GALACTIC COSMIC RAY CURRENTS AND MAGNETIC FIELD IRREGULARITY DEGREE IN HIGH-SPEED SOLAR WIND STREAMS

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ABSTRACT

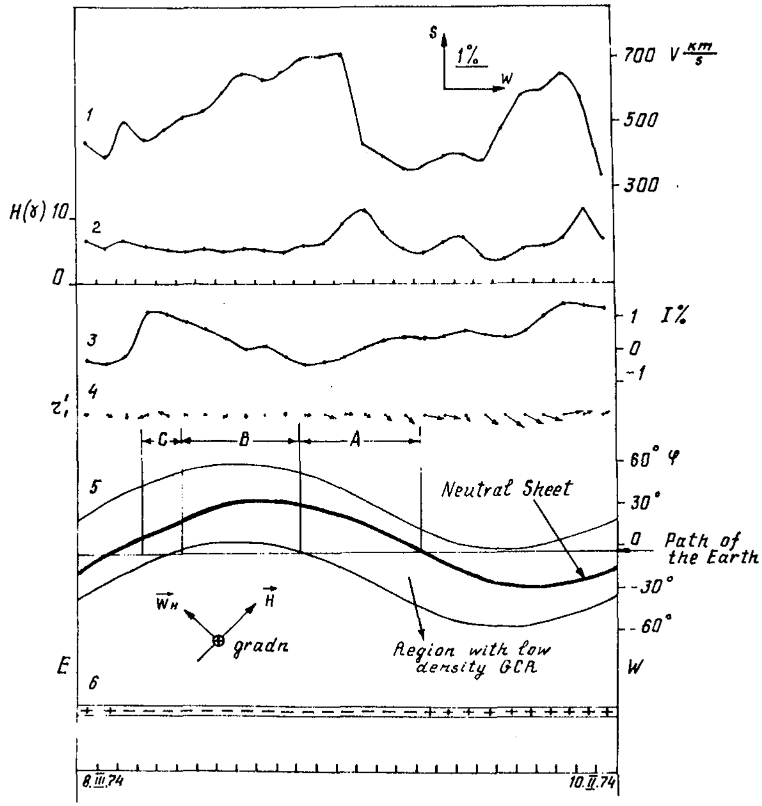
Currents of galactic cosmic rays (GCR) obtained by global survey method are analyzed. The cases of almost total disappearance of GCR currents are compared with the results of direct measurements of the solar wind parameters. The conclusion is made on a restricted application of the convective-diffusive mechanism of the GCR modulation by the solar wind during the occurence of stationary and regular magnetic fields in the interplanetary medium.

1. Introduction. The cases of almost total disappearance of the GCR currents in a body of the recurrent high-speed streams of the solar wind during three rotations of the Sun for 1974 were indicated in [1] . Here we consider in detail the above phenomenon using the results of direct measurements of the solar wind and interplanetary magnetic field parameters [2] .

2. Results. We used hourly values of the GCR currents obtained by the global survey method [3] on neutron monitor world net data.

As it is known [4] 1973-1974 were characterized by the existence near the Earth of very wide and stable high-speed streams of the solar wind from polar coronal holes. In January - March 1974 the two-sector structure of IMF with noticeably predominance of the negative sector were observed. At this time there were no significant flare origin disturbances of the wind. The GCR intensity was close to the almost unmodulated level which is characteristic for the solar activity minimum in 1976 and it then began to decrease probably due to the solar activity increase.

In the Figure the solar wind speed V , strength H and signs of IMF, intensity I and diurnal values of the GCR currents $\mathfrak{Z}_1^1$ for one rotation of the Sun for 1974 are shown. The $\mathfrak{Z}_1^1$ are shown as arrows the direction and length of which coincide with the direction and value of currents in the solar-earth coordinate system (scale is at the top). The Earth's position with respect to the neutral IMF sheet during one rotation of the Sun is schematically shown. The



The parameters of the solar wind, IMF and GCR for February 10 and March 8, 1974.
1 - solar wind speed, 2 - IMF strength,
3 - isotropic GCR intensity, 4 - GCR currents in the solar-earth coordinate system, 5 - a scheme of a modulation region of GCR in the solar wind high-speed streams, 6 - the signs of IMF

Earth's heliolatitude corresponds to the analyzed period. The maximum heliolatitude of the neutral sheet was observed to be +30° [5] and it corresponds to the largest removal of the Earth's orbit by 0.5 AU in the meridional plane. In the first narrow high-speed stream the Earth is within the modulation region and the currents behave themselves usually. Therefore we consider here the behaviour of the GCR currents only in the second, wider streams. The velocity of the solar wind stream up to values ~ 700 km/s the IMF strength increases up to 10 γ and the GCR intensity insignificantly (~ 1%) decreases.

According to the behaviour of the GCR currents the whole considered period can be divided into three parts (Figure, A, B, C). During period A when the Earth enters the high-speed stream an is in the region of the decreased GCR density, the currents have the usual azimuthal direction and the value according to the convective-diffusion mechanism. In 3 days after the IMF disturbance the GCR currents almost completely disappear (their value is within the accuracy of hourly measurements $\sim 0.1\%$, direction is unstable) (period B). This period lasts ~ 6 days to its end the intensity is insignificantly re-recovered.

During period C ~ 3 days before the arrival of the next sector boundary the GCR currents (significant in value) are eastward from the Earth-Sun line nearly perpendicular to IMF force line (about 5-6 hours LT in terms of the GCR anisotropy).

Similar behaviour of the GCR currents which is characteristic for each A,B,C periods was observed at passage of the same high-speed stream in two preceding rotations of the Sun [1].

3. Discussion. In [6] it was established that in the body of recurrent high-speed streams emitted from the coronal holes the IMF irregularity degree $F = D_{\perp}/D_{\parallel}$ is almost zero. Therefore on such streams the GCR modulation takes place only in a narrow region located from both sides of the neutral IMF surface. Based on such conceptions we try to understand the observed behaviour of GCR currents in recurrent high- speed streams.

As it is known [3] the GCR current can be presented as follows: $\vec{W} = \vec{W}_c + \vec{W}_d + \vec{W}_H$,

where $\vec{W}_c$ is the current caused by convection of particles by the solar wind, $\vec{W}_d$ is diffusive stream, $\vec{W}_H$ is diffusion caused by perpendicular density gradient known as the Hall's current.

In part A, in the region with the decreased density the GCR currents are due to convection and diffusion according to the above expression. In region B which is mostly remoted from the neutral sheet in equatorial and meridional planes the Earth falls into the regular and stationary IMF where there are no any scattering centers. In such a field by [7] the convection and the diffusion are absent and the Hall's current [3] appears only when there are density gradients. In the case of the regular field the GCR density gradients will exist at the distance of only one Larmor radius from the boundary of region with decreased density (in our case $\rho \approx 0.04$ AU). As it is seen from the Figure in the region B the GCR density gradient and therefore the Hall's current will not be observed.

In region C the approach of the next sector boundary or of the neutral sheet will be manifested as the Hall's current occurence on a scheme shown in the bottom of the Figure. And the current of the aligned diffusion in this region will be absent while the next sector boundary will arrive since IMF force lines connect the Earth with the west undisturbed hemisphere of the Sun.

For a totally regular field we can write [3] :

$$\vec{W}_H = \left[\frac{\vec{H}}{H} \times \nabla_{\perp} I\right].$$

If the value of GCR currents in region C is known one can estimate the value of the GCR density gradient perpendicular to ecliptic plane ($\nabla_{\perp} I \approx 8\%/AU$).

On the other hand, if the stream is stationary then a radial density gradient at the next disturbance of GCR intensity estimated on $\frac{\partial I}{\partial t} = - \nabla_z \vec{V}$ is $\nabla_z I \approx 4\%/AU$.

Both obtained values of gradients do not contradict each other if to take into account the flattening of the GCR modulation region to the neutral sheet.

4. Conclusion. From the above one can conclude the following:

a) In recurrent solar wind high-speed streams from polar coronal holes observed in 1973-1974 the IMF inhomogeneities causing GCR modulation are located only in a relatively narrow region near the neutral sheet. In some favourable cases (January - March 1974) when this sheet is located far enouth, the Earth can get into the region of IMF with superhigh regularity degree where the GCR modulation is practically absent.

b) In such fields the GCR currents (anisotropy) are absent since neither convection nor diffusion of particles exist. At approach of the neutral sheet the Hall's current can occur because of occurence of perpendicular density gradients.

References.

1. Samsonov, I.S. et al., (1981), Proc.17-th ICRC, Paris, 3, 310.
2. King, I.H., (1977), Interplanetary Medium Data Book, Greenbelt.
3. Krymsky, G.F. i dr., (1981), Kosmicheskie luchi i solnechnyi veter, Novosibirsk, Nauka.
4. Kovalenko, V.A., (1983), Solnechnyi veter, Moskwa, Nauka.
5. Samsonov, I.S. et al., (1979), Proc.16-th ICRC, Kyoto, 3, 481.
6. Korzhov, N.P., (1982), Karty polyarnostei globalnogo magnitnogo polya Solntsa i konfiguratsiya mezhplanetnogo tokovogo sloya v 1971-1978. Irkutsk.
7. Stern, D., (1964), Planet.Space Sci., 12, 973.