The sidereal anisotropy of cosmic rays around $3 \cdot 10^{15}$ eV observed at a middle north latitude.

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ABSTRACT

The sidereal time variation of cosmic rays (median primary energy : $3 \cdot 10^{15}$ eV) is investigated with air shower observations at Akeno, Japan (900 m a.s.l.) which started in September 1981. Air showers are detected by a coincidence requirement on several muon detectors. The result obtained for three years is suggestive of a big semi-diurnal variation (0.37 % in amplitude). On the other hand, the diurnal variation is rather small than the semi-diurnal one. The feature of the sidereal anisotropy supposed from the present result looks quite different from that below 10^{14} eV.

1. Introduction. In Bangalore Conference (1983), a review on sidereal anisotropies in air shower observations was given by Linsley (1). The anisotropy beyond 10^{14} eV is still ambiguous, because of poor statistics and also because most of results except that by Daudin et al. (2) are not from air shower observations proper to the study of the sidereal anisotropy. Recently we have carried out air shower observations at Akeno, Japan (35°47'N, 138°30'E, 900 m a.s.l.) with the aim of studying the sidereal anisotropy around $3 \cdot 10^{15}$ eV.

2. Observations. The observations are made by using four muon detectors (25 m^2, 50 proportional counters, 2 m thick concrete) being located 100$\sim$200 m apart from each other. The detection of air showers is done by the following triggering requirements. Fifty proportional counters in each muon detector are divided into four groups of ten counters with spacing of three counters. For detection of shower, at first, a coincidence of incident particles is selected in the mode of "any two groups out of four counter groups" in each muon detector, and next, another coincidence is done in the mode of "any three- or four-fold coincidence" among the coincidence signals fed from those four muon detectors.

The response function was obtained from the analysis of air showers (1844 events) detected by the above-mentioned conditions. The result (normalized integral response function) is shown in Fig. 1, where solid points and open circles are values derived via the determinations of muon size and electron size, respectively. In this analysis the following points are noted. (1) The median primary energy is about $3 \cdot 10^{15}$ eV. (2) The zenith angle distribution of detected air showers per solid angle is proportional to $\cos^{5.2}\theta$ (θ : zenith angle). (3) Although the present triggering was doubted if it was favoured for detecting muon-rich showers, no significant distinction from cases of electron triggering was found.

The continuous observations have been carried out since September

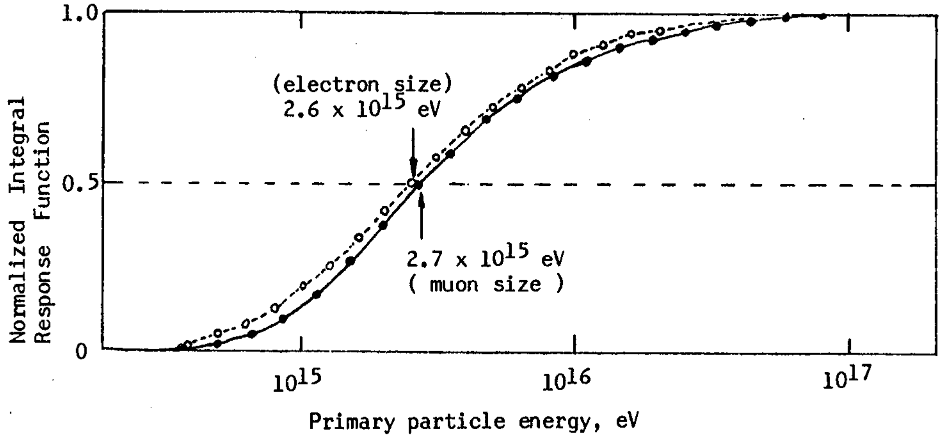


Fig. 1 Response function.

1981. In the following, a result obtained for three years until August 1984 is reported. The number of events is, in total, 2,237,059 showers observed in 962 days, after the rejection of days in which complete observations (with stable operation under constant condition throughout the day) were not fulfilled.

3. Results. Fig. 2 shows harmonic vectors in solar, sidereal and anti-sidereal time, averaged over three-year data without correction for barometric pressure effect or so on. The barometric pressure effect is of - 0.19 ± 0.03 % per mb. Open circles, P, shown in the figure are vectors expected from the barometric pressure effect. The other vectors, S, are variations of rate of single-particle incidences into four muon detectors including background radia-

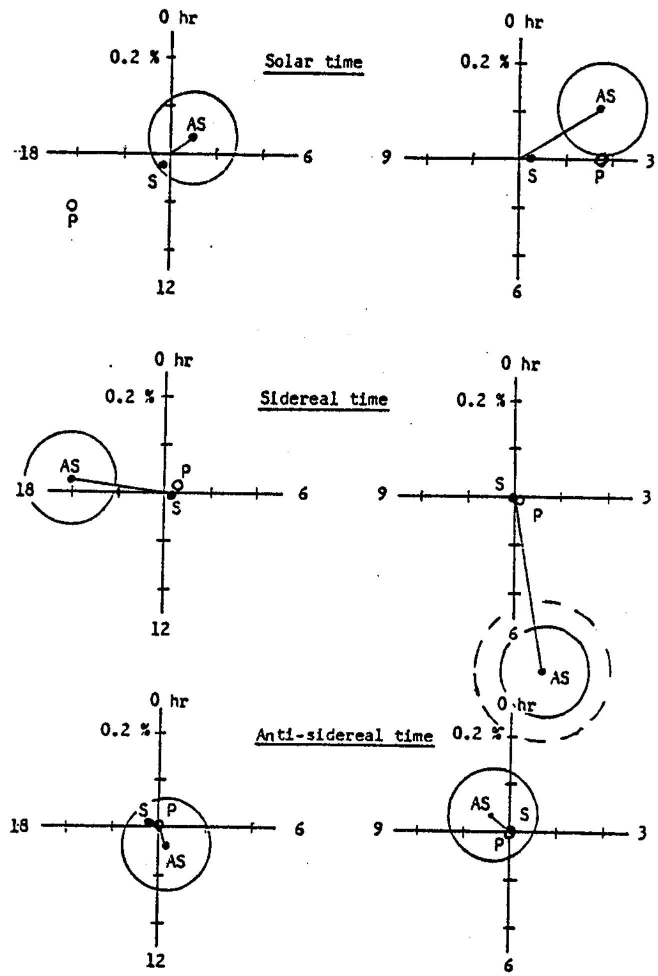


Fig. 2 Harmonic vectors.

tion from surrounding concrete. The regression coefficient to air shower rate is at most of a factor 2, and so the variation related with single-particle rate is negligible. The error circle around air shower rate AS means the standard deviation of mean amplitude derived from the scatter of hourly values. This deviation is of 0.1 % and almost equal to that estimated from total number of recorded air showers. The dotted circle will be explained in the last paragraph.

The results are summarized as follows :

(1) The solar diurnal variation is very small. There is, however, a discrepancy from the vector P expected from barometric pressure effect. Main part of this discrepancy may be interpreted as atmospheric temperature effect.

(2) The solar semi-diurnal vector is not inconsistent with the barometric pressure effect.

(3) The amplitude of sidereal diurnal variation is as much as twice of the standard deviation and so the existence of the diurnal anisotropy is still hazy.

(4) The semi-diurnal vector in sidereal time is of 0.37 ± 0.10 % and 5.7 ± 0.8 hour. The existence of this vector will be discussed again in the last paragraph.

(5) The diurnal as well as semi-diurnal variations in anti-sidereal time are small.

4. Sidereal semi-diurnal variation. As mentioned above, it seems that a big sidereal semi-diurnal vector is existent. Further analyses on this anisotropy were made. One is the monthly shift of semi-diurnal vector on solar time coordinate, as shown in Fig. 3. Except the shift from (Feb., Aug.) to (Sep., Mar.), the anti-clockwise turning of the vector with month is very suggestive of the existence of the sidereal anisotropy. However, another analysis shows that the sidereal vector obtained for each half-year is rather widely distributed than the scatter expected from statistical fluctuation of hourly values, as shown in Fig. 4. The dotted circle in Fig. 2 is corresponding to this wide distribution of the vector. Therefore, in order to confirm the existence, it may be necessary to wait for more accumulation of the data. At present we have no idea to interpret why the vector scatters so widely, although we are trying to seeking for the reason.

5. Summary. The sidereal time variation around $3 \cdot 10^{15}$ eV was investigated with air shower observations at Akeno which started in September

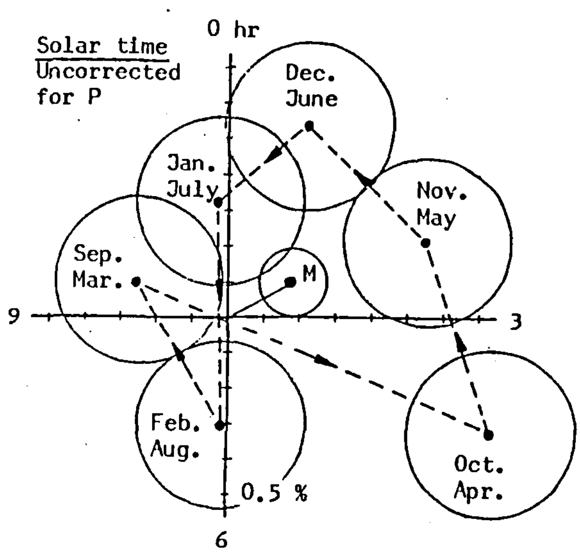
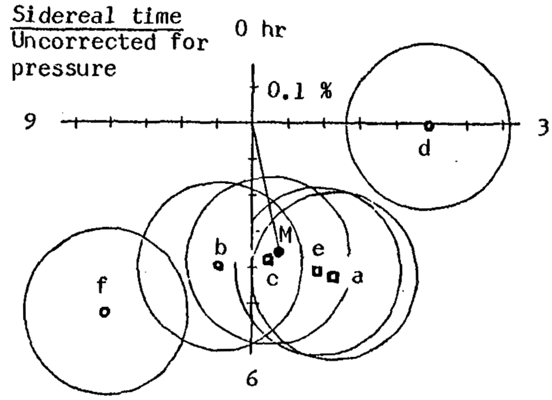


Fig. 3 Monthly vector of semi-diurnal variation in solar time.

1981. The result obtained for three years gives a big semi-diurnal vector in sidereal time, 0.37 ± 0.10 % and 5.7 ± 0.8 hour. Although we need to accumulate more data in order to confirm the existence, it is very interesting that the semi-diurnal vector seems bigger than the diurnal vector, because the diurnal vector has been confirmed to be bigger than the semi-diurnal vector at north latitudes in the region below 10^{14} eV.

Although the above semi-diurnal vector was given with the standard deviation estimated from the fluctuation of hourly value, if we consider the wide distribution of the vector obtained for each half-year, the statistic for confirming its existence is still unsufficient (now the significance level = 1 %).



a : Sep. 1981 - Feb. 1982
b : Mar. 1982 - Aug. 1982
c : Sep. 1982 - Feb. 1983
d : Mar. 1983 - Aug. 1983
e : Sep. 1983 - Feb. 1984
f : Mar. 1984 - Aug. 1984
M : Sep. 1981 - Aug. 1984

Fig. 4 Distribution of sidereal semi-diurnal vector for each half-year.

The barometric pressure effect is explainable mainly with longitudinal development of muon size.

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References.

1. Linsley J. : Conf. Papers 18th ICRC, Bangalore, 12, 135, (1983).
2. Daudin J. et al. : Nuovo Cimento, 3, 1017, (1956).