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North-south anisotropy of cosmic rays and the IMF neutral surface

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The dependence of the north-south cosmic ray anisotropy on the Earth's distance to the neutral surface of interplanetary magnetic field (IMF) is investigated. It is shown that the value of this anisotropy increases with away from the neutral surface, and its direction depends on both the polarity of general magnetic field of the Sun and the IMF sector sign.

1. Introduction

The neutral surface (current sheet) of heliomagnetosphere, separating the heliospheric magnetic field into two hemispheres of opposite sign, essentially influences on the galactic cosmic ray modulation. The value of the sheet deformation increases from minimum to maximum of solar activity, the neutral sheet is most often manifested in the form of two- or four- sectorial structure.

In the previous works [1], [2], the dependence of the cosmic ray intensity on the value of IMF neutral sheet deformation was shown. In [3] it was established that the long-term modulation of cosmic rays by solar wind depended on both the neutral sheet deformation, and the solar activity level. However, the relative contribution of the two factors depends on the polarity of general magnetic field of the Sun. At the positive polarity the influence of the solar activity level, and at the negative polarity the cone angle of neutral sheet dominate. Such circumstance is in conformity with known concepts of a drift of cosmic rays in the IMF.

A number of works [4]-[10] is devoted to a problem of the influence of the neutral sheet on the north-south cosmic ray anisotropy. In some works [5]-[7], [9] it is emphasized that the north-south anisotropy depends on solar activity but it weakly depends on the Sun's magnetic cycle. In [8] it is shown that the orientation of this anisotropy depends not only on the IMF sign, but the polarity of general magnetic field of the Sun as well. The north-south anisotropy is characterized by the hard energy spectrum [4], [8]. The present work is the continuation of [8].

2. Discussion

As an indicator of the north-south anisotropy, the mean daily values of muon cosmic ray intensity at the Nagoya station are used registered with the telescopes at an angle of 49° relative to the zenith to the south (S2), east (E2), north (N2) for the period of 1980 to 1998. The combination of those directions forms a component GG=(N2-E2)+(N2-S2) most sensitive to the north-south anisotropy [11], [12]. In the subsequent text, it will be denoted as A_{NS}. Data on the IMF neutral current sheet are taken from the work [13]. The angular distance from the Earth's heliolatitude to the neutral sheet is taken for the distance χ of the neutral sheet. The positive value of χ is the reference of an angle to the north of the Earth's heliolatitude. To identify the values of A_{NS} to the angle χ, the average solar wind propagation speed is taken as 400 km/ s. Fig. 1 presents, as an example, the temporal change of the neutral sheet χ and the cosmic ray north-south anisotropy A_{NS} for 1984 and 1994. Those years are the cases of the negative ($qA < 0$) and positive ($qA > 0$) polarity of general magnetic field of the Sun, respectively. The long-term trend has been excluded of the temporal change of A_{NS}. In the above years the two-sectorial structure is dominant. Note that at $qA < 0$ the negative correlation, and at $qA > 0$ the positive correlation between A_{NS} and χ are observed. The correlation coefficient between them varies within

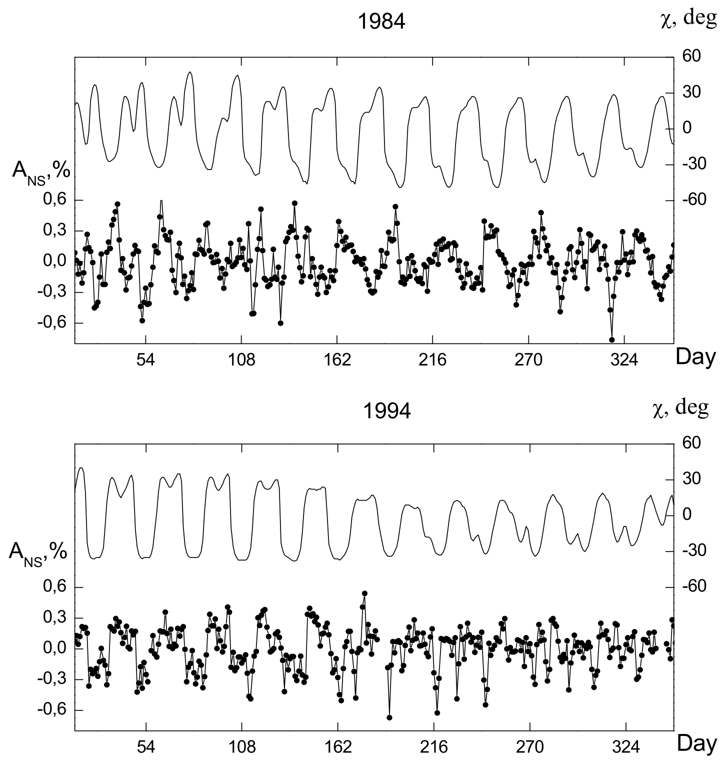

Figure 1. Variations of heliolatitude of the IMF neutral current sheet χ and north-south cosmic ray anisotropy A_{NS} in 1984 and 1994.

the limits of -0.6 to 0.6 and apparently has the 22-year periodicity (Fig. 2). Thereby, the correlation disappears during a sign-change of general magnetic field of the Sun.

Fig. 3 demonstrates the dependence of the north-south anisotropy A_{NS} observed on the Earth's distance to the IMF neutral sheet χ for two epochs of the Sun's magnetic dipole orientation ($qA < 0$ and $qA > 0$). As can be seen, the absolute value of north-south anisotropy increases with away the neutral sheet from the Earth. A sign of the anisotropy orientation depends on both the sign of IMF sectors and the sign of the Sun's magnetic dipole orientation. So, for example, in 1992-1998 ($qA > 0$) in the region of heliosphere with the negative field direction with away from the neutral surface, the positive north-south anisotropy increases, and in the case when the Earth moves away from the current sheet, while in the heliosphere region with the field positive sign, the negative anisotropy increases. The inverse dependence of A_{NS} on the current sheet position is observed in 1980-1989. Therefore, the magnetic field sign in that hemisphere, where is the Earth, plays a role. Such a feature of the anisotropy points to its gradient origin. The anisotropy can be as a consequence either heliolatitudinal or radial gradient. The heliolatitudinal gradient directs from the neutral surface in the case of the positive polarity and at the negative polarity it directs to the neutral surface. The anisotropy is produced by the transverse diffusion. In the positive sector of magnetic field the anisotropy consequently has the positive

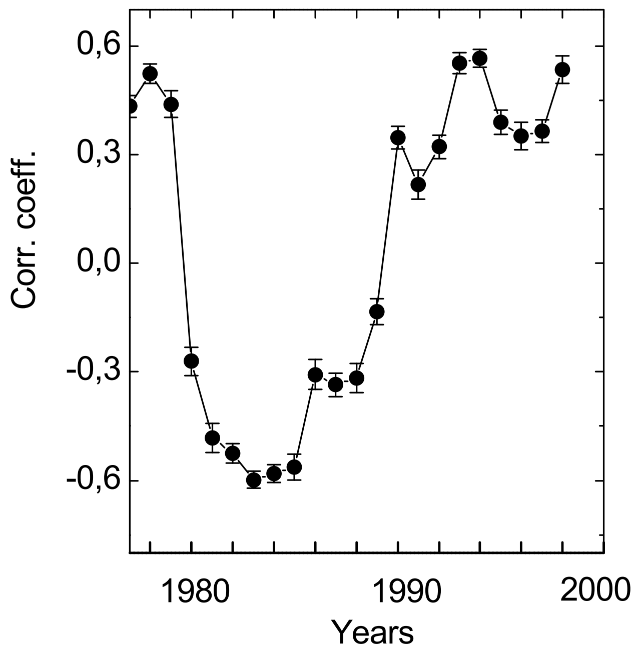

Figure 2. Correlation coefficients between χ and A_{NS}.

sign independently of the field polarity. The radial gradient is always positive, and the anisotropy is of the negative sign in the positive sector of magnetic field independent of the total polarity also. The dependence observed argues for the predominance of the action of the radial gradient.

As shown in the works [4], [8] the north-south anisotropy is of the hard energy spectrum. To estimate the initial anisotropy value, the receiving vectors [11] are used. At the distance of the Earth from the neutral sheet equal to $|\chi| = 40°$, the initial anisotropy is 0,26 % and 0,11 % for the epochs $qA > 0$ and $qA < 0$, respectively.

3. Conclusions

The sign of the north-south anisotropy within the limits of one Sun's rotation depends on the sign of IMF sectors. In the positive sector the anisotropy is negative independently of the magnetic dipole orientation and is produced by the radial gradient. The value of anisotropy increases with away of the Earth from the neutral current sheet.

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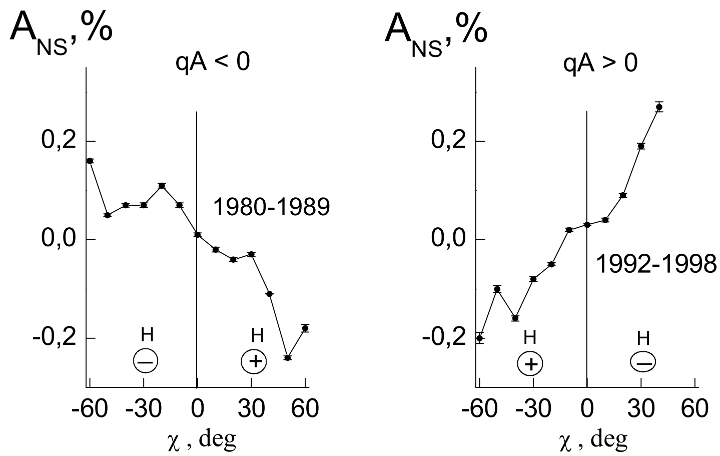

Figure 3. Cosmic ray north-south anisotropy, A_{NS}, versus the angular distance of the Earth to the current sheet χ at different epochs of the Sun's magnetic cycle.

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