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STUDY OF NORTH-SOUTH ASYMMETRY IN RELATIVISTIC ALPHA-PARTICLE INTENSITY

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Abstract

The results of measuring the north-south (N-S) asymmetry in relativistic alpha-particle intensity on board Cosmos-900 satellite are presented and discussed. The data presented are analyzed in terms of some model representations.

Studying the N-S galactic cosmic ray intensity asymmetry yields information on the modulation processes relevant to the galactic cosmic ray particle motions in interplanetary magnetic fields, for the degree of the particle isotropy beyond the heliosphere is very high (the anisotropy amplitude in the 10^{10}-10^{15} eV range fails to exceed 0.1% [1,2]).

A few mechanisms can be responsible for the particle intensity asymmetry in the heliosphere [3-5]. This aspect of the problem was studied in some experiments [6-9]. However, the experiments dealt mainly with protons and did not give any direct experimental evidence for alpha particle behaviour.

In the present work, the alpha-particle intensity asymmetry data have been inferred from the Cosmos-900 Cerenkov detector readings. The detector radiator was a 30-cm diameter acrylic plastic sphere. The instrument had a few digital channels to record relativistic particles of different charges, including those above unity and above two [10].

The nearly circular orbiting Cosmos-900 (a ~500 km orbital altitude, an 83^o orbit inclination to the equator plane) was launched on March 30, 1977 and made measurements until October 30, 1979. During the measurement period, the solar activity was rising, while the measured galactic particle intensity was decreasing [11]. The orbital altitude was also decreasing, but the orbit remained essentially circular. In any case, the difference in orbital altitudes did not affect the results of measuring the intensity asymmetry.

The figure shows the data from one of the satellite orbits and presents the readings of three channels that recorded the $Z \geq 2$ relativistic particles. The data displayed in the figure correspond to the satellite motions from the equator to the North pole, then to the equatorial regions again, and, after that, to the southern polar cap. The expressed broken shapes of the curves are due, first f all, to the telemetry resolution (3-5%) because the data acquisition time was 20 s and the statistical support was sufficiently high (1.5-2.0% for the first channel that recorded the relativistic alpha-particles). The counter was mounted outside the satellite in such a way that, as the satellite moved northwards, the instrument was open for the particles arriving from the east and was partly shielded by the satellite matter against the particles arriving from the west. In the case of southward satellite motion, the shielding situation reversed as regards the east-west direction. Obviously, the shielding effects prove to be noticeable when the satellite flies through the equatorial regions and do not affect the measurement results in the polar caps.

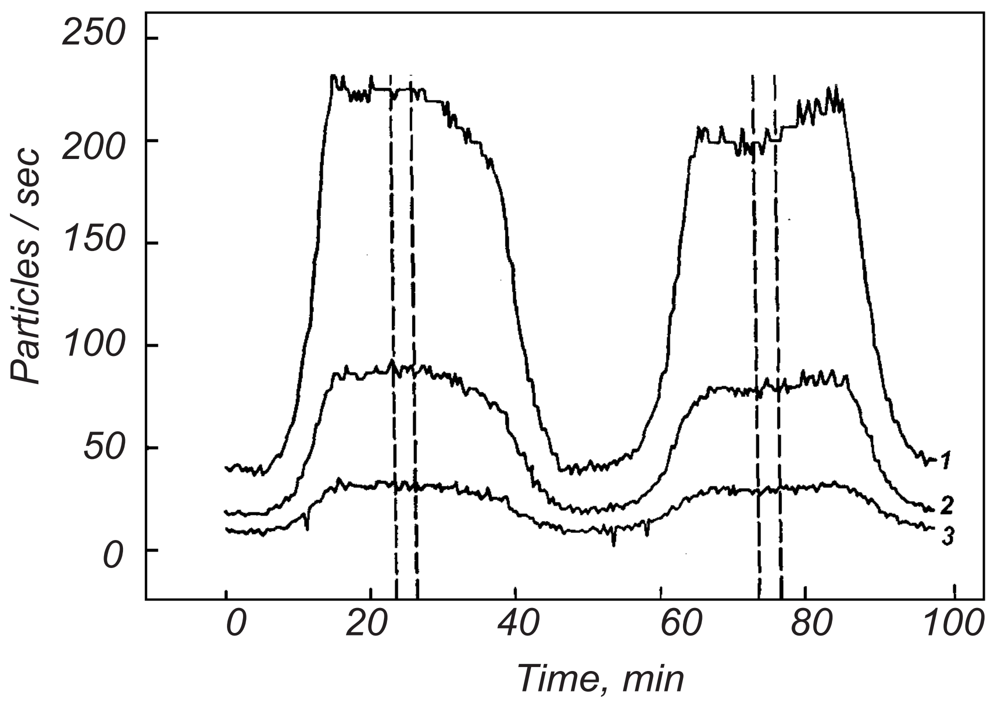

Figure 1: The alpha-particle intensity versus flight time for three measurement thresholds in the northern and southern hemispheres in one of the Cosmos-900 orbits. Curve 1 is the >500 MeV/nucleon data. Curve 2 is the >800 MeV/nucleon data. Curve 3 is the 1200 MeV/nucleon data. The vertical dashed lines are magnetic shells L = 20. The measurement period was from 2252UT on March 29 to 0024UT on March 30, 1979.

The impact of the magnetospheric effects (radiation belts, particle precipitations, return albedo particles) on the asymmetry was eliminated by selecting only the flight trajectory sectors where the magnetic shell parameter $L > 20$, with subsequent averaging over all orbits for 24 hours in either of the hemispheres. The galactic cosmic ray flux asymmetry can be found by different methods. In the case of the balloon and satellite measurements, however, the asymmetry must obviously be determined to be a ratio of the difference in the fluxes measured in the northern (N_N) and southern (N_S) hemispheres to their half-sum, i.e.,

$$A = 2(N_N - N_S)/(N_N + N_S).$$

The table below presents the asymmetry data obtained by averaging the readings of three channels displayed in the figure. From the table it follows that the asymmetry is mainly positive, is characterized by large fluctuations, and, as a whole, increases with time (though, formally, the asymmetry maxima were observed in 1978). On the average, the asymmetry increased with alpha-particle energy during the measurement period March, 1977 to October, 1979, although this trend was not observed during all the measurement runs [12].

1977		1978				1979	
Date	A%	Date	A%	Date	A%	Date	A%
June 6	0,79	Jan. 30	6,6	Sep. 24	4,27	Jan. 10	2,4
June26	-1,93	Jan. 31	8,23	Oct. 3	5,15	March 19	4,6
Oct. 11	4,2	Feb. 7	9,1	Oct. 11	1,57	March 25	8,3
Nov. 17	0	March 17	4,6	Dec. 10	5,77	Aug. 16	4,2
Nov. 17	0	March 26	3,97	Dec. 15	6,87	Aug. 23	2,1
Nov. 23	4,0	May 5	4,37	Dec. 18	6,6	Aug. 26	2,43
Dec. 4	4,0	July 30	-1,47	Dec. 24	6,2		
Dec. 8	3,13	Sep. 19	5,6				
<A> = 1,77 %		<A> = 5,6 %				<A> = 4,01 %	

Thus, as a whole, the data obtained agree with the measurement results of the channels that recorded the $Z \geq 1$ particles [9]. The agreement between the $Z \geq 1$ and $Z \geq 2$ data indicates that the measured asymmetry is due to the cosmic ray nuclear component, rather than to, for example, detection of secondary electrons from the atmosphere. In work [9] it is also noted that, for the above mentioned measurement period, the Cosmos-900 data are in a good agreement with the stratospheric data as regards the energy and time dependence and the sign of the asymmetry and disagree with the measurement on the Meteor satellite, which indicated a negative asymmetry.

Let the above results be examined in terms of some model representations. The drift model [3,4] establishes that protons and other positively-charged particles drift towards the helioequator during the parallel orientation of the rotation vector and magnetic moment of the Sun. The asymmetry is positive in the northern heliosphere (the positive sector) and negative in the southern hemisphere (the negative sector). Under sign reversal in the Sun's general magnetic field, the drift direction changes, but, as before, $A > 0$ in the positive sectors and $A < 0$ in the negative sectors [8]. In that case, the drift velocity and, hence, the *A* values depend on field line curvature and on magnetic rigidity of particles. The *A* values rise with increasing the curvature and the rigidity. The magnitude of the effect due to this mechanism can readily be estimated.

It is well known that $u/c \sim \rho/r$, where u is drift velocity; c is particle velocity; ρ is Larmor radius of particles; r is radius of field line curvature. Let the estimation be made for protons. If $E_{kin} \sim 1$ GeV, then $\rho = 10^{11}$ cm, whereas $r \sim 10^{13}$ at a 300 km.s^{-1} solar wind velocity, i.e., $u/c \sim 10^{-2}$. Obviously, the real field lines differ from the Archimedean spiral, so the r value may be much lower. That is, in the case of protons and, especially, alpha-particles at identical energies per nucleon the given mechanism can support an asymmetry of a few percent.

The asymmetry can also arise from the inequality between the solar wind velocity and the Sun's rotation angular velocity in the northern and southern hemispheres [5]. This mechanism fails also to result in the *A* sign reversal depending on particle energy, which was noted in [9] for protons.

We are of the opinion that the effect of the diffusion mechanism should not be disregarded. Namely, the cosmic ray intensities and number densities may be different in the northern and southern hemispheres of the heliosphere because of a different solar activity of the Sun's northern and southern hemispheres. In such a situation the *A* value may prove to be energy-dependent, while the drift mechanism effect reduces, in the general case, to a variation, rather than sign reversal, of the asymmetry.

REFERENCES

1. Cosmic Ray Astrophysics, ed. by V.L.Ginzburg, Nauka, Moscow, 1984, p.357.
2. L.I.Dorman. In: Problems in Cosmic Ray Physics, Nauka, Moscow, 1987, p.65.
3. H.Moraal, L.T.Gleeson, G.M.Webb. Proc. 16th ICRC, Kyoto, 1979, v.3, p.1.
4. G.M.Webb, L.T.Gleeson, H.Moraal. Proc. 15th ICRC, Plovdiv, 1977, v.3, p.12.
5. J.W.Bieber. J.Geophys.Res., 1988, v.3, No.A6, p.5903.
6. S.I.Avdyushin, N.K.Pereyaslova, Yu.M.Kulagin, N.N.Nazarova, I.E.Petrenko. Izv. Akad. Nauk SSSR, ser. fiz., 1981, v.45, No.4, p.612.
7. N.K.Pereyaslova, P.E.Pokrevsky, Yu.I.Stozhkov. Izv. Akad. Nauk SSSR, ser. fiz., 1988, v.52, No.12, p.2010.
8. E.V.Gorchakov, V.A.Iozenas, Yu.V.Mineev, M.V.Ternovskaya. Izv. Ross. Akad. Nauk, ser. fiz., 1995, v.59, No.4, p.113.
9. K.G.Afanasiev, E.V.Gorchakov, V.A.Iozenas, M.V.Ternovskaya. Izv. Akad. Nauk SSSR, ser. fiz., 1991, v.55, No.10, p.1010.
10. E.V.Gorchakov, V.A.Iozenas, M.V.Ternovskaya, V.G.Afanasiev, K.G.Afanasiev. Kosmich. Issl., 1981, v.19, No.2, p.310.
11. E.V.Gorchakov, V.G.Afanasiev, K.G.Afanasiev, V.A.Iozenas, P.P.Ignatiev, M.V.Ternovskaya. Kosmich. Issl., 1988, v.26, No.2, p.331.
12. E.V.Gorchakov, V.A.Iozenas, M.V.Ternovskaya. Izv. Ross. Akad. Nauk, ser. fiz., 1997, v.61, No.6, p.1134.