Sidereal diurnal variations of cosmic rays in the energy range < 300 GeV

S K Gerasimova, P Yu Gololobov, P A Krivoshapkin
G F Krymsky and G S Pavlov
Yu.G. Shafer Institute of Cosmophysical Research and Aeronomy of Siberian Branch of the Russian Academy of Sciences, 31 Lenin Ave., 677980 Yakutsk, Russia
E-mail: s.k.gerasimova@ikfia.ysn.ru

Abstract. Based on data of long-term measurements of muon intensity at the surface and underground on the depth of 7, 20 and 60 m w.e. at Yakutsk (62°01′ N, 129° 43′ E) the sidereal and antisidereal variations of galactic cosmic rays during periods of positive and negative epochs of the general magnetic field of the Sun.

1. Introduction
Study of sidereal-diurnal variations at IKFIA began from the analysis of data of the continuous registration of cosmic ray rigid component intensity with the ionization chamber ASK-1. In [?] the average change of sidereal-diurnal variation was found with the help of a method of Darwin with the amplitude 0.06±0.002 % and maximum time 22.9±0.5 hours by local time. Later the data of the crossed telescopes were involved. For example, in [?] the analysis of the data for 1958-1960 obtained by means of the muon telescopes located at different depths was given. The author made the following conclusions:
- on the ground surface the time of sidereal-diurnal wave maximum for the northern telescope falls at the earlier time than for the southern telescope;
- on the depth of 7 m w.e the amplitudes of sidereal and antisidereal waves within errors are equal among themselves but phase differences of 6 hours between northern and southern telescopes are observed;
- on the depths of 20 and 60 m w.e. the antisidereal variation is absent, while a sidereal wave on the depth of 20 m w.e. exists;
- at all levels of registrations the identical tendency of discrepancy of sidereal-diurnal wave phases by readings of telescopes directed to the north and to the south, respectively, is observed. The first northern telescopes, as a rule, show the earlier time of maximum than the last ones.
Later investigation of sidereal-diurnal variations were continued in [?], [?], [?].

In recent years the interest to the sidereal-diurnal variations of cosmic ray intensity in the range of Tev - energies registered with the major arrays grows all over the world.

2. The Yakutsk spectrograph of cosmic rays
At present the cosmic ray intensity is registered with the neutron monitor and muon telescopes located on the ground surface and on the depths of 7, 20 and 40 m w.e. The registration data
Table 1. The observed sidereal-, antisidereal-daily variations at negative and positive polarity.

| Polarity | Sidereal |          | Antisidereal |          | Sidereal |          | Antisidereal |
|----------|----------|----------|--------------|----------|----------|----------|--------------|
|          | Amp., %  | Phase, h | Amp., %      | Phase, h | Amp., %  | Phase, h | Amp., %      | Phase, h |
| V 0      | 0.040    | 17.6     | 0.034        | 3.1      | 0.008    | 21.5     | 0.021        | 3.8      |
| V 7      | 0.028    | 19.3     | 0.018        | 2.0      | 0.014    | 22.0     | 0.013        | 1.5      |
| V 20     | 0.024    | 18.9     | 0.021        | 1.8      | 0.018    | 23.4     | 0.013        | 1.2      |
| V 60     | 0.021    | 20.4     | 0.019        | 1.4      | 0.013    | 23.3     | 0.004        | 23.3     |
| ASK      | 0.014    | 12.3     | 0.007        | 14.5     | 0.024    | 15.2     | 0.005        | 17.9     |
| N 0      | 0.026    | 15.5     | 0.033        | 5.9      | 0.006    | 19.4     | 0.020        | 5.9      |
| N 7      | 0.051    | 20.1     | 0.024        | 1.4      | 0.014    | 23.3     | 0.015        | 0.0      |
| N 20     | 0.045    | 20.5     | 0.026        | 0.5      | 0.020    | 0.4      | 0.025        | 23.4     |
| S 0      | 0.046    | 19.5     | 0.031        | 1.8      | 0.014    | 23.1     | 0.020        | 0.9      |
| S 7      | 0.020    | 18.3     | 0.026        | 7.2      | 0.015    | 21.9     | 0.018        | 5.2      |
| S 20     | 0.016    | 15.2     | 0.007        | 6.8      | 0.014    | 21.1     | 0.012        | 5.0      |

are available at http://www.ysn.ru/ipm/. In database there are the registration data for many years by the ionization chamber ASK-1 (1953-2004), and data of the neutron monitor and muon telescopes since 2003. At the site there is also the information on acceptance characteristics of muon telescopes.

3. Data analysis and discussion
In this work the data of muon telescopes for 1972-2011 are used. The data are divided into periods of the negative and positive polarity of the general solar magnetic field. Table 1 lists the amplitudes and phases of the first harmonics of sidereal- and antisidereal-daily variations.

During the period of negative polarity the amplitude of sidereal-diurnal variation is higher than during the positive polarity for all directions of registration (a vertical, the north 30°, the south 30°). In this case the sidereal-diurnal variation amplitude with the depth of registration decreases for the vertical and southern telescopes, and for the northern telescope the reverse is true (as the depth increases, the amplitude increases). It is manifested more brightly at negative polarity, than at positive one.

4. Conclusions
Dependence on the polarity of the general magnetic field of the Sun may indicate that the sidereal-diurnal variations are of heliospheric origin. Phase of sidereal-diurnal variations is approximately the 19 hour local time, which may indicate the existence of an anisotropic flow perpendicular to the axis of rotation of the Sun.

Acknowledgments This work was supported by the Russian Foundation for Basic Research (projects Nos. 12-02-98506 and 12-02-98507), Program No. 10 of the Presidium of the Russian Academy of Sciences, and grant No. NSH-1741.2012.2 from the President of Russia for support of leading scientific schools.

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Figure 1. Observed sidereal-daily (black line) and antisidereal-daily (red line) variations in the local sidereal and antisidereal time for various registration levels at negative polarity.

Figure 2. Observed sidereal-daily (black line) and antisidereal-daily (red line) variations in the local sidereal and antisidereal time for various registration levels at positive polarity.

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Figure 3. Sidereal- and antisidereal-daily variations for the North telescope at negative polarity.

Figure 4. Sidereal- and antisidereal-daily variations for the North telescope at positive polarity.

Figure 5. Sidereal- and antisidereal-daily variations for the South telescope at negative polarity.

Figure 6. Sidereal- and antisidereal-daily variations for the South telescope at positive polarity.