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Annual variation of heliotail-in anisotropy

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Abstract. One of Authors reported that the cosmic ray sidereal daily variation in the energy region less than 10TeV was due to two kinds of anisotropy. One is the galactic anisotropy from the direction of the right ascension 0 hour. The other is discovered directional excess flux (called tail-in anisotropy) from the direction 6 hour and observed only in the energy less than 10TeV. It is suggested that the excess flux is solar origin and the direction toward it seems to coincide with the expected heliotail-in direction. In this paper, it is shown as one more evidence of the directional flux is larger at the winter solstics when the Earth is close to the magnetotail and smaller at the remote side of the tail-in anisotropy.

1. Introduction

It was suggested by Compton and Getting (1935) that a cosmic ray anisotropy may be produced on the Earth by the motion of the solar system relative to the cosmic ray gas. Many observations of cosmic ray sidereal variation have been made with this suggestion. In the low-energy region less than 10TeV, howevere, any model of anisotropy has difficulty in explaining the observed variations. Such a difficulty was resoluved through the discovery of two kinds of anisotropy (Nagashima et al.1998,hereafter, called Ref.1). Co-existence of the galactic and tail-in anisotropies have been also confirmed by D.L.Hall et al (1999). In this paper, one more evidence of the existence of tail-in anisotropy is shown.

2. Sidereal daily variation

The cosmic ray data used for the present analysis are those of the muon telescopes at the underground stations Sakashita (latitude 36N, longitude 138E, depth 80mwe),Matsushiro (latitude 37N, longitude 138E, depth 236mwe) and Hobart (latitude 43S, longitude 147E, depth 36mwe) . The characteristics of the telescopes are shown in Tabe 1.

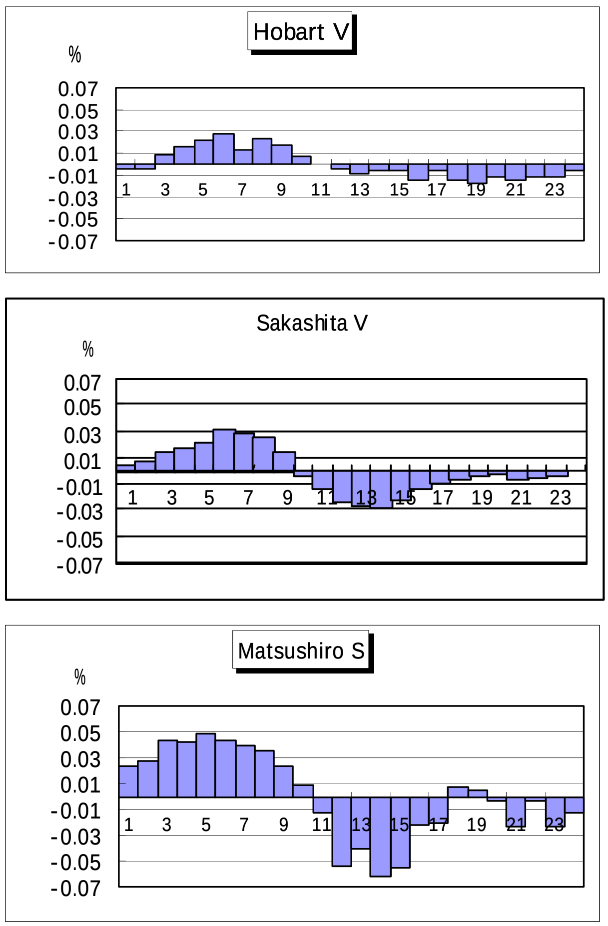

Figure 1. Cosmic ray sidereal variation observed with muon telescope at Hovert (vertical) , Sakashita (vertical) and Matsushiro (south) .The variations are corrected for the influence of the solar daily variation by the method that uses the anti-sidereal daily

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variation (see Ref. 1 and Section 2)

It was pointed out in Ref.1 that the cosmic ray sidereal daily variation in the energy region less than 10TeV is due to two kinds of anisotropy, one is a galactic anisotropy from a direction right aascension 0 hour and declination –20 degrees and characterized by a directional deficit flux of cosmic rays confined in a narrow cone with the half opening angle 57 degrees from the direction of right ascension 12 hour and declination 20 degrees. The other is the heliomagneto-tail anisotropy of solar origin,which is observed only in the energy region less than 10TeV with its maximum near 1TeV and characterized by a directional excess flux confined in a narrow cone with 68 degrees from the direction 6 hour and –24 degrees almost parallel to that right ascension 6h and declination –29.2 degrees of the heliomagnetotail expected from the proper motion of the solar system.

Station	Center direction		median energy	Period
Telescope	latitude	longitude	GeV	
Hovert V	43S	147E	184	1958--1983
Sakashita V	36N	138E	331	1978--1993
Matsushiro S	4N	138E	803	1985--1994

Table 1. Characteristics of the telescope

Hobart vertical telescope directed to a high southern declination sweeps only the excess cone and observed the variation due to the tail-in anisotropy. The variation is characterized by a narrow and sharp peak at 6h on a flat background, as shown in Figure 1. On the other hand, the vertical telescope at Sakashita and S-telescope at Matsushiro in the intermediate declination sweep the excess and deficite cones and observes the resultant variation of the sidereal daily variation due to the galactic anisotropy and tail-in anisotropy. The peak and valleys increase in magnitude with energy from a comparison of the variations at Matsushiro with Sakashita in Figure 1, indicating that the tail-in and galactic anisotropies have spectra that increase with energy.

3. Annual variation of tail-in anisotropy

The response to the excess flux due to the tail-in anisotropy is maximum at the December soltice when the Earth is closet to the tail and minimum when it is farthest from the tail, at the June solstice, shown at the conjectual sketch in Figure 7a of Ref. 1. We divide the data to two period. One is the period of October, Nobember, December, January, February and March , called tail-in side and the other is the period of April, May June, July, August and September called opposite side of tail. Figure 2a, 2b and 2c show the sidereal daily variations in tail-in side and the opposite of tail.

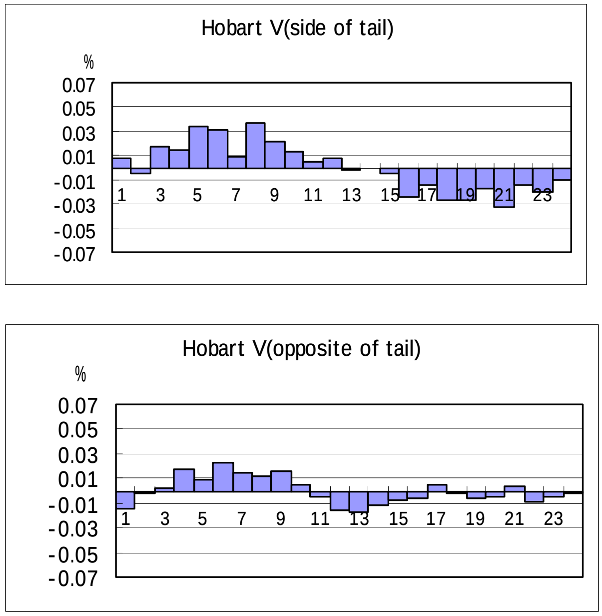


Figure 2a The sidereal daily variations at vertical telescope at Hobart in tail-in side and the opposite side.

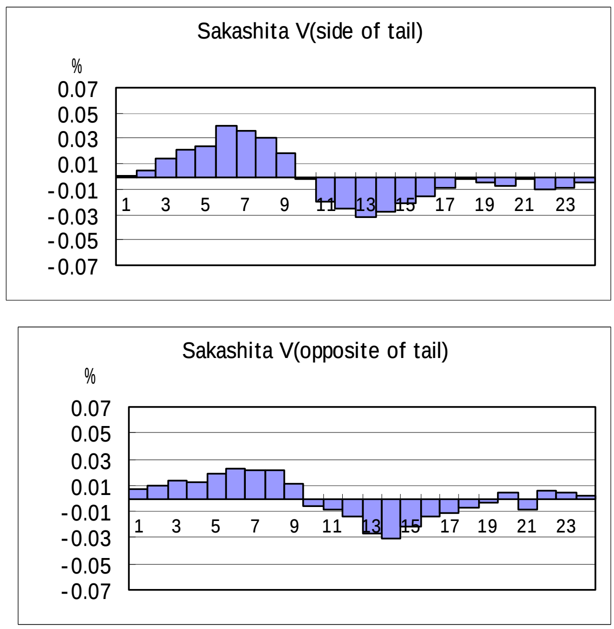
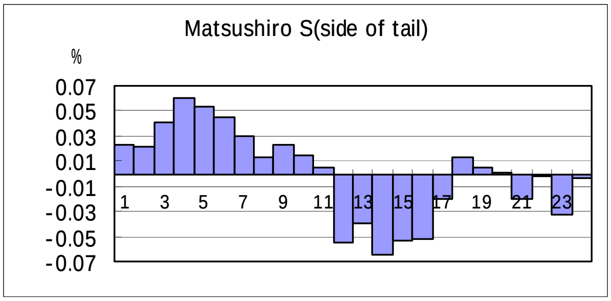


Figure 2b The sidereal daily variations at vertical telescope at Sakashita in tail-in side and the opposite side.



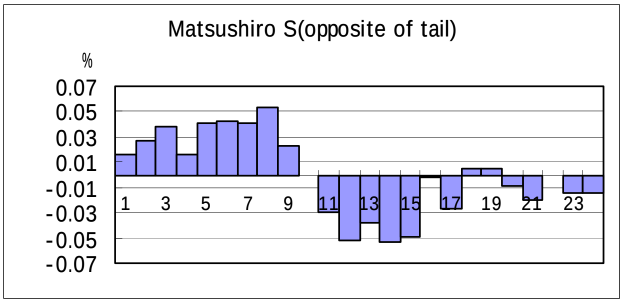


Figure 3c. The sidereal daily variations at S telescope at Matsushiro in tail-in side and the opposite side.

It is shown that the magnitude of peak at 6 h in the opposite side of tail is smaller than that in the tail side at vertical telescope at Hobart in Figure 2a. Also, shown that the magnitude of peak at 6h in the opposite side of tail is smaller than that in the tail side at V-telescope at Sakashita but the valley at 12h is nealry same in both side in Figure 2b. This fact mean that the tail-in anisotropy is sheltered by the solar magnetosphere. The magnitude of peak at 6h is a little small in the opposite side at S-telescope at Matsushiro. The sheltering effect of tail-in anisotropy by the solar magneto-sphere is dependent on the median energy of the telescope. The size of the solar magnetosphere is expected from the reduction rate between the tail-in side and the opposite side.
From this reduction rate (our own criterion), we estimated the size of the solar magnetosphere about 0.5 ,0.2 and 0.1 AU for Hobart, Sakashita and Matsushiro, respectively. The estimated size of solar magnetosphere is shown as the function of the median energy of the telescope in Figure 3. The value of 10TeV was obtained by the air shower observation.in Tibet (M..Amenomori et al. ,1999), shown that the size of solar magnetosphere is the rigid radius. The size of the solar magnetospere is inversely proportional to the median energy, as shown in figure 3. This fact is resonable as the interaction with the cosmic rays to the magnetic field is inversely proportional to the energy and shows that the existence of tail-in anisotropy of cosmic ray is valid.

4. Conclusion

We divide the observation data of the sidereal daily variation to the period of tail-in side and the period of the opposite side of tail.
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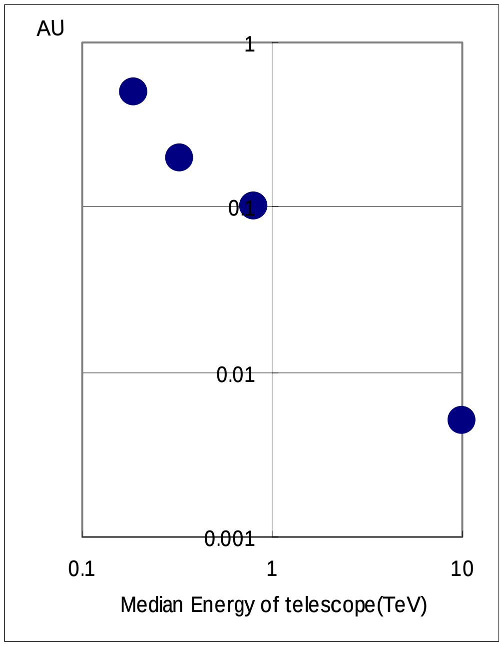

Figure 3. The dependence between the estimated size of solar magnetosphere and the median energy of the telescope. The median energy is expressed by a unit of TeV. The point of 10TeV comes from the air shower observation in Tibet.

The magnitude of peak at 6h in the opposite side of tail reduce in comparison to that in the tail side. This fact shows that the tail-in anisotropy of cosmic ray is sheltered by the solar magnetosphere. Inversely, this shows the exsistence of the tail-in anisotropy. The reduction rate between the tail-in side and the opposite side is dependent on the meadian energy of the telescope. From the reduction rate, we estimated the size of the solar magnetosphere. This is inversely proportinal to the median energy.

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