Studies on Cosmic Ray Sidereal Anisotropy with the Multidirectional Muon Telescope at Ooty

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Abstract

We have developed a multidirectional telescope capable of recording individual muons with angular accuracy of about 5 degrees. This muon telescope consists of ~ 3000 proportional counters with total area of ~ 420 m^2 with threshold energy > 1 GeV. The telescope is a component of the GRAPES-3 experiment at Ooty in southern India (N 11.4, E 76.7 and 2200m altitude). The very large muon counting rate $\sim 1.8 \times 10^8$ per hour, achieved due to the very large area of the telescope, gives us great advantage for cosmic ray modulation studies. The analysis of data with such high statistics enables us to have a sensitive measurement of sidereal variation within a single year of observation. Further, since our telescope is located near the Equator, we are able to observe both the Northern and the Southern hemispheres simultaneously. We present here the results on the sidereal variation obtained with this multidirectional muon telescope for the observational period, 2000–2001. We report here on Tail-in and Loss-corn anisotropies through detailed analysis. We also discuss other possible explanations for the present observations.

1. Introduction

Many causes are contributing for the variation of gallactic cosmic rays intensity variation energy above around 10 GeV.[1][3][4][5][6][7] Though there might be some effect arising from the solar magnetic field ranging greater than 100 AU[1], major contribution would come from the outside of it. That is gallactic space origin. So far we are not able to point out the exact cause of anisotropy in sidereal daily variation of Cosmic Rays.

Nagashima and Fujimoto et. al. claimed that they have observed two type of anisotropy called Loss Corn and Tail in with the results from several observation, Nagoya, Sakashita, Norikura, Hobart.[4][6] They proposed that Loss corn defect should occur due to the gallactic magnetic field around the Solar systems

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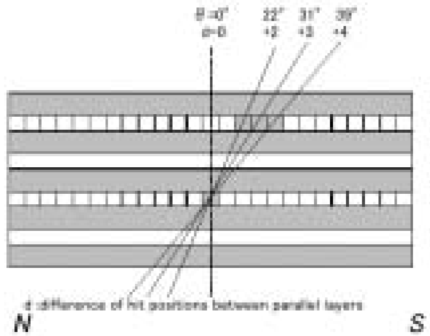

Fig. 1. a Cross sectional view of multidirectional muon telescope

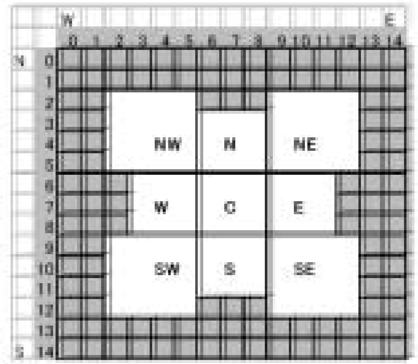

Fig. 1. b Schematic figure for combined direction

and excess flux of cosmic rays can be expected from Tail in.[4][6][7] According to them there must be bow shock which can be formed with the interaction between solar magnetic field and inter stellar plasma. If the bow shock is formed, it becomes easy to enter from opposite direction, toward the Tail of the magnetic field. The energy of their data is ranging from 10 GeV to 10^4 GeV.[6][9]

According to them Loss Corn defect exist in direction of right ascension 12^{h}, declination 20 degrees and Tail in 6^{h}, declination -16 degrees. Since our muon telescopes are located near Equator (N 11.4, E 76.7), we have a great advantage of looking them simultaneously.[10]

2. Data analysis and results

We have collected multidirectional muon intensity data from 1999 to 2001.

3 units of telescope were operational in 2000 and 12 units were operational in 2001. Our multidirectional muon telescopes can observe $15 \times 15 = 225$ direction simultaneously. In order to achieve better statistics the directional muon data is combined for 9 direction. Each direction is named as follows, NW, N, NE, W, C, E, SW, S, SE and they are shown in Fig. 1b.

The procedure of the analysis is described in details elsewhere in this conference. In order to eliminate the common error first we made the differential data as follows. The data coming from westward is subtracted from the data from eastward and we have reconstructed the sidereal hourly variation for one day with integrating this differential data.[2][4]

We have categorized the muon data according to the polarity of Interplanetary Magnetic Field, Toward and Away from the Sun. The polarity of each day was determined from the satellite data of ACE level2. Calculating the 72hour moving average we adopted the value at 20h UT for corresponding day's polarity.

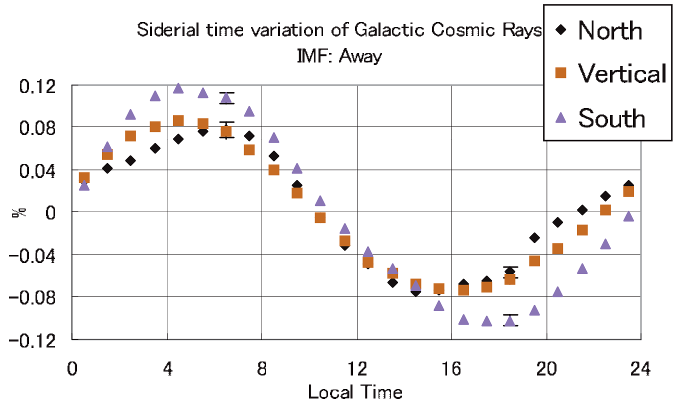

Fig. 2. Sidereal time variation of Cosmic rays (Away)

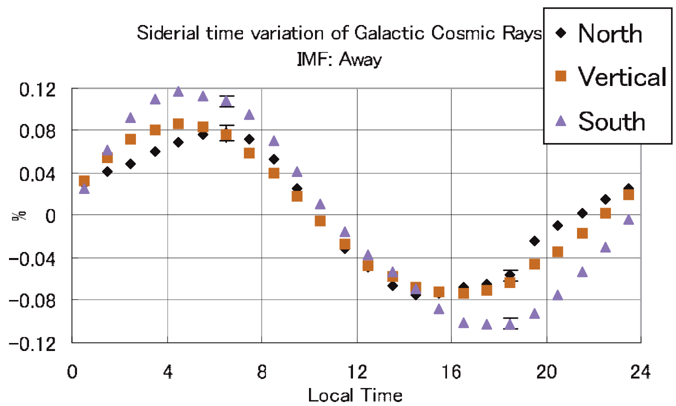

Fig. 3. Sidereal time variation of Cosmic rays (IMF: Toward)

One can clearly see typical sine wave like shape of hourly sidereal time variation of cosmic rays with the IMF polarity Away from the Sun in Fig. 3. Since this anisotropy comes from so called Swinson flow, it is expected to have a peak in 6^h in case of Away and same kind of variation is expected for Toward also having a peak in 18^h from same Swinson flow.[1] But the variation in Toward' data does not look smooth and nice. The reason why this smearing of peak in Toward's data happened is not clear at present. It may have some connection with the north-south asymmetry in solar time variation of muons which we report in this conference. Or it could be due to the strong IMF, since the activity of Sun is nearly at maximum around 2000 and 2001. To deduct this pseudo-sidereal effect we have made the average of Away and Toward data. Please see Fig. 4. We don't see clear Tail in anisotropy at 6h and Loss corn at 12h in Fig.4. This might be due to the strong activity of Sun and its IMF. If the intensity of IMF is strong, incoming cosmic rays might be scattered and then the peak would have become flat. We would like to confirm present result with continuing this observation up to quiet season of the Sun's activity.

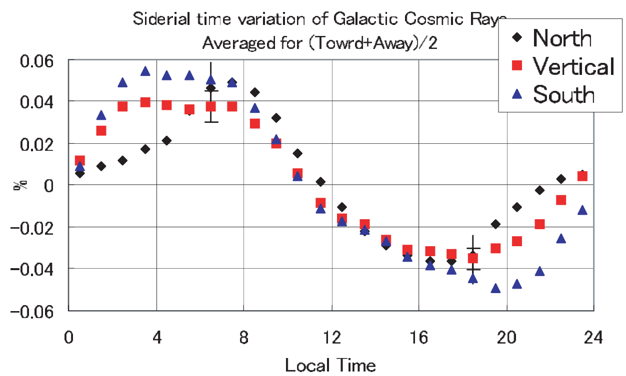

Fig. 4. Sidereal time variation of Cosmic rays (Toward+Away)/2

3. Acknowledgement

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4. References

(1) SwinsonJD.B, J. Geophys. Res., 745591,1969
(2) Nagashima, K.,et al., Nuovo Cimento, C(6), 550. 1983a
(3) Alexeenko, V.V., and Navara G., Lett Nuovo Cimento, 42(7), 321., 1985
(4) Nagashima, K. and Fujimoto, K.,et al., Nuovo Cimento, 12C(6), 695., 1989
(5) Bergamasco, L., Proc 21st Int Cosmic Ray Conf., Adelaide 6, 372–375.,1990
(6) Nagashima, K., Fujimoto, K., and Jacklyn, R.M., J. Geophys. Res., 103, A8, 17429., 1998
(7) Munakata K.,et al., Proc 26th Int Cosmic Ray Conf., SaltLake City, 7, 293–296., 1999
(8) Munakata K.,et al., Proc 27th Int Cosmic Ray Conf., Hamburg, 10, 3919–3922., 2001
(9) Fujimoto K.,et al., Proc 27th Int Cosmic Ray Conf., Hamburg, 10, 3927–3929., 2001
(10) Kojima H.,et al., Proc 27th Int Cosmic Ray Conf., Hamburg, 10, 3943–3945., 2001