THE INFLUENCE OF THE EARTH'S MAGNETOSPHERE ON THE HIGH-ENERGY SOLAR PROTONS

G.A.Bazilevskaya
P.N.Lebedev Physical Institute of the Academy of Sciences of the USSR, 117924,Leninsky Prospect,53, Moscow, USSR

V.S.Makhmutov
Industrial Institute of Roudny, 459120,Roudny, USSR

T.N.Charakhchyan
Institute of Nuclear Physics, Moscow State University, 119899,Moscow, USSR

Abstract

The North-South asymmetry in the fluxes of solar protons with the energy ~70-200 MeV in stratosphere at the invariant latitudes 62°-76° is discussed.

1.Introduction. In the earth's polar regions the intensity of the solar protons with the energy above the critical energy of geomagnetic cutoff is, according to the Liouville theorem, the same as in the interplanetary space. The penumbra in the polar regions is small and the East-West effect is also small /1/. However the geomagnetic cutoff rigidity R_c in polar regions is difficult to calculate because it is not sufficient to include only the internal sources of the geomagnetic field. According to /2/, during the magneto-quiescent periods the real value of R_c can be less by 0.1 GV than the calculated value because of the external sources. During the geomagnetic storms the real value of R_c is still lower.

2.Observations. The stratospheric exploration of the cosmic rays (CR) initiated in the USSR in IGY provides information on the energy spectrum and absolute flux of the solar protons intruding into the earth's atmosphere. The detector consists of two Geiger counters forming the telescope interlaid with the 7 mm thick aluminium filter /3/. The data on the stations of the stratospheric CR observations are listed in the Table. Although the calculated values of R_c are 0.5GV and 0.6 GV at Olenya and Apatity respectively, the lower

Table. Polar stratospheric stations

Station	Geograph.coordinates Latitude	Longitude	Invariant Latitude	R_c,GV /2/	E , MeV
Olenya, (Murm.reg.)	68.95 N	33.05 E	65.7	0.5	125
Apatity, (Murm.reg.)	67.55 N	33.33 E	62.5	0.6	175
Mirny	66.57 S	92.92 E	76.4	0.03	0.48

energy limit of the observed solar protons at these locations is nevertheless always determined by the ionization absorption in the residual atmosphere and is sometimes as low as 50 MeV. This means that even in the magneto-quiet periods the rigidity of geomagnetic cutoff at Olenya and Apatity is not higher than 0.3 GV.

Since the asymptotic directions of CR arrival in the Murmansk region (Olenya, Apatity) and at Mirny are different /2/, the N-S anisotropy in the stratospheric observations can be expected in case of the pitch-angular anisotropy of the solar cosmic ray (SCR)fluxes in the interplanetary space. This effect is usually observed only near the onset of a proton event. If the SCR intensity at the atmospheric boundary is not isotropic this leads to the discrepancy between the flux values of solar protons obtained with a single counter and a telescope. This effect sometimes happens /4/, but the present paper will deal with the N-S anisotropy which appears after the maximum of a proton event. In such cases the data of a single counter and a telescope coincide as a rule, so the pitch-angular isotropy at the atmospheric boundary takes place.

3.Comparison of the results for the Northern and the Southern hemispheres. During the period of combined measurements in the Southern and the Northern hemispheres, starting from 1963, about 60 solar proton measurements simultaneously within an hour have been performed. From these data we excluded the balloon flights during which the temporal dynamic of intensity was observed and also the data obtained at the onset of events when according to the neutron monitor data the SCR angular anisotropy was observed. In 31 of the remainder 43 flights the results agree within 10% accuracy. In 10 flights the SCR flux was higher in the Northern hemisphere, among them 6 flights manifested discrepancy more than 30%; 2 measurements showed the excess SCR flux at Mirny.

The most remarkable case of the N-S anisotropy is the SCR event of 12.10.81 reported in /5/. During this event 10 flights in the Southern hemisphere and 39 flights in the Murmansk region were carried out. Some energetic spectra measured during this event are presented in Fig.1 together with the Meteor /6/ and IMP-8 /7/ data. The IMP-8 differential spectrum is recalculated by us to the integral spectrum taking into account the intensity of protons with $E \geqslant 90$ MeV according to the Meteor data. The features of the event in question are: 1/ the anisotropy is not persistent; 2/ when the N-S anisotropy is observed the satellite data agree with the Mirny data, and thus in the Northern hemisphere there is an excess flux of particles. According to Meteor observations in the polar caps there was no any noticeable anisotropy at $E \geqslant 90$ MeV during this period /6/. We may infer that an excess flux of particles in the Murmansk region has a magnetospheric origin . The surplus flux causes the steepening of proton spectrum at $E < 200$ MeV which can be seen in Murmansk data even without any comparison with simultaneous Mirny data /5/. This excess cannot be accounted for by the bremsstrahlung of the auroral electrons because these are not registered with a telescope. A certain contribution of the bremsstrahlung can be admitted only at 03-04 UT and 15-16 UT observations on 13.10.81.

The time behaviour of the anisotropy is shown in Fig.2 It is seen, that the value of the excess flux (if occurs) gradually decreases with time. The spectrum index of the excess flux, γ, is equal to 3-5 and it increases up to ~ 14 during the last flight on 15.10.81. The anisotropy calculated as $\alpha = (I_N - I_S)/(I_N + I_S)$ also becomes stronger to the end of the event. In the bottom of Fig. 2 we give the values of K_p- index /8/. We failed to reveal any correlation between the N-S anisotropy and geomagnetic disturbances.

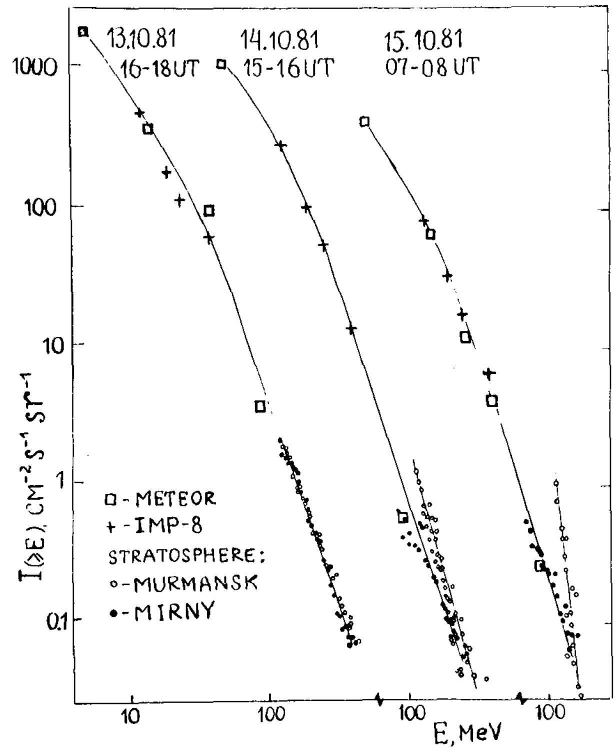

Fig. 1 Examples of energy spectra of solar protons according to stratospheric and satellite data

4. Discussion. The N-S asymmetry in the fluxes of solar protons with E≅70-200 MeV is occasionally observed in the stratosphere. The 700-1000 km height satellite observations in the polar caps /6/ have not confirmed the presence of the anisotropy. The SCR fluxes in the polar caps agree with the Mirny data. The surplus flux of particles in the Murmansk region is not persistent, has a steep energetic spectrum and the maximal energy does not exceed ~ 200 MeV. There is no correlation with the geomagnetic disturbances, but an especially strong anisotropy was observed during the latest phase of the event more than a day after the sudden commencement of the geomagnetic storm marked by a triangle in Fig. 2. Similar effects against a background of the geomagnetic storms were observed in the stratosphere during powerful proton events of the 19-th solar cycle /3/. The spectrum steepening was supposed to be associated with the particles accelerated or localized near the front of the interplanetary shock of flare origin. However the direct

measurements in the interplanetary space have shown that the energy of storm particles is not higher than 30 MeV /9/. Unfortunately no measurements in the Southern hemisphere were made at that time.

The difference between Murmansk and Mirny is that Murmansk is situated on the closed magnetic shell and Mirny on the open one. An important fact is that the effect is limited in the energy range of particles which penetrate mainly through the tail of the magnetosphere /10/. The nonadiabatic processes leading to an additional flux of high-energy protons should play a role here /11/.

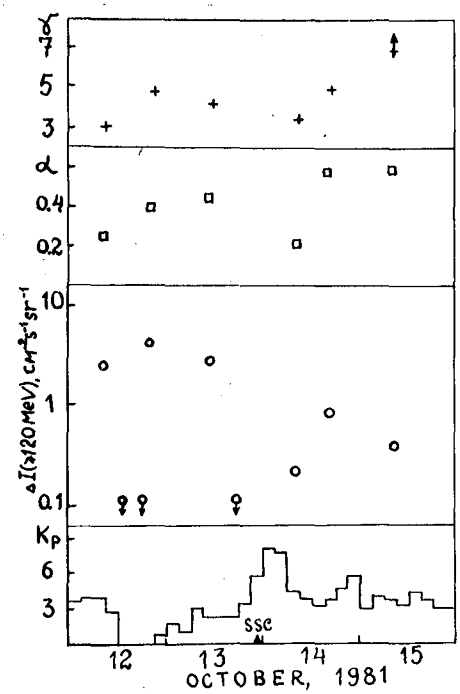

Fig. 2. Time behaviour of an excess flux of particles in Murmansk region.

References.

1. Dorman,L.I.,Smirnov,V.S.,Tyasto,M.I.,(1971),Cosmic Rays in the Earth's Magnetic Field.Moscow, Nauka.
2. Shea, M.A., Smart,D.F.,(1975), AFCRL-TR-0247.
3. Charakhchyan,A.N.,(1964),Uspekhi Fiz. Nauk, v.83,p.35.
4. Borovkov,L.P., et al.,(1982) Izv. Acad. Nauk SSSR, ser.fiz., v.46, p.1709.
5. Bazilevskaya,G.A., et al.,(1983),Proc.18-th ICRC, Bangalore, v.4, p.189.
6. Avdyushin,S.I.,Pereyaslova,N.K.,(1983),Izv. Akad. Nauk SSSR, ser.fiz., v.47, p.1805.
7. Solar-Geophysical Data,(1984),475(II), U.S.Dep.of Commerce, Boulder, USA.
8. Solar-Geophysical Data (1981),448(I), U.S.Dep.of Commerce, Boulder, USA.
9. McDonald, F.B.,(1981),Proc. 17-th ICRC., Paris,v.13, p.189.
10. Gall,R.,Bravo,S.,(1981),J.Geophys.Res.,v.86,p.2467.
11. Il'in,V.D., et al.,(1984),Izv. Acad. Nauk SSSR, ser. fiz., v.48, p.2200.