Proceedings of ICRC 2001: 3948 © Copernicus Gesellschaft 2001

ICRC 2001

North-south asymmetry in the electron and proton fluxes: dependences on their energy and on solar activity

E. V. Gorchakov and Yu. V. Mineev

Skobeltsyn Institute of Nuclear Physics, Moscow State University; 119899 Moscow, Russia.

Abstract. The value and sign of the North-South asymmetry in the electron and proton fluxes of low (E_e = 0.19-3.0 MeV, E_p = 1.0-60.0 MeV) and high ($E_e \geq$7.0 MeV, $E_p \geq$ 500.0 MeV) energies are studied as dependent on the particle energy. The Cosmos-900, Ohzora, and Intercosmos-19 (polar caps) data are used. The North-South asymmetry value and sign are treated to depend on solar activity and on the IMF sector structure and sign (Gorchakov et al.,1987). The high-energy data show that concentrations of galactic cosmic rays in the northern and southern heliosphere may be different with the excess value and sign being dependent on particle energy. The IMF sector structure effect reduces usually to variations in the value, rather than sign, of the asymmetry (Gorchakov et al., 1997). The North-South asymmetry in the low-energy electron fluxes is mostly negative during positive B_z and sunward IMF (Gorchakov et al.,1995). The value of the asymmetry in galactic cosmic rays has been found to increase little with rising energy, and the asymmetry sign to reverse during the solar maximum. The asymmetry sign of the low-energy electron fluxes is predominantly opposite in phase to the high- and low-energy proton fluxes. The drift effects are assumed to depend on the product of the signs of particle charge and IMF sector, rather than on either of the signs separately.The results are compared with the ballon and satellite Meteor measurements in 1977-2000 years.

1. Introduction

Studying of the north-south asymmetry in cosmic rays helps us get a deeper insight into the processes of cosmic ray propagation and modulation. This work presents the magnitude and sign of the north-south asymmetry in charged particles of low energies (the >1.0 MeV protons and the >0.19 MeV electrons) and high energies (the >400 MeV protons and α-particles) inferred from measurements on Cosmos-900, Intercosmos-19, Ohzora, and some other satellites. The unique experiment to study the north-south asymmetry in the relativistic protons and α -particles was made during solar activity rise from the minimum to the maximum in 1977-1979 on the Cosmos-900 satellite (a 500-km altitude, 83^{o} inclination, circular-orbit). The 400-2200 MeV proton north-south asymmetry has been shown to increase with rising energy and solar activity. It has been concluded that the >400 MeV proton number density was higher in the southern heliosphere in the beginning of the experiment, while the high-energy (up to 2200 MeV) proton number density was higher in the northern heliosphere throughout the observation period. Studying the >400 MeV/nucleon α-particle fluxes has confirmed the earlier conclusions concerning the asymmetry dynamics of the relativistic protons and demonstrated that the electron fluxes are insignificant and can be disregarded. The large-aperture Čerenkov detector asymmetry readings are unique for the relativistic protons and in α-particles and were obtained first for the α-particles. During the same period (in solar maximum of 1979 and in solar minimum of 1986), Intercosmos-19 and Ohzora measured the north-south asymmetry of low-energy protons and electrons. The measurements have demonstrated that the low- and high-energy particles are very different in their asymmetry dynamics, magnitude, and sign. Therefore, the low- and high-energy particle north-south asymmetry dynamics was studied as a function of the IMP sign and sectorial structure. The asymmetry magnitude has been found to depend on the IMP sign. The results are compared with the balloonborne and satellite (Meteor) measurements in 1977-1998.

2. Study of the galactic cosmic ray asymmetry

The Cosmos-900 experiment began in March 1977 and ended in October 1979. The initial orbital altitude was 500 km. Within that period, the solar activity level changed from its actual minimum to maximum (Cycle 21 began in the mid-year of 1976, the solar maximum was observed late in 1979). The asymmetry A (i.e., the northern-southern counting rate difference divided by the counting rate half-sum) was calculated for the periods without any solar cosmic ray flares and Forbush-effects. The polar cap data ($L\geq20$, $\Lambda\geq77^{o}$) alone were averaged. This restriction has eliminated the impact of geomagnetically-trapped radiation, albedo from opposite hemisphere, and latitude effects of cosmic rays

Initially, to eliminate the longitude dependence and to get a good statistical accuracy, the averaging was made over all orbits of a day. After that, the global variations were analysed by calculating the annual averages of 1977, 1978, and 1979. The resultant data have shown that the asymmetry magnitude does not exceed a few percent and increases with energy. In 1977, the asymmetry was negative at relatively low energies ($E_p \geq$400 MeV) and increased at higher energies. As solar activity rises, the low-energy particle flux must decrease, so the mean particle energy increases in each of the detection channels. The measurement data correspond this ideology and, therefore, we can conclude from the above experimental results that the low-energy cosmic ray concentration was high in the southern heliosphere in the beginning of the measurement period, whereas the high-energy concentration was higher in the

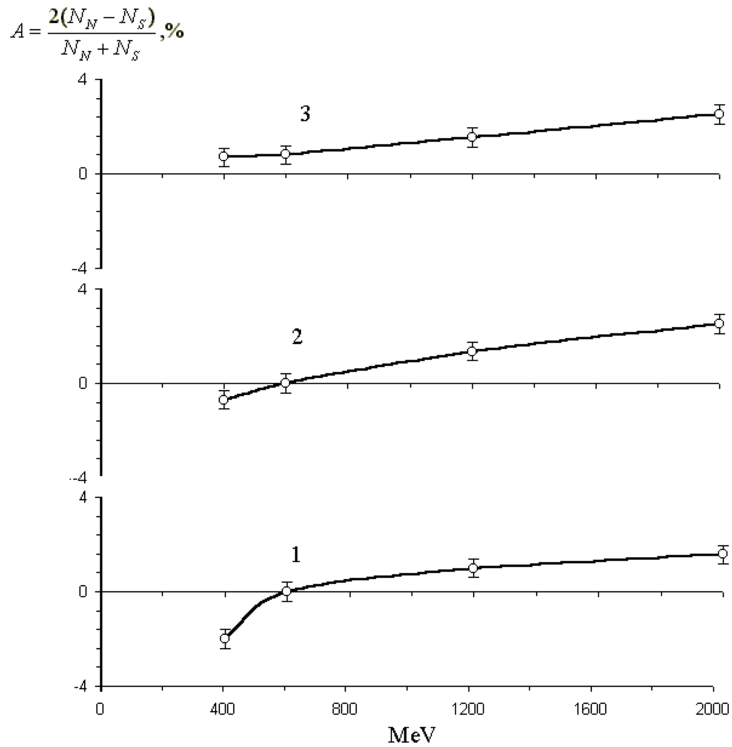

Fig.1. North-south galactic cosmic ray asymmetry versus energy. Curve 1 is for 1977, 2 – 1978, 3 – 1979

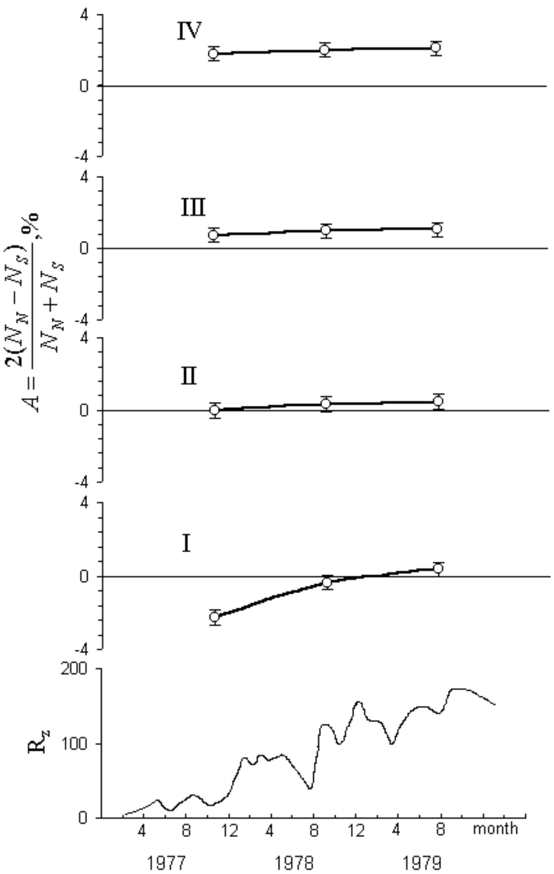

Fig. 2. Solar activity dependence of the north-south asymmetry.I –E> 400 MeV, II – E>600 MeV, III – E>1200 MeV, IV – E>2000 MeV.

northern heliosphere throughout the experiment. Fig. 1 illustrates that situation.Fig.2 shows magnitude A and sign of north-south asymmetry for of solar activity in 1977-1979 years.

It should be noted that relativistic electrons can also contribute to the counting rates of the low-energy detection channels of the instrument. However, the relativistic electron fluxes are low in the primary galactic cosmic rays, while the electrons produced in the satellite matter or in the Earth atmosphere by the galactic nuclear component can only reflect the Properties of that component and fail to affect the experimental results. To have an additional support to that reasoning, however, the asymmetry was also studied using the α-particle detection channels that cannot record protons and electrons. The results have confirmed the earlier conclusions. It would also be very interesting to seek for a dependence of the asymmetry on the IMF structure. Work (Gorchakov et. al. 1997) treats the feasibility of the dependence in terms of the drift model (Moraal et. al. 1997) and claim that the asymmetry as a whole is determined by the diffusion mechanism due to the difference of the galactic cosmic ray concentrations in the heliospheric hemispheres, whereas the drift mechanism can only change the magnitude, rather than sign, of the asymmetry.

3. Study of the low-energy cosmic ray asymmetry

Thus on the satellite "Ohzora" a study of energetic electrons 0.19 – 6.4 MeV in the magnetoshere of the Earth and in the northern and southern polar caps was carried out with the help of a semiconductor telescope and using the dE-E methods (Kohno et. al. 1990)The "Ohzora" satellite was launched on 14 Februare of 1984, the altitude was 350 – 850 km, Inclination – 75 degree. Energetic electrons with energy E = 0.19 – 6.4 MeV in the eight intervals in area L > 20 during 7 September – 7 October 1986 were studied (Mineev et. al.1998). Differential energetic spectra of electrons were obtained on the basis of the measurements on "Ohzora" satellite in the north and south polar caps.

The spectra can be approximated by the function

$$J = a E^{-\gamma} \quad (1)$$

Where γ =1.7, E is energy, index a is somewhat different for the north and the south polar caps,

$$a_N < a_S \quad (2)$$

Values of electron flux intensity, at energies ≅ 1 MeV, are:

$$J_N < J_S \quad (3)$$

Where J_N –intensity of electron fluxes in the north polar cap, J_S – intensity of electron fluxes in the polar cap.

The value of spectrum index $\gamma \cong 1.7$ possibly is an indication of the galactic origin of electrons in the polar caps. The north – south asymmetry A of electron was cancelled using the formula :

$$A = J_N - J_S / J_N + J_S \quad (4)$$

Differential energetic spectra of cosmic electrons with energy 0.19—6.4 MeV obtained on "Ohzora" satellite during 1986 were compared with data from other spacecraft during 1968 — 1976 years (Pioneer 8,9 — 1968-1969 years, IMP-6 — 1971, IMP-7 — 1972, Prognoz-4 — 1976). Despite the fact that measurements were made by means of semiconductor telescopic system there are significant discrepancies in the measurment spectra. The largest flux values were obtained on satellite "Ohzora", the minimal value on satellite IMP-7. In Fig.3 the results of asymmetry measurements for every day during 7 September – 7 October 1986 are shown.. Asymmetry behavior has a complicate character, but is negative although there are positive values too. As it can be concluded from (Gorchakov et.al. 1995), the asymmetry sign and value depend on a sectorial structure of the interplanetary field (IMF). According to (Mineev et. al. 1978) the value and direction of IMF sufficiently influences the position and size of polar cap area, at this time north – south part of IMF B_Z controls the sizes and B_X and B_Y parts define the drift to another relatively to the centre of the polar cap.(Gluchov et. al. 1982). In the work (Fennel 1973) it is cofirmed that asymmetry sign, as a rule, is defined by the direction of the radial part of IMF.The paper (Mikirova et.al. 1983),concerning the connection of solar cosmic ray E > 5 MeV in polar caps, with sectorial structure of IMF shows:if the field is directed from the sun a large intensity will be in the north polar cap and vise versa. As for the experiment on "Ohzora" satellite predominantly negative meanings of asymmetry ware observed at prodominantly positive value of B_Z, in according to the King catalogue (King 1996).As evidenced by analysis of other data from the catalogue the magnetic field is oriented to the Sun predominantly. We should also take into account the probability of measurung not only energetic electrons but predominantly side coming with E> 50.0 MeV by the spectrometer of "Ohzora" satellite. It is possibly that values of asymmetry obtained are related to a mixture of energetic electrons and protons with energy E> 50.0 MeV.Background fluxes of protons during 1986 are well known and displayed in (Zeldovich et. al. 1995) where as background fluxes of electrons for the two last cycles of the solar activity are displayed in (Mineev et. al. 1978).

4. Conclusion

1. The Cherenkov counter data has shown that the northern and southern heliosphere galactic cosmic ray concentrations can be different, with the asymmetry degree and sign being energy-dependent. At the same time, the IMF structure affects the magnitude, rather than sign, of the asymmetry.
2. The obtained data indicate a predominantly negative north-south asymmetry of energetic electrons at positive meaning of B_Z and predominant orientation of the magnetic field towards the Sun.
3. Sign of north-south asymmetry of electrons depends on IMF sectorial structure strongly in the difference with protons.
4. Obtained data for protons are in good accordance with stratosheric measurments (on ballons). But measurments on "Meteor" satellite don't usially in agreement this data obtained on "Cosmos-900".

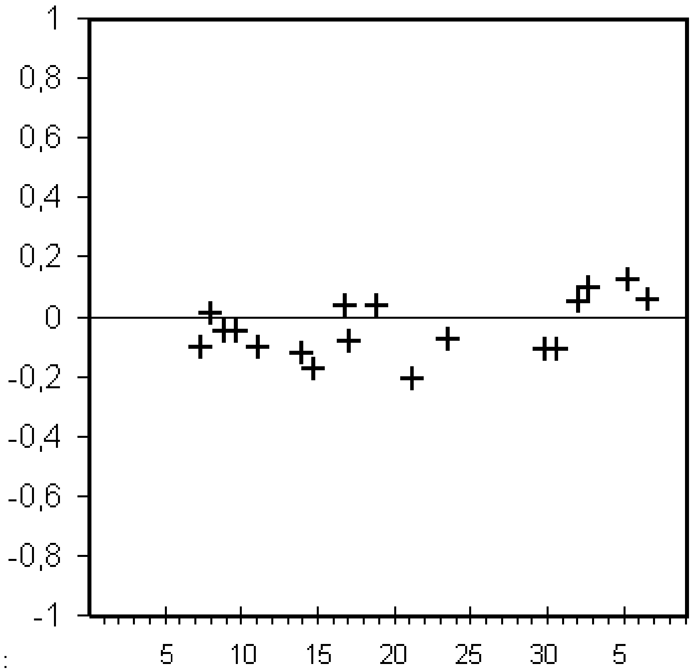

Fig3. The north-south asymmetry of cosmic electrons

References

Gorchakov E.V., Afanasiev K.G., Afanasiev V.G., Ignatiev P.P. et.all.
20 th Intern. Cosmic Ray Conference 1987, v.4., p.243
Gorchakov E.V., Iozenas V.A., Ternovskaya M.V.
Izv. AN RAN, ser. Fis. 1997, v. 61, N 6, p. 1134.
Gorchakov E.V., Iosenas V. A., Mineev Yu.V. Ternovskaya M.V.
Izv. AN RAN. ,ser. Fis. 1995, v. 59. N 4, p. 113.
Moraal H. Gleeson L. T., Webb G. M. Proc. 16 ICRC. Kyoto, 1979, v.3, p.1.
Kohno T., Munakata K., Nagata K., Murakami H., et.al.
Planetary and Space Science 1990, v. 38, N 4 p. 483.
Mineev Yu.V., and T.Kohno Proceedings 16 th ECRS De Acala, Spain 1998, p.75
Mineev Yu. V., Savenko I.A., Saveliev V.G., Spir'kova E.S.
Space Res., 1978, v.16., N 6, p. 953
Glukhov G. A., Mineev Yu.V. Izv. AN. SSSR ser. Fis. 1982, v.46 p.1656
Fennel J.F. JGR ,1973, v.78., p.1036.
Mikirova N. A., Perejaslova N. K. Geomag. and Aeromy, 1983, v.23, N 4, p.479
King J.H. Interplanetary Medium. Data Book, Supplement 1,2. National Space Science, Data Center / Wqrd Data Center A. For Rockets and Satellites.1996.
Zeldovich M. A., Logachev Yu. I., Kecskemety K., Kiraly P. and V. Varga. 24 ICRC, 4, 1995, 4, 1995, p. 405