed vectors are corrected for the Compton-Getting effects as shown in Fig. 3 by △ and ⊙ respectively.

Since cosmic ray particles are spiralling around the intersteller magnetic field frozen in the gaseous matter, it is more likely that the observer in the solar system observes the Compton-Getting effect due to the second relative motion. Then the true galactic anisotropy has maximum in the direction 23.5 hr. for *3F* showers. The fact that the 1st and 2nd

Table I.

Compton-Getting Effect	Direction				Magnitude
	ℓ (°)	b(°)	δ_o(°)	α_o(°)	η_1 (%)
Due to the proper motion of solar system (20 km/s)	44	25	20	17.9	0.031
Due to the relative motion of solar system to the Orion arm (20~30 km/s)	150-160	~ 0	52-45	4.-4.7	0.047 -0.031

harmonic vectors are different in phase by 6 hours from each other, suggests that they might be produced by the loss-cone type anisotropy[6]. In order to estimate the direction of the reference axis and the opening angle of the loss-cone, the following facts are utilized.

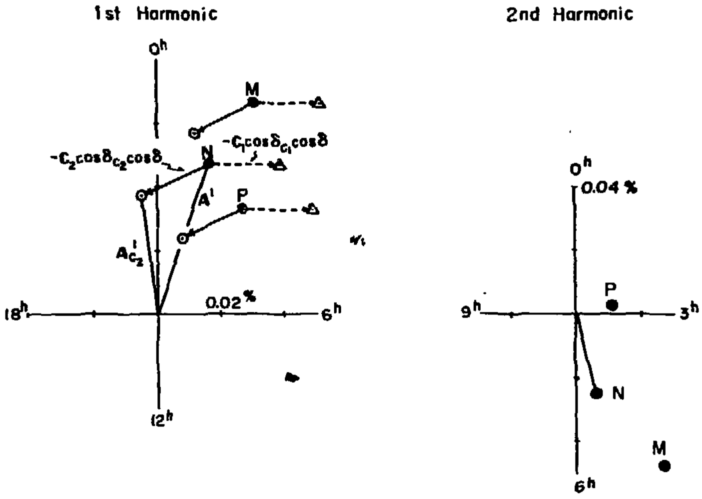

Fig. 3.

As there is only a small difference in the observed diurnal vectors in the northern (Norikura and Musala) and southern (Poatina) hemispheres, the north-south asymmetry ($\vec{a}^1_2$) in the 1st harmonics is not so large. Using the difference between Norikura and Poatina, $\vec{a}^1_2$ is derived as ~0.010 %, while the 2nd space harmonic component $\vec{a}^2_2$ is derived from the average of 2nd harmonics at Norikura and Poatina as ~0.014 %. The ratio of a^1_2/a^2_2 is used to obtain the declination δ_o of the reference axis by the following relation[7,8],

$$a^1_2/a^2_2 = 4\cdot|\tan\delta\cdot\tan\delta_o| ,$$

where δ is the declination of average viewing direction of the telescopes. Then this gives the direction of anisotropy as δ_o~12° and right ascension α_o~0 hr., which corresponds to the galactic latitude of b~-50° and longitude of ℓ~115°.

This direction is not exactly coincides with the general direction of the Orion arm as shown in Fig. 4, but it may represent the true direction of the magnetic line of force in the vicinity of the solar system.

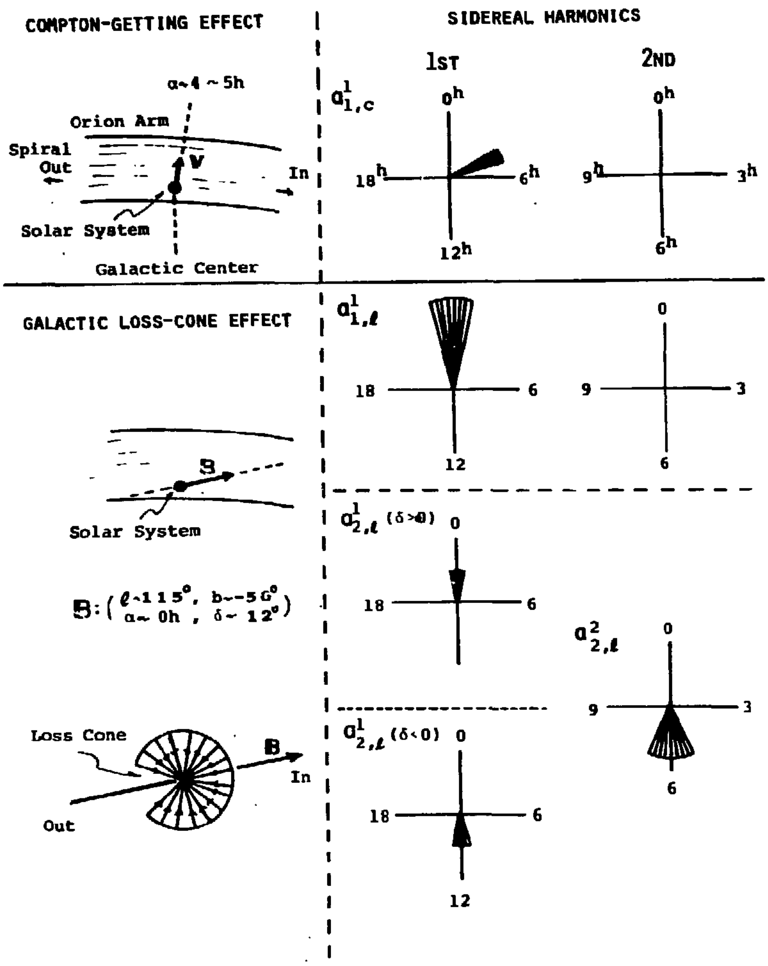

Fig. 4

The half opening angle χ_c of the loss-cone is estimated from the ratio a^2_2/a^1_1 as ~71° by the following equations[6,8].

$$a^1_1 = \eta_1\, P^1_1\, (\sin\delta_\circ)\quad P^1_1\, (\sin\delta)$$

$$a^2_2 = \eta_2\, P^2_2\, (\sin\delta_\circ)\quad P^2_2\, (\sin\delta)$$

$$\eta_1 = -3/4\ (\sin^2\chi_c)\ \Delta I/I_\circ$$

$$\eta_2 = -5/4\ (\sin^2\chi_c\ \cos\chi_c)\ \Delta I/I_\circ$$

where P^m_n is the semi-normalized associated Legendre function, $I_\circ$ is the averaged directional intensity in interstellar space and ΔI is the decrement of the intensity from the direction in the loss cone.

These facts suggest that the observed sidereal anisotropy is produced by the diffusion of cosmic ray particles along the galactic magnetic field with some loss mechanisms in the region of the spiral-out direction from the solar system.

3. Discussions

The sidereal anisotropies derived from the small air shower experiments at Mt. Norikura together with the results from Peak Musala and Poatina, showed the existence of galactic anisotropies.

Two possible origins of the observed anisotropies are discussed and the amount and the direction of these anisotropies [illegible] been derived. One of them may be due to the motion of the solar system [illegible] to the interstellar gaseous matter, and has an amplitude of ~0.019 % and time of maximum in ~4.4 hr. sidereal time at Mt. Norikura. Another source of the sidereal variation may be due to the loss-cone-type anisotropy of the cosmic ray intensity around the galactic magnetic field, the direction of which is estimated as $\alpha_0 \sim 0$ hr. and $\delta_0 \sim 12°$. The half-opening angle of the loss cone is ~71° and the decrement of the intensity from the direction in the loss cone is ~0.09 %. This loss-cone-type anisotropy is considered to be due to the diffusion of cosmic ray particles in the galactic magnetic field and the less reflection of the particles from the spiral-out direction due to the boundary effect in the vicinity of the outer edge of the Galactic arm.

Somogyi[9] presented another model of the galactic anisotropy, based on the air shower observation at Peak Musala. The model is not compatible with the present one. This discrepancy may be mainly due to the insufficient statistical accuracy of observations and also to the incomplete worldwide network of the high energy cosmic ray observations, especially in the southern hemisphere.

References

1. Nagashima, K., H. Ueno, K. Fujimoto, Z. Fujii, S. Sakakibara and I. Kondo; Proc. Int. Cosmic Ray Conf. Munich, 4, 1503 (1975).

2. Gombosi, T., J. Kota, A.J. Somogyi, A. Varga, B. Betev, L. Katsarski, S. Kavlakov and I. Khirov;
Proc. Int. Cosmic Ray Conf. Munich, 2. 586 (1975).

3. Fenton, A.G. and K.B. Fenton;
Proc. Int. Cosmic Ray Conf. Munich, 4. 1482 (1975).
Fenton, A.G. and K.B. Fenton;
Proc. Int. Cosmic Ray Symposium on High Energy Modulation, 313 (1976)

4. Fujimoto, M; Non Stable Phenomena in Galaxies,
IAU Symp. No. 29, Ed. M. Arakeljan (Acad. Sci. Armenia USSR), 453 (1967).

5. Roberts, W.W.; Ap. J. 48, 1 (1969).

6. Fujii, Z.; Rep. Ionos. Space Res. Japan, 25, 242 (1971).

7. Jacklyn, R.M.; Proc. Int. Cosmic Ray Conf. London, 1, 141 (1965).
Jacklyn, R.M.; ANARE Scientific Reports, Series C(11) Cosmic Rays, Pub. No. 114 (1973).

8. Nagashima, K.; Rep. Ionos. Space Res. Japan, 25, 189 (1971).

9. Somogyi, A.J.;
Proc. Int. Cosmic Ray Symposium on High Energy Modulation, 142 (1976).