Observation of Anisotropy of Cosmic Rays with Solar Time Using the Multidirectional Muon Telescope of GRAPES-3 Shower Array

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Abstract

We have used the East-West method in which the observational data of the West-ward direction is subtracted from the East-ward direction. With this method, we are able to eliminate the common components varying with time. We have been able to obtain accurate sidereal time variation of cosmic rays from the last 3 years of observations and those results are being presented elsewhere in this conference. Now we are confident that we can reduce the noise level significantly with this analysis. Using the data taken during 2000–2001 we have found anisotropy in Solar time variation of cosmic rays. This anisotropy shows maxima in the direction of 15^h Solar time with the North oriented telescope and 9^h Solar time with the South oriented telescope. These peaks can also be seen in both year's data separately. These features may be related with the density gradient of cosmic rays in the Solar system. We are attempting to get detailed understanding for these observations while accumulating more data. Further studies under different experimental conditions are considered desirable. Details of observations and results would be discussed at the conference.

1. Introduction

Our multidirectional muon telescope is located at Ooty. (E78, N11, 2,200m a.s.l.) It is constructed to measure the muon components in Air shower experiment named GRAPES-3. Since it is situated near equator, it has a great advantage to be able to observe both northern and southern sky simultaneously.

Angular resolution of this telescope is about 14 degree for vertical direction and resolution becomes better for larger zenith angle. The most unique feature is its large detection area of 560 m^2. It makes us possible to obtain solar a anisotropy with very high statistics. We report here a existence of new type of solar time anisotropy of primary cosmic rays. The cause of it is not obvious still.

Diffusion-convection theory can well describe the solar time anisotropy of

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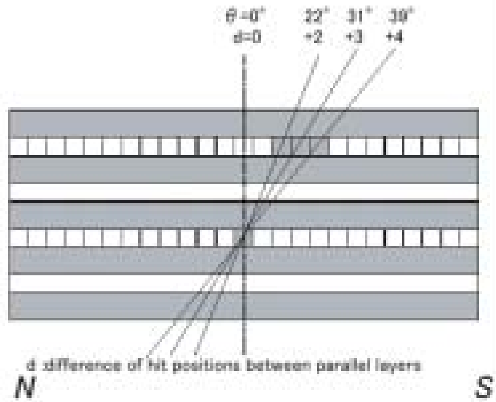

Fig. 1. a Cross sectional view of multidirectional muon telescope

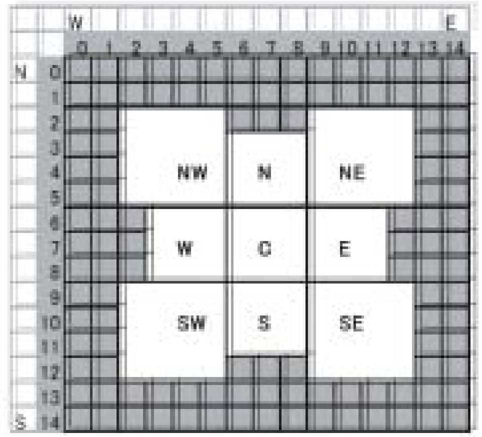

Fig. 1. b Schematic figure for combined direction

cosmic rays with energy above several GeV. It was proposed by Parker in 1958. This anisotropy does not depend on polarity of IMF. The maximum appear in 18 hour and its amplitude is about 0.3% at Ooty. Some people claimed that there are other kind of anisotropy different from Parker model.[1][2]

Swinson reported the 3 hour-15hour anisotropy should exist due to vector production of density gradient vertical to solar equatorial plane and IMF. This anisotropy should appear in the direction of adding to the 18 hour anisotropy.[2] Munakata et. al. presented that there are two anisotropy caused by north-south symmetry and north-south asymmetry. Their experimental results using two multi-directional muon telescopes one at Nagoya (for northern hemisphere) and another at Hobart (southern hemisphere) shows IMF independence. They have observed the 5 hour–17hour anisotropy.[4][5]

2. Analysis and results

Fig. 1a shows the cross sectional view for the part of one of multidirectional muon telescope. The dimension of the unit is 6m $\times$ 6m and its effective detection area is 35 m^2. 16 units of them are put side by side and total area is around 560 m^2. Though it can observe $15 \times 15 = 225$ different direction simultaneously, we have combined some of the directions and grouped them in 9 directions shown in fig. 1b. Each direction is named as NW, CE, NE, CW, C, CE, SW, SC, SE. We have analyzed the data from April 1999 to December 2001.

These categorized data are analyzed with the following process.

1. Data is corrected with barometric pressure

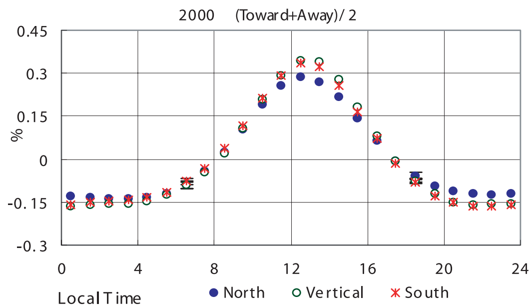

Fig. 2. a Solar time variation of Cosmic rays

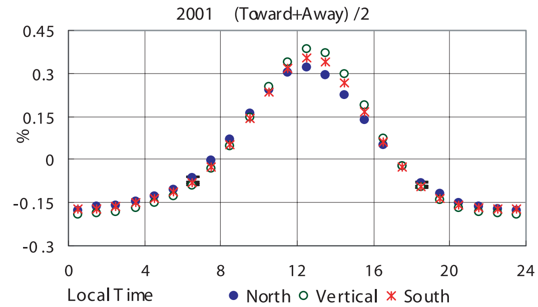

Fig. 2. b Solar time variation of Cosmic rays

2. Normalized with daily mean
3. Data from west is subtracted from the data from east, making NE-NW, E-W, SE-SW.

With these subtraction of westward data from eastward we can eliminate the common error, such as temperature effect and many of the intrinsic apparatus error[3]. Using these subtracted data set we reconstructed the hourly data to obtain the solar time variation of the cosmic rays.

Considering those observed data from individual telescope as an independent data set, observational error for the solar time variation is estimated. Since only one unit has been operational in 1999, error cannot be evaluated for 1999's results.

We used ACE-level2 data to determine the direction of IMF. We have calculated the 72 hour moving average of Bx and By (in GSM coordinate) and adopted its value at 22:00 UT for the polarity of IMF on corresponding day.

Solar time variation of galactic averaged cosmic rays (Toward+Away)/2 has been shown in Fig. 2a, b. It is very clear that there is an anisotropy at around 13h. This peak can be well explained with Parker's Diffusion Convection model if the geomagnetic deflection at Ooty is considered.

Fig. 3a, b, c also shows the solar time variation averaged with (Toward-Away)/2 from the same data set. You can clearly see the north-south asymmetry in the graph though the amplitude of the signal is somewhat small. 1999's data looks slightly different from other year's results. Since only one unit of telescope is operational in 1999, we would rather put emphasis on the results from 2000 and 2001.

As we describe in Introduction if one assume the cause of this anisotropy arises from the vector product of magnetic field and cosmic ray density gradient perpendicular to the solar equatorial plane, anisotropy can be expected in 3h–15h. Though the north direction's shows around 15–16h peak, corresponding south data does not have corresponding dip at that time, but has the dip in around 10h.

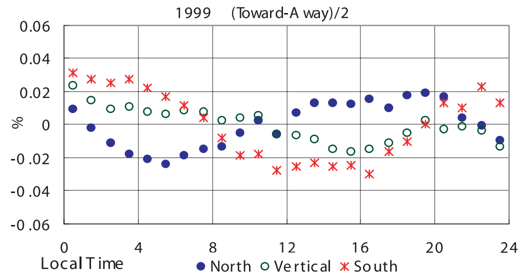

Fig. 3. a Solar time variation of Cosmic rays

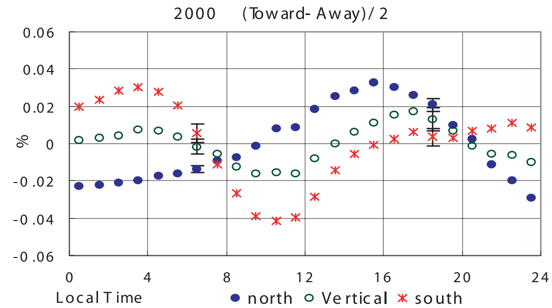

Fig. 3. b Solar time variation of Cosmic rays

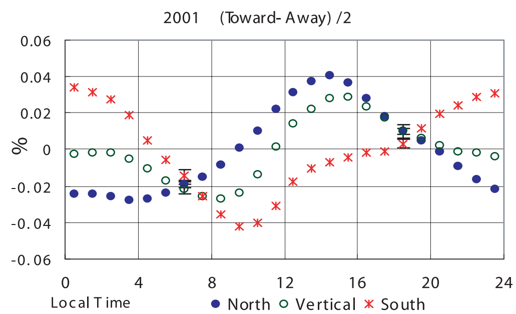

Fig. 3. c Solar time variation of Cosmic rays

It suggest that there would be other type of anisotropy and it persist for more than two years. To investigate further these aspect we are constructing similar multidirectional muon telescope in Akeno observatory, JAPAN.

3. Acknowledgement

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4. Refereces

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