Chapter 5

DEPARTMENT OF SPACE PHYSICS

5.1. STAFF

5.1.1. Scientific staff

Ján Baláž, Pavol Bobík, Radoslav Bučík (from May 2004), Ladislav Just (died on March 7, 2004), Karel Kudela (Head of Department), Marián Slivka

5.1.2. Technical staff

Vladimír Kollár, Igor Strhársky, Ronald Langer, Jana Štetiarová, Samuel Štefánik, Anna Tomičová

5.2. SCIENTIFIC ACTIVITIES

5.2.1. Introduction

The department of Space Physics is one of the oldest departments of the Institute. The current research of the department is oriented to the experimental study of energetic particles in space. Along with the cosmic ray (CR) studies related mainly to the ground based measurements, the experimental studies of medium energy particles on the satellites are continuing. The two types of studies are devoted mainly to obtain the relevant information on the physical processes within the Earth's magnetosphere and in the heliosphere: those in which the energetic particles are either directly involved or those on which the particles provide a remote characteristic. In addition, the passive dosimetric studies on the orbital station and the heavy nuclei interactions are also continuing. The dynamics of energetic particles are studied in relations to the effects of space weather.

5.2.2. Projects

Slovak Grant Agency VEGA:

2/1147/21 Transport of energetic particles in the magnetosphere and heliosphere
Principal Investigator: K. Kudela
Deputy of Principal Investigator: M. Slivka (the project finished in December 2003).

1/9036/02 Production of secondary particles in nuclear interactions of relativistic nuclei in emulsion detector
Deputy of Principal Investigator: L. Just (the project finished in December 2004)

2/4064/24 Energetic particles in space: relations to space weather
Principal investigator: K. Kudela, started in January 2004.

Agency for Support of Science and Technology:

APVT 0259 Monitoring of energetic particles in nearth surrounding of Earth: relations to space weather – influence on flight personnel (started from October 2002, joint with the Air Force Military Hospital, Kosice)
Principal Investigator: K. Kudela

5.2.3. International collaboration.

In the period 2003-2004 the collaboration with scientists and technicians of many institutions in abroad was productive and influenced the activity, scientific orientation and results obtained in the Department. Among them the collaborations with colleagues from laboratories in the following countries is listed below:

Czech republic (Faculty of Mathematics and Physics of the Charles University Prague; Institute of Nuclear Physics of the Czech Academy of Sciences, Prague; Institute of Atmospheric Physics,of the Czech Academy of Sciences, Prague)

Finland (University of Oulu)

Greece (Demokritos University of Thrace, Xanthi)

Hungary (RMKI KFKI Physical Institute, Hungarian Academy of Sciences, Budapest).

China (Center for Space Science and Applied Research, Beijing)

Ireland (Space Technology Ireland of National University of Ireland, Maynooth).

Italy (IFSI CNR, Institute of Physics of Interplanetary Space, Rome; INFN Milan)

Poland (CBK, Center for Space Research, Polish Academy of Sciences, Warsaw)

Russia (NIIJaF MGU, Nuclear Physics Institute of the Moscow State University; Space Research Institute, Russian Acad. Sci., Moscow; Institute of Cosmophysics and Aeronomy, Yakutsk; IZMIRAN)

Sweden (Institute of Space Physics, Kiruna)

Ukraine (University of Kiev; Main Astronomical Observatory, Kiev)

USA (NASA GSFC, Greenbelt, MD; University of Alabama, Huntsville; MSFC, Huntsville, Alabama)

The collaboration with several institutions in Slovakia was productive, e.g. with Astronomical Institute of Slovak Acad. Sci., Tatranská Lomnica, Faculty of Electrotechnical Engineering and Informatics, Technical University Košice, Faculty of Science, P.J. Šafárik University Košice).

The list is not complete and several other collaborations started recently.

5.3. RESULTS

5.3.1. Cosmic ray dynamics at neutron monitor energies and above [11-18,36,46-54,56-59,64-70,77,106-108,119-120,127-135]

The measurements of secondary cosmic rays by neutron monitor at Lomnický štít run in continual regime with the preliminary data displayed in real time at http://neutronmonitor.ta3.sk and updated with 1 min resolution.

We have developed a code to reconstruct the cosmic ray trajectory in the Earth's magnetosphere. This code solves the Lorentz equation and propagates a particle backward in time. The Tsyganenko'89 magnetic field model represents the external field disturbances.

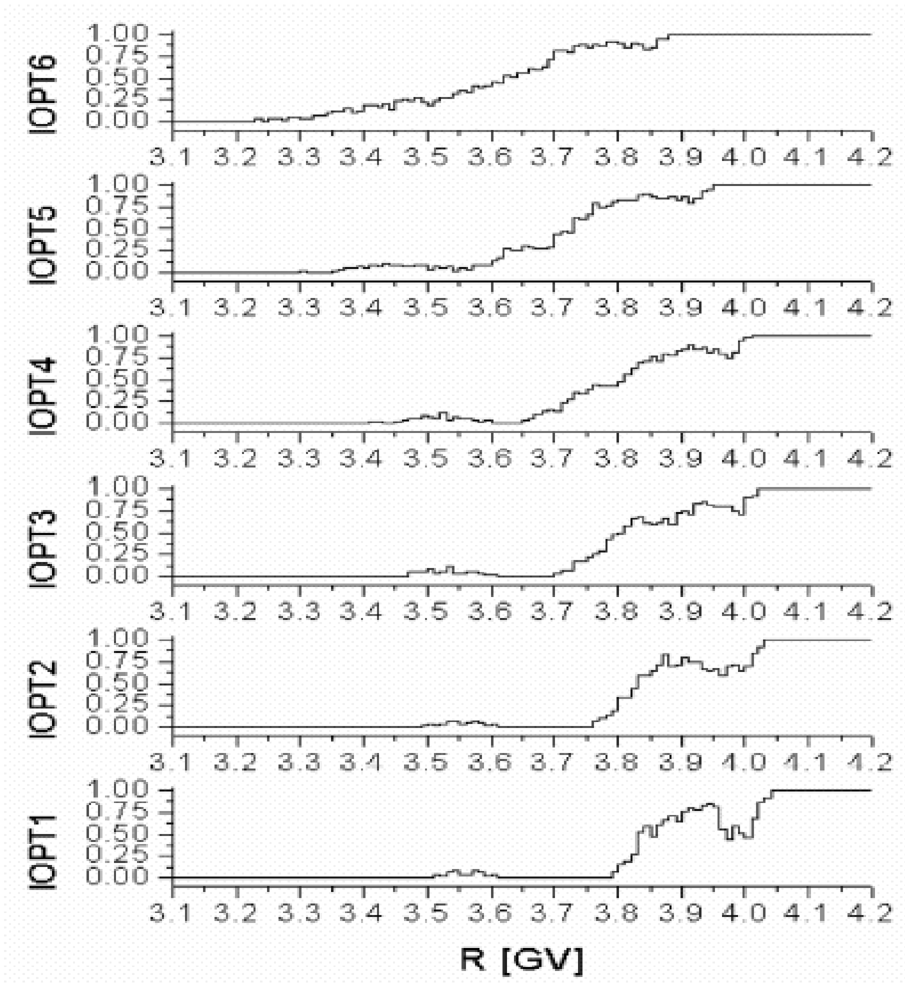

Fig.1. The transmissivity functions for Lomnický Štít, 24-hour averaged, calculated using the Ts89 model for different levels of geomagnetic activity as calculated according to Tsygenenko 89 geomagnetic field model.

Detailed computations of the cosmic ray trajectories in IGRF field model were used for creating maps of constant vertical cutoff rigidity in the past. The result relatively strongly depends on the correctness of the expansion of the geomagnetic field potential for the past periods.

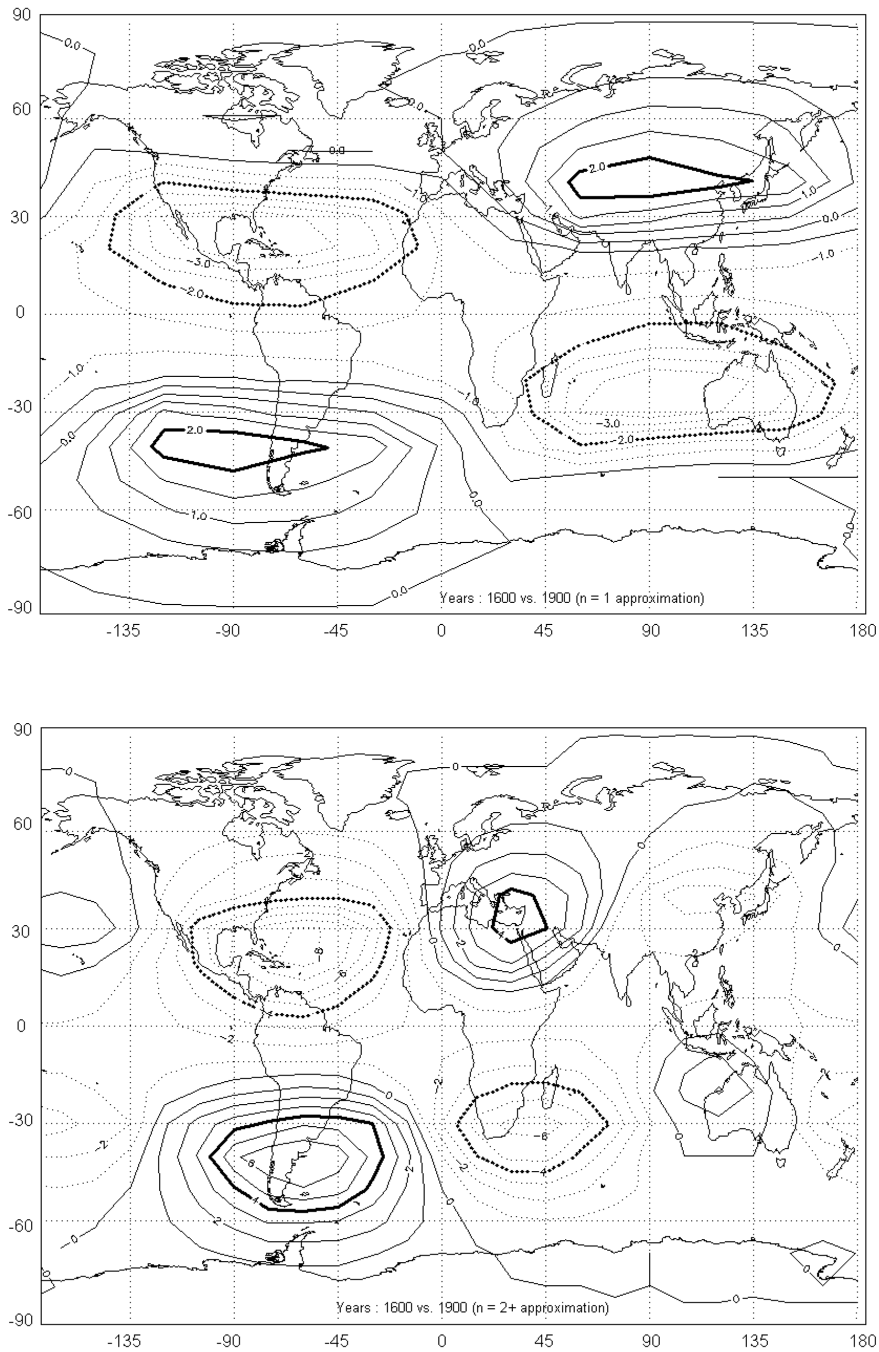

Fig. 2. The contours of differences of the vertical cutoff rigidity for the epochs 1600 and 1900 obtained for dipolar approximation (upper panel) and for the approximation using first 10 Gauss coefficient of geomagnetic field potential expansion.

The total magnetic field was evaluated also by using the International Geomagnetic Reference Field (IGRF) for the period 2000-2005 with the external magnetic field model Tsyganenko-96. This code has been used both for a simulation of randomly generated inputs and for the analysis of the AMS-01 experiment data taken during the STS-91 Space Shuttle mission in June 1998. We have built the transmission function in the magnetosphere for 1998 for several regions with dif-ferent geomagnetic latitude. The same simulation has also been performed for the magnetic conditions of the year 2005, the expected starting time of the long-duration AMS-02 data taking. Then we have estimated the variation of the transmission function with time and obtained the primary Cosmic Ray flux at the altitude of 400 km starting from the flux at 1 AU as predicted by the CREME96 model. As AMS-01 has shown, measured spectra of protons at Space Shuttle orbit are contaminated by a population of secondaries. The method of the magnetospheric transmission function in combination with measured (AMS-01) and simulated (CREME96) cosmic protons spectra can be used to disentangle the contribution of primary protons to the measured spectra. Furthermore this method can be used to recover cosmic ray spectra outside the magnetosphere, starting from measured primary spectra in near Earth orbit.

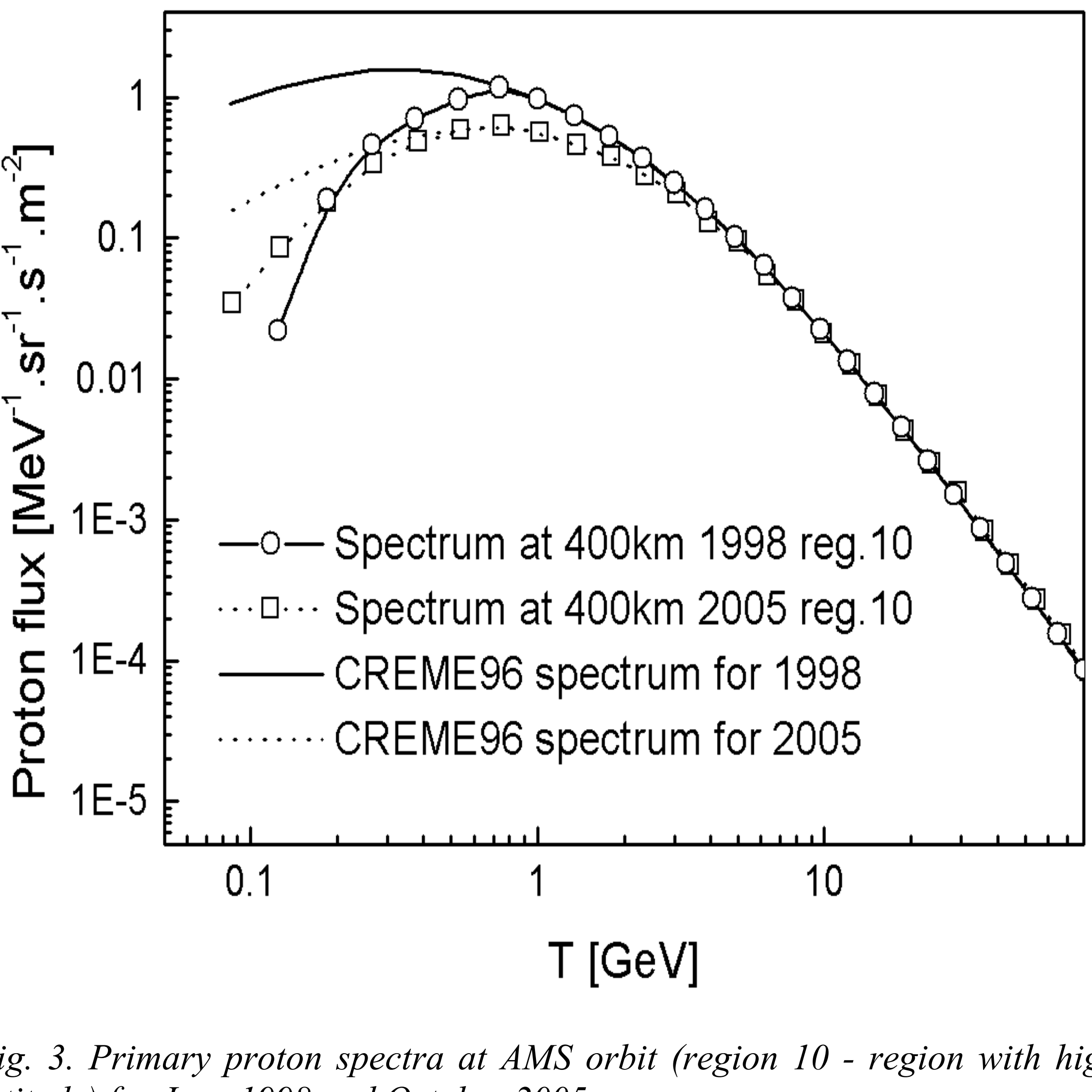

Fig. 3. Primary proton spectra at AMS orbit (region 10 - region with highest latitude) for June 1998 and October 2005.

5.3.2. Medium energy particles within the magnetosphere and near its boundaries

5.3.2.1. High apogee satellites. Interball and others[6,7,9,10,20,25,26,34,40-45,60,71,73-76,79,80,101,113-115,121-123,125,126]

Both case and statistical studies were done with using the large amount of data by energetic particle instruments DOK-2 on Interball-tail and Interball-aueoral, as well as by its simplified versions DOK-S on the corresponding subsatellites, Magion-4 and Magion-5.
Ions (10 to several 100 keV) are common feature in the region upstream from the Earth's bow shock. However, their origin remains the subject discussed and not unambigously solved yet. We used data of DOK-2 on Interball-1 (~20-600 keV). Extensive set of ions upstream from the Earth's dayside bow shock for a wide variety of geomagnetic and solar wind conditions. Previously we described the pattern at low energies (~20 to 30 keV). We presented a survey describing the dependence of the diffusive ion flux at various energies on θ_{Bn}, on geomagnetic activity, and on the component of the solar wind speed parallel to IMF **B.**
Out of ~43000 we selected 7829 bins when the connection to the bow shock was found according to the model and simultaneously the ratio of lowest energy count rates of detectors 2 and 1 did not exceed factor of 2 (diffusive events, 0.5<1p1/1p2<2).

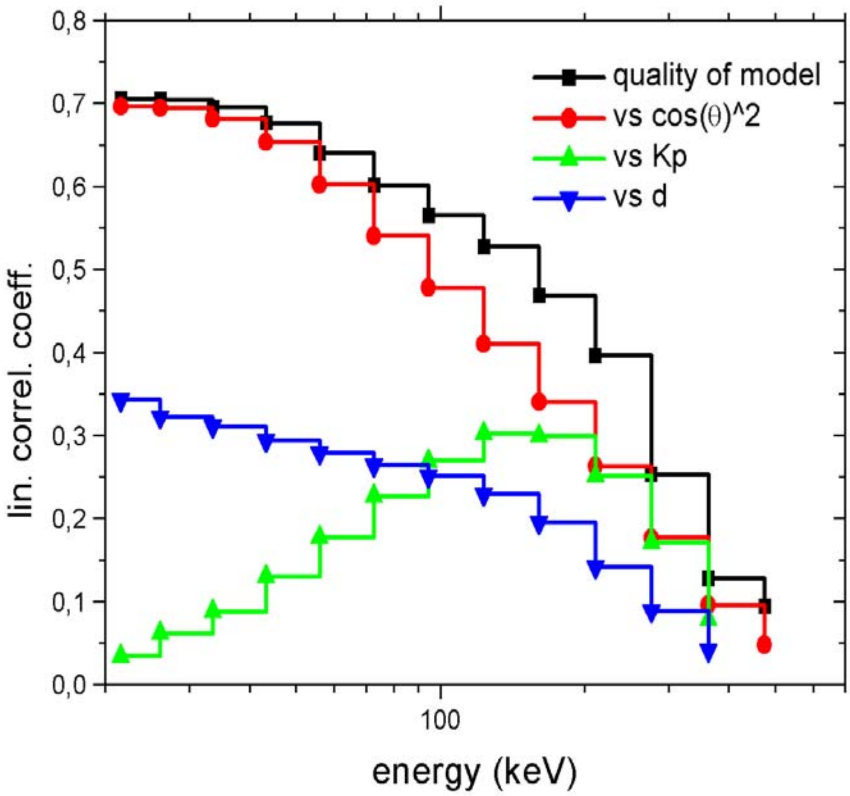

Fig.4. The linear correlation of the ion flux in the upstream region at different energies with the angle θ_{Bn} , with Kp and with d (distance to the bow shock along the magnetic field line).

Most important parameter controlling the flux of energetic diffusive ions outside the bow shock up to ~ 150 keV is θ_{Bn} . While flux correlation with θ_{Bn} decreases with the energy, the correlation with Kp increases and both values are comparable above 150 keV.

For quasi-parallel shocks the slope of energy spectra of is strongly correlated with Vsw.cos(θ_{Bn}). However, it is also correlated with geomagnetic activity. For Bz>0 slightly higher correlation of the spectral slope is found with Vsw.cos(θ_{Bn}) than for Bz<0.
Signatures of both mechanisms, i.e. of preferential acceleration of solar wind ions at quasiparallel shock by Fermi mechanism, and of magnetospheric particle contribution to the upstream ion population, are seen. We show how their relative importance is changing with the energy on Interball orbit.
It was shown that the high correlation of energetic ions in the region upstream from the Earth's bow shock with the geometry to the bow shock is seen in the diffusional quasi-isotropic cases, while for the anisotropis cases there is much better relation to the level of geomagnetic activity than to the bow shock geometry.

5.3.2.2 Low altitude satellite measurements [8,19,23,24,27-33,35,37-39,55,61-63,72,78,81-99,105,109-112,116-118,124,136]

CORONAS I.

From the experiment SONG the fluxes of γ rays and their connection to radiation belt electrons were studied.

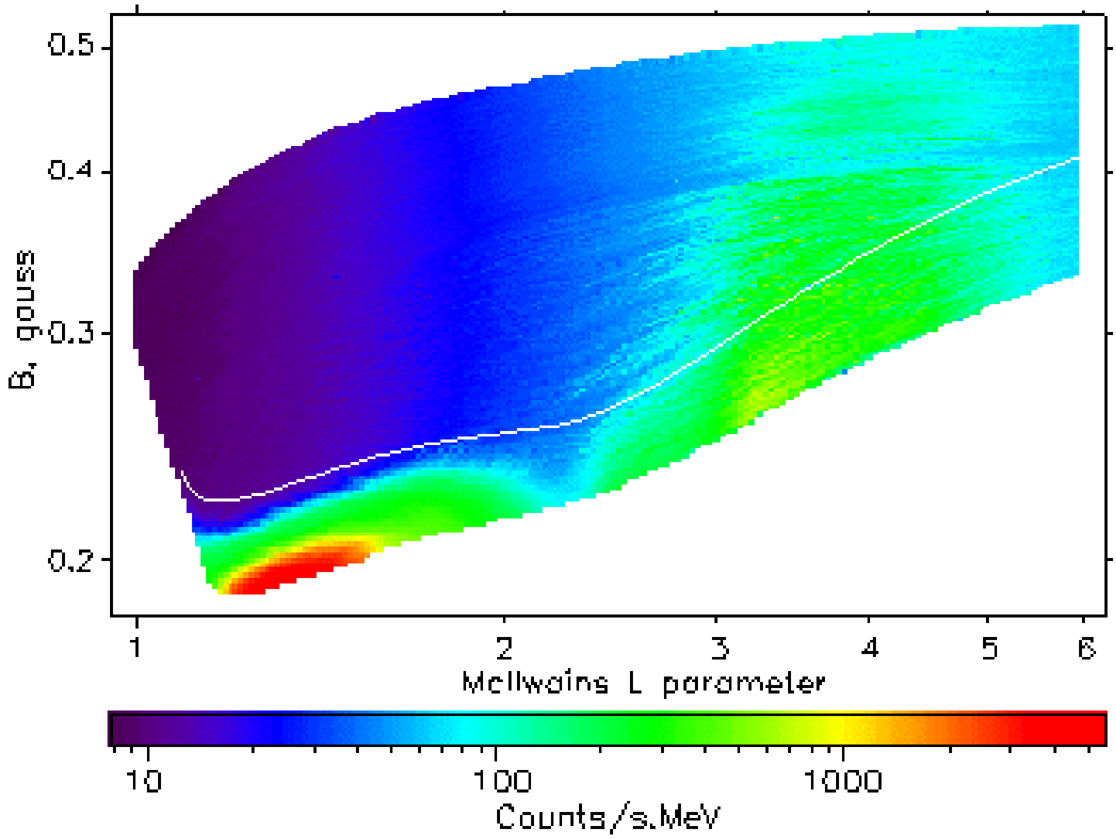

Fig. 5. The L-B distribution of 3.-8.3 MeV gamma-ray fluxes at ~ 500 km as measured by the SONG instrument on board CORONAS-I satellite. The color-coded fluxes (in counts/s.MeV) are averaged throughout the period March-June

1994. The white line represents mirror points (indicated by value of B) at 500 km for which minimum longitude trace altitude Hmin is exactly at 100 km.

Since altitude 100 km can be considered as a limit between zero and total absorption in the Earth's atmosphere, the line in the graph separates L-B space on two parts, the region of stable trapped charge particle population (the area below the white line where Hmin >100 km) and area of atmospheric drift loss cone particles (above the line, Hmin< 100 km).

In the Earth's environment the electron bremsstrahlung is only significant mechanism for production of gamma rays in energy range of 3.-8.3 MeV. The contribution of Compton scattered gamma rays comming from decay of neutral pi mesons originating in the nuclear interactions of protons in any local matter can also be considered.

The most intense fluxes observed at L<2 are due to local production (in satellite matter) of stable trapped particles (mainly electrons) in the inner radiation belt. The presence of enhanced fluxes in atmospheric drifft loss cone (where particles live ten's minutes) for L> 2.5 indicate their high temporal variability in the outer radiation belt. There, also particles precipitated into the local loss cone contribute to the gamma ray production in both areas separates by white line. The gamma rays in the outer radiation zone are therefore combination of artificial (satellite) and atmospheric emission caused by stable trapped and precipitating particle/electron population. The higher fluxes observed in the inner zone simply reflect fact that at low altitudes (~ 500 km), satellite can reach the highly populated equatorial region only in the inner radiation belt. This is also explaining for the steeper flux gradient in the inner zone which is controlled by the density distribution of the atmosphere.

CORONAS-F .

Low altitude polar orbiting satellite CORONAS-F is measuring the energetic particles both electrically charged as well as gamma rays and neutrons successfully from August 2001 until at least end of October 2004. Large amount of measurements was analyzed in cooperation with Skobeltsyn Institute of Nuclear Physics, Moscow State University.

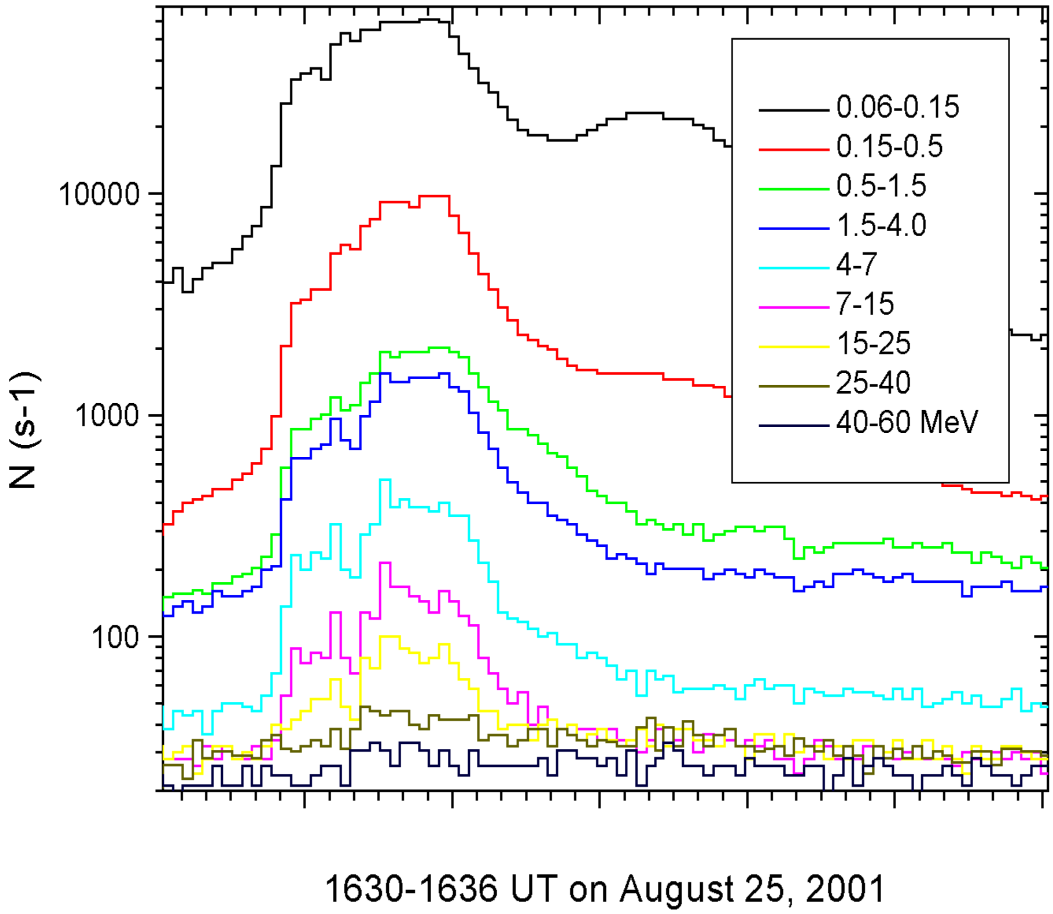

Fig. 6. Data obtained from measurements by SONG instrument on CORONAS F satellite during the solar flare with high energy gamma ray emission on August 25, 2001. The count rates in different channels are displayed. A strong increase of high energy gamma rays (up to at least 20 MeV) was observed from that solar flare. SONG experiment observed also increase due to solar neutrons from that flare in time coincidence with ground based measurements of solar neutrons.

The unusually strong solar, interplanetary and geomagnetic disturbances observed in late October and in November 2003 produced also emissions of high energy solar gamma rays.

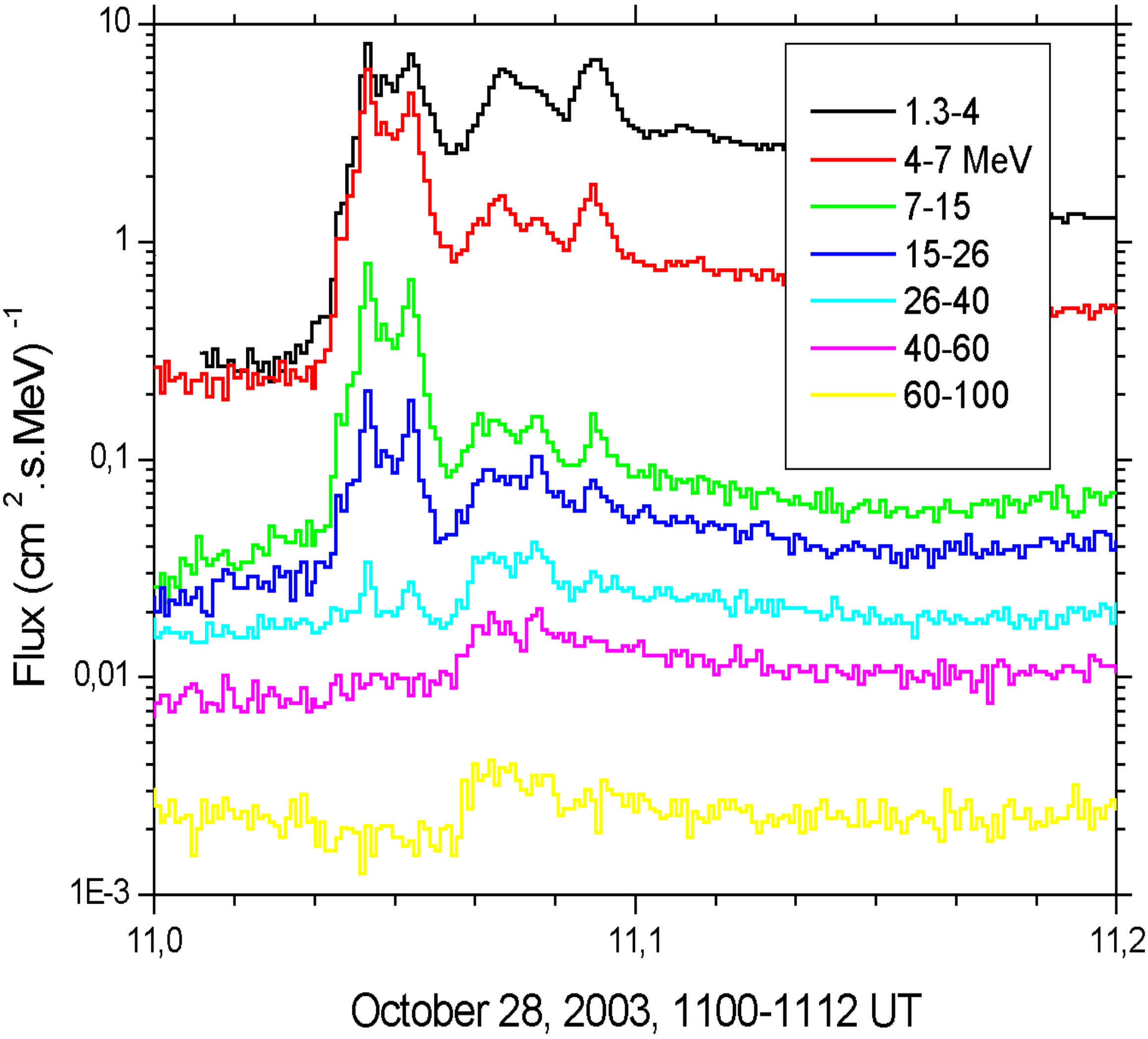

Fig. 7. The flux of gamma rays observed by SONG-M from the solar flare on October 28, 2003. The flare was of class 17.2 and of importance 4B, its coordinates were S16E18.

The strong geomagnetic disturbances in late October – November 2003 lead also to unusual redistribution of the energetic electrons of the outer radiation belts, as observed on CORONAS-F.

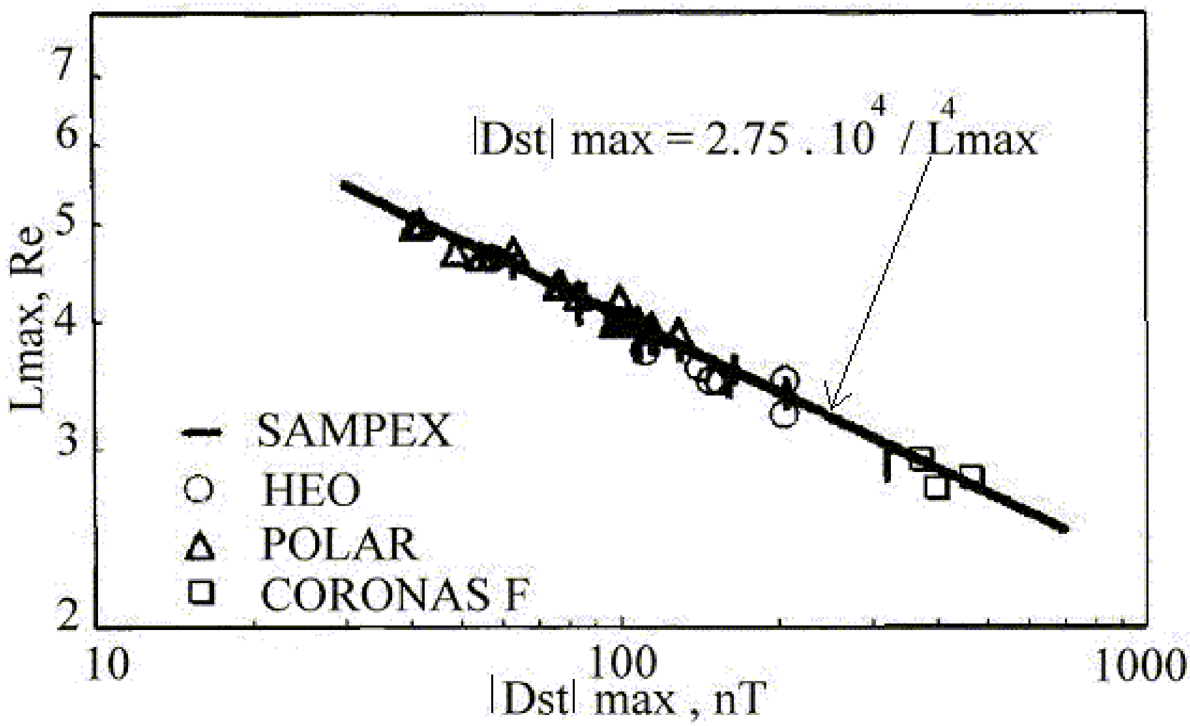

Fig. 8. During the three geomagnetic storms in late October and in November 2003 a strong shift of the position of the outer electron radiation belt maximum to unusually low L values was observed by CORONAS-F. It was possible to test the value of the shift earlier found empirically and confirmed at weaker geomagnetic disturbances. The three points added at the scatter plot L_{max} *vs* $|Dst|_{max}$*, measured by SAMPEX, HEO accomplished by CORONAS-F indicate the validity of the relation between* L_{max} *and* $|Dst|_{max}$ *for strong disturbances.*

5.3.3. New experiments in space.

Project Double Star / NUADU [102,103,104]

The energetic neutral atom imager NUADU is one of the scientific instruments on TC-2 of

Double Star mission (cooperation ESA and China). TC-2 was launched in China on July 25, 2004 onto the orbit with 90 ^{o} inclination, apogee ~38 thousand km and perigee ~680 km. The orbital period is ~11.5 hours. The NUADU instrument was constructed with participation of Ján Baláž and Igor Strhársky of the Department of Space Physics in the frame of cooperation between STIL Maznooth, Ireland and IEP SAS, under the supervision of Prof. Susan McKenna-Lawlor, PI of the experiment. After the launch the instrument started to work correctly according to the expectations based on tests before the launch. The first examples of events with energetic neutral atom emission indications have been found.

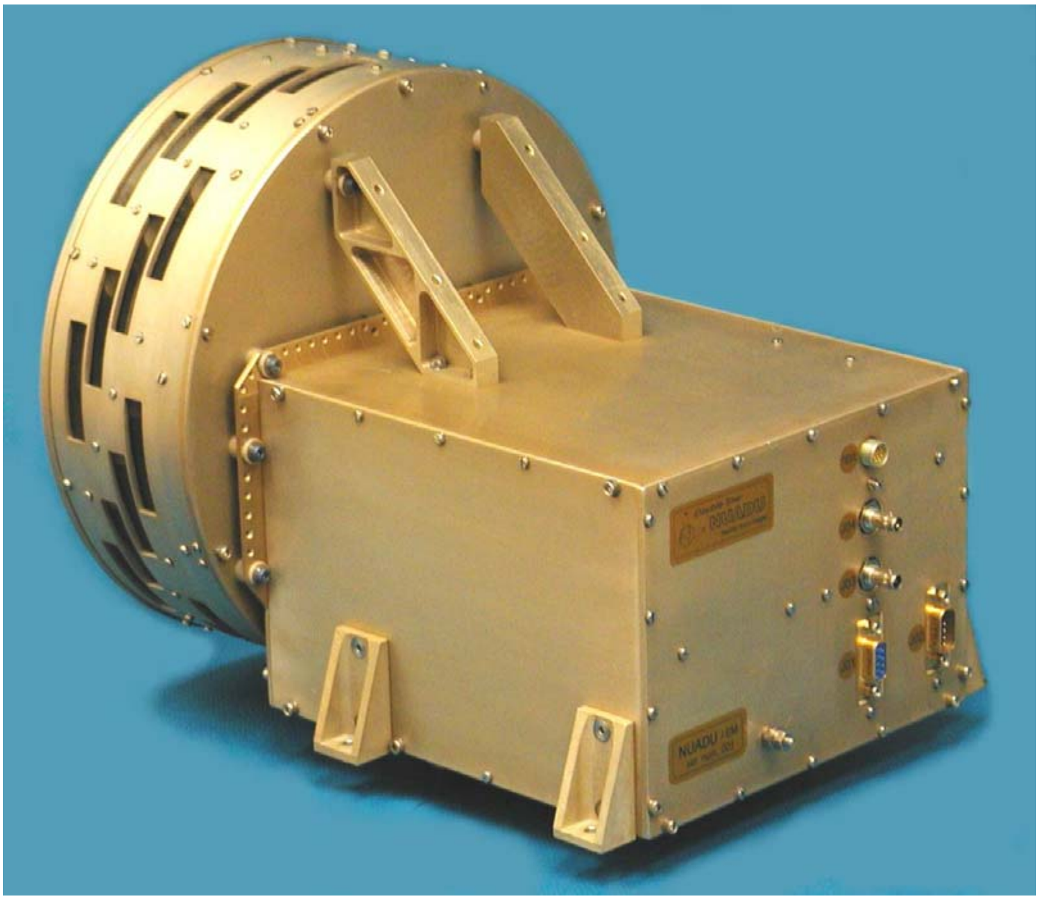

Fig. 9. Ireland's national instrument NUADU (NeUtral Atom Detector Unit) for China's Double Star Polar Mission (Principal Investigator Susan McKenna-Lawlor). Launch is scheduled for July 2004. IEP SAS participated in the development and construction of this experiment.

5.3.4. Fragmentation of nuclei in emulsions [1-5,21,22]

Several original physical results were obtained from the analysis of nuclear emulsion tracks created in the accelerator experiments oriented to the study of fragmentation of energetic nuclei. This work yielded into publications in refereed international journals. The work was done by Dr. Ladislav Just, PhD, who died on March 7, 2004.

5.4. Papers and presentations.

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