Galactic anisotropy of ∼10TeV cosmic-ray intensity observed by the Tibet air shower array

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Abstract

We examine the galactic cosmic-ray anisotropy by analyzing the sidereal daily variation (SDV) of ∼10TeV cosmic-ray intensity observed by the Tibet II and Tibet III air shower arrays, during total 49 months between 1997 and 2001. It is found that the spurious variation in the extended-sidereal time (367c/y) becomes insignificant when the non-uniformity in the observation period is properly taken into account in the analysis. The SDV (366c/y) with ∼0.1% amplitude, on the other hand, remains significant in a good agreement with the result by the Mt.Norikura air shower experiment. The daily variation in the solar time (365c/y) also becomes quite consistent with the Compton-Getting anisotropy due to the earth's revolution around the sun. This is the most accurate result of the anisotropy ever reported in this energy region.

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1. Introduction

The galactic anisotropy of the high energy cosmic-ray intensity gives us important information on the interstellar space surrounding the heliosphere. The anisotropy can be detected as the daily variation of the cosmic-ray intensity in the local sidereal time. Since the amplitude of the anisotropy is small as $\sim 10^{-3}$ (0.1 %), one needs to keep any spurious variations as small as possible for the precise detection of the anisotropy. Such spurious variations include those of the instrumental and atmospheric origins. In our previous paper, we succeeded to derive the sidereal daily variation (SDV) of ∼10 TeV cosmic-ray intensity with a great significance, by applying the "E-W" technique to the data recorded by the Tibet II air shower array [1].

Our previous paper [1] also presented the average daily variation in the solar time, which was expected from the Compton-Getting Anisotropy (CGA) due to the earth's orbital motion around the sun. The observation of this anisotropy with an extremely small amplitude (∼0.03 %) can offer a good opportunity for a crucial test of the observation and the data analysis schemes. The systematic deviation of the observed variation from that expected from the CGA was attributed to the "seasonal variation" of the SDV, possibly due to the heliospheric modulation [1]. However, our preliminary analysis based on the calculation of the orbital motion of 10 TeV cosmic-rays in the model heliosphere suggested that the modulation effect is too small to explain such a seasonal variation.

2. Data analysis

In the present paper, we analyze the SDV of cosmic-ray intensity observed by the Tibet II air shower array during a period between February 1997 and August 1999 and by the Tibet III array between November 1999 and October 2001. The total 49 months period is covered by these observations. In analyzing the data during the latter period covered by the Tibet III array, we selected the shower events with the identical trigger condition used for the former period covered by the Tibet II array, keeping the mode energy of primary cosmic-rays at ∼10 TeV throughout the period analyzed. The average count rate was 3.1×10^{5} counts/hour (87 Hz). The shower events recorded in each hour were then classified into the "east" and "west" (E- and W-) groups according to the geographical longitude of the incident direction of each shower.

In obtaining the average daily variations, we eliminate the variations common for all the incident directions, simply by subtracting the variation in W-group from that in the E-group. As this subtracted variation can be regarded as the "derivative" of the original variation with respect to the time, we can reconstruct the original variation free from the common variations by "integrating" the subtracted variation [2]. We also notice that there is a significant non-uniformity in the observation period through each year. The average duty cycle exceeds 90 % in December and January, while it is below 50 % in September and October. In the present analysis, we also correct the average daily variation for this non-uniformity.

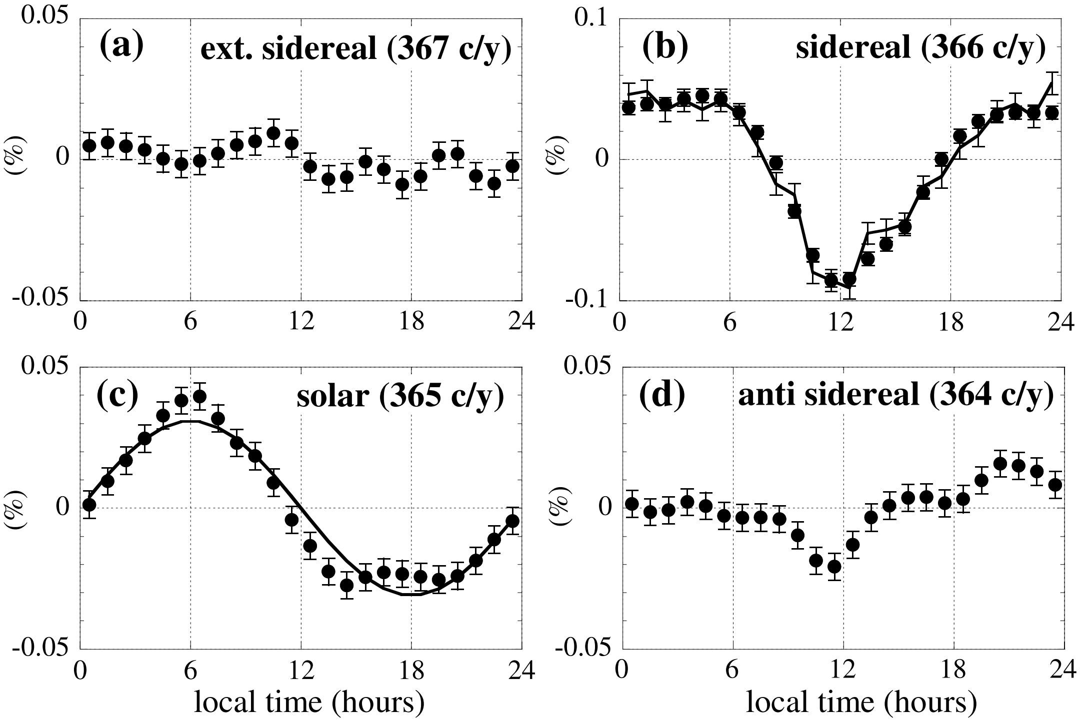

Fig. 1. The average daily variations in the extended-sidereal (a), sidereal (b), solar (c) and anti-sidereal times (d). The variation expected from the CGA is plotted by the solid curve in (c). The error bars connected by the solid line in (b) show the SDV reported by the Mt.Norikura air shower experiment [2].

3. Results and Conclusions

Fig.1 shows the average daily variations in the extended-sidereal (367 cycle/year), sidereal (366 c/y), solar (365 c/y) and anti-sidereal (364 c/y) times obtained from the present analysis. We deduced the errors by applying the identical analysis method to the count-rate time series produced by numerical simulations taking account of the counting rate errors. This is needed because the variations in this figure are "integrated" with respect to the time and the data points in the figure are not independent to each other.

As seen in Fig.1(a), the average variation in the extended-sidereal time is not significant anymore. This suggests that the significant variation reported in [1] was due to the non-uniformity in the observation period, for which the average variation is corrected in the present analysis. At the same time, the variation in the solar time in Fig.1(c) also becomes consistent with the variation expected from the CGA plotted by the solid curve. The first harmonics of the observed variation in Fig.1(c) has the amplitude of 0.032±0.001 % and the phase of 5.69±0.17 hrs, while the variation due to the CGA is expected to have the amplitude of 0.031 % and the phase of 6.01 hrs. This is the most precise measurement of the CGA ever reported in this energy region (see [3] for a comparison).

It is seen in Fig.1(b) that the SDV remains significant in a good agreement with the variation observed by the Mt.Norikura air shower experiment [2]. The variation in the anti-sidereal time in Fig.1(d), however, is also significant with the amplitude of about 0.01%, indicating that a small spurious variation is still remaining in the average variation. Further analysis is needed to identify the origin of such variation and eliminate it from the average variation.

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5. References

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